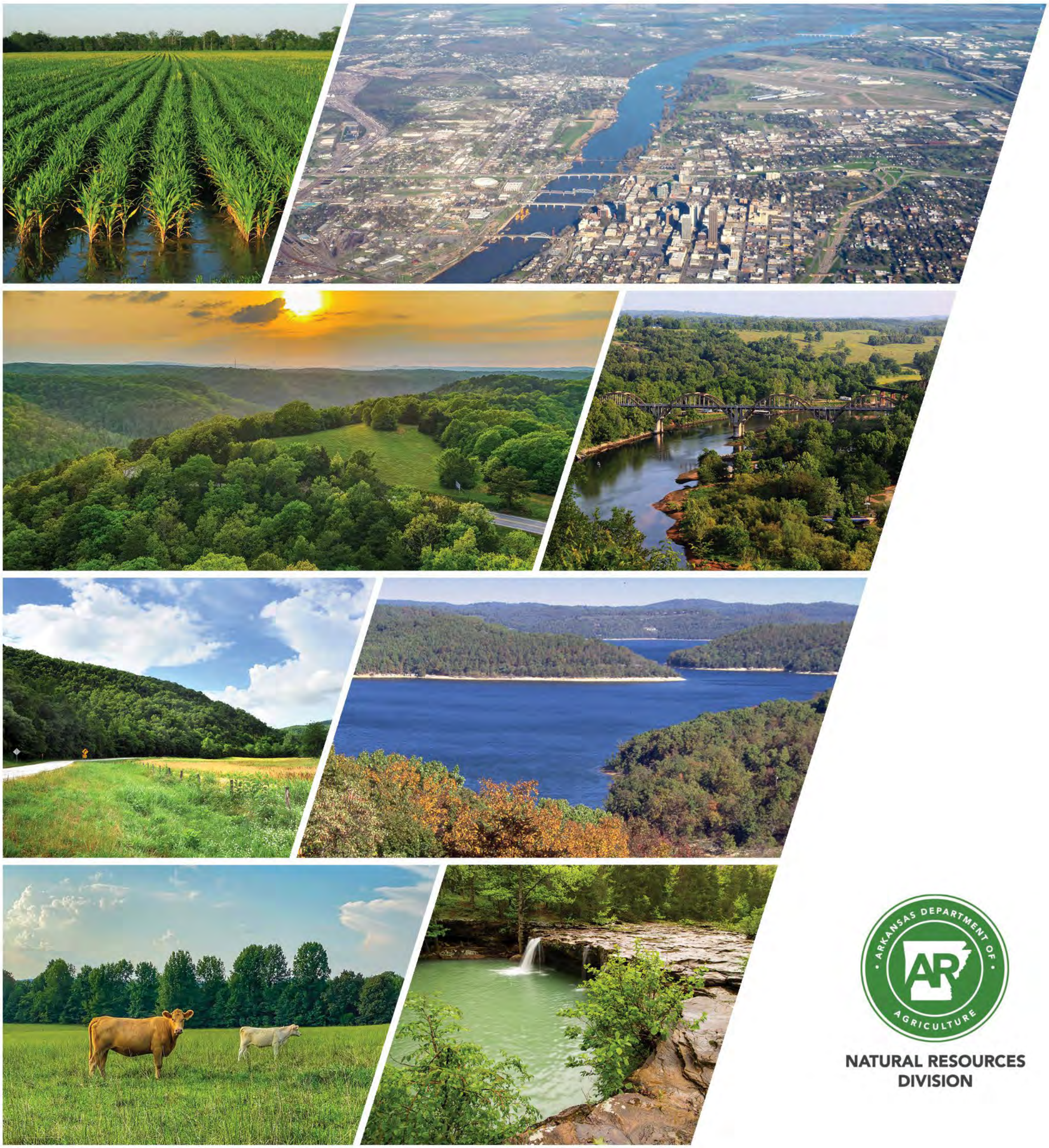
2022
Arkansas Nutrient Reduction Strategy (ANRS)



ARKANSAS DEPARTMENT OF AGRICULTURE

NATURAL RESOURCES DIVISION

Arkansas Department of Agriculture
Natural Resources Division

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Acknowledgement

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Executive Summary

Nutrient pollution is one of America's most widespread, costly, and challenging environmental problems. It is caused by excess nitrogen and phosphorus entering America's waterways, usually from human activities. The primary sources of nutrient pollution are runoff of fertilizers, animal manure, and sewage. While plants and animals need nutrients to grow, excessive nutrients can cause harmful algal blooms in lakes and streams and contribute to the hypoxic zone in the Gulf of Mexico. Additionally, many other pollutants, e.g. primarily sediment, also degrade many of Arkansas's waterbodies. While nutrients and sediments can be linked there are existing state (Nonpoint Source Pollution Program) and federal (Mississippi River Basin Initiative and National Water Quality Initiative) that solely focus on improving water quality for multiple pollutants.

ARKANSAS NUTRIENT REDUCTION STRATEGY

The Arkansas Nutrient Reduction Strategy (ANRS) was initiated by the 2014 Arkansas Water Plan update and is a response to federal initiatives to address the Gulf of Mexico Hypoxic Zone. The purpose of the ANRS is to reduce nutrient concentrations in Arkansas watersheds, providing local benefits and helping to shrink the Gulf of Mexico Hypoxic Zone. This is accomplished by working closely with stakeholders to adaptively manage and aggressively implement relevant voluntary conservation practices and programs to safeguard state and regional economic prosperity, environmental quality, and recreational opportunities for current and future generations.

Beginning in 2018, the Natural Resources Division began efforts to update the ANRS through an extensive stakeholder process. Stakeholders were represented by state, federal, academia, conservation and agriculture industry non-governmental organizations (NGOs), and private citizens. Late in 2020, stakeholders were assembled to provide a project status update and to solicit feedback. Asmall 15-person coordination team was formed to assist in improving the technical information with the ANRS. In part, the coordination's team recommendation was to improve statistical robustness in identifying nutrient priority watersheds.

In 2021, the Natural Resources Division in partnership with the Arkansas Water Resources Center conducted a water quality analysis of all subbasin level watersheds (Appendix A). The goal was to prioritize watersheds based on extensive statewide water quality monitoring data. All watersheds were classified into four Tiers. Tier 1 had the greatest potential for both nitrogen and phosphorus reduction based on sufficient data as outlined in Appendix A. Tier 2 had the greatest need for future monitoring investments due to demonstrated nutrient reduction needs, data limitations, or both. Tier 3 and Tier 4 did not have high demonstrated nutrient reduction needs. Tier 3 needed to expand on gathering more data, and Tier 4 focused on continuing statewide efforts.

The three main goals of the ANRS are:

- Goal 1: Increase or maintain downward trends for Tier 1 watersheds.
- Goal 2: Enhance water quality monitoring to inform nutrient trends for Tier 2 watersheds.
- Goal 3: Continue efforts in all watersheds.

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Acronyms

AACD	Arkansas Association of Conservation Districts
ACEP	Agricultural Conservation Easement Program
ACP	Arkansas Conservation Partnership
ACT	Avoiding, Controlling, and Trapping
ADA	Arkansas Department of Agriculture
ADH	Arkansas Department of Health
AFA	Arkansas Forestry Association
AFB	Arkansas Farm Bureau
AGFC	Arkansas Game and Fish Commission
ANRS	Arkansas Nutrient Reduction Strategy
API	Arkansas Phosphorus Index
ASU	Arkansas State University
AWRC	Arkansas Water Resources Center
BMP	best management practice
CAFO	concentrated animal feeding operation
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
DEQ	Arkansas Department of Energy and Environment Division of Environmental Quality
EQIP	Environmental Quality Incentives Program
FD	Arkansas Department of Agriculture's Forestry Division
FSA	Farm Services Agency
GI	green infrastructure
HAB	harmful algal bloom
HTF	Hypoxia Task Force
HUC	hydrological unit code
IRWP	Illinois River Watershed Partnership
LID	low impact development
MARB	Mississippi/Atchafalaya River Basin
MRBI	Mississippi River Healthy Watersheds Basin Initiative
MS4	municipal separate storm sewer system
NGO	non-governmental organization
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
NRD	Arkansas Department of Agriculture's Natural Resources Division
NWQI	National Water Quality Initiative
POTWs	publicly owned treatment works
RC&D	Resource Conservation and Development Council
RCPP	Regional Conservation Partnership Program
TMDL	total maximum daily load
TNC	The Nature Conservancy
TN	total nitrogen
TP	total phosphorus
UADA	University of Arkansas, Division of Agriculture
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WMP	watershed management plans
WRP	Wetland Reserve Program
WWTP	wastewater treatment plant

Section 1. Introduction

Background

The Arkansas Nutrient Reduction Strategy (ANRS) was initiated by an update of the Arkansas Water Plan and Arkansas's participation on the Gulf of Mexico Hypoxia Task Force. The ANRS is a strategic framework that outlines opportunities, both regulatory and voluntary, that are available to improve water quality for the benefit of Arkansans and to reduce Arkansas's overall nutrient levels and exports. The strategy serves as an effort to encourage engagement, research, and education to partnerships and the public regarding the protection of Arkansas's waters. The ANRS is not a regulatory document and does not supersede existing water laws governing water quality issues in Arkansas. This document will guide the state in achieving nutrient reduction so local and downstream water quality goals are ultimately met.

Existing State Authority

The State of Arkansas has invested significant voluntary, incentive-based, and regulatory effort to address point and nonpoint source (NPS) pollution in Arkansas's streams, rivers, and lakes. These multi-agency efforts have been implemented through state and federal partnerships for the protection and maintenance of aquatic resource functions and the environmental benefits enjoyed by all citizens.

While affordable and good quality water is generally abundant throughout Arkansas for a multitude of purposes, impacts to beneficial uses caused by excessive nutrient loading exists in some of Arkansas's streams and lakes. The State of Arkansas, through the Arkansas Department of Health (ADH); Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ); and Arkansas Department of Agriculture's Natural Resources Division (NRD), exercises jurisdiction and management of water as it relates to beneficial uses, i.e., environment, economy, public health. Through coordination of regulatory and voluntary programs, these agencies provide the foundation for implementing water quality improvement activities at the state level. In addition, partnership with other local, county, state, federal, nonprofit, academic, and private sector entities is essential to the protection, maintenance, and enhancement of all beneficial water uses in Arkansas.

Organizational Setting

Federal Level

There are many federal agencies that are involved in water quality. Federal agencies such as the Federal Emergency Management Agency, the National Oceanic Atmospheric Administration, the Department of Interior, and the U.S. Geological Survey (USGS) have a role in protecting water quality. However, the three main federal agencies that are highlighted in the ANRS are:

Environmental Protection Agency

The U.S. Environmental Protection Agency (USEPA) is an independent federal agency, created in 1970, that sets and enforces rules and standards that protect the environment and control pollution. USEPA enforces federal clean water and safe drinking water laws, provides support for municipal wastewater treatment plants, and takes part in pollution prevention efforts.

Natural Resources Conservation Service

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) helps America's farmers, ranchers, and forest landowners conserve the nation's soil, water, air, and other natural resources. All programs are voluntary and offer science-based solutions that benefit both the landowner and the environment. NRCS conservationists provide technical expertise and conservation planning for farmers, ranchers, and forest landowners wanting to make conservation improvements to their land. Farmers, ranchers, and forest landowners can receive financial assistance from NRCS to make improvements to their land.

Farm Services Agency

The USDA Farm Services Agency (FSA) serves all farmers, ranchers, and agricultural partners through the delivery of effective, efficient agricultural programs for all Americans.

State Level

Arkansas's statutory authority to directly impact water quality resides primarily in three agencies: NRD, DEQ, and ADH. Other state agencies, including the Arkansas Department of Agriculture's Forestry Division (FD); Arkansas Game and Fish Commission (AGFC); Arkansas Natural Heritage Commission; and the University of Arkansas Division of Agriculture (UADA), Cooperative Extension Service play an important role in state management of water resources.

Arkansas Department of Agriculture's Natural Resources Division

NRD manages Arkansas's NPS pollution program. The program includes voluntary implementation of NPS pollution abatement and management activities. Activities and projects are coordinated through local conservation districts whenever possible. NRD has authority to establish nutrient surplus watersheds (Arkansas Code Annotated § 15-20-1104). In nutrient surplus watersheds, special limitations govern poultry, livestock, forage, and crop production operations that involve land-application of litter, sewage sludge, and commercial fertilizer (Arkansas Administrative Rule 138.00.05-004).

Arkansas Department of Energy and Environment Division of Environmental Quality

DEQ is Arkansas's main environmental protection agency, charged with protecting, enhancing, and restoring the environment for Arkansans. DEQ manages Arkansas's point source pollution programs. DEQ regulates municipal wastewater, industrial waste, some stormwater runoff, and liquid animal waste systems.

Arkansas Department of Health

ADH regulates the collection, treatment, and operation of domestic wastewater, excluding industrial discharge. On-site wastewater systems must be sited, planned, designed, constructed, and installed in accordance with the ADH's "Rules and Regulations Pertaining to General Sanitation" and the "Rules and Regulations Pertaining to Onsite Wastewater Systems." ADH is also the primacy agency for the Safe Drinking Water Act within the state, including source water protection.

Arkansas Department of Agriculture's Forestry Division

FD protects Arkansas's forests and those who enjoy them from wildland fire and natural hazards while promoting rural and urban forest health, stewardship, development, and conservation for all generations of Arkansans.

Arkansas Game and Fish Commission

AGFC conserves and enhances Arkansas's fish and wildlife and their habitats while promoting sustainable use, public understanding, and public support.

University of Arkansas Division of Agriculture

UADA is a statewide, system-level entity to administer agricultural teaching, research, and extension programs. UADA includes the Agricultural Experiment Station, which is Arkansas's primary research agency for agriculture and related areas, and the Cooperative Extension Service, which delivers information and technology to the public. UADA strengthens agriculture, communities, and families by connecting trusted research to the adoption of best practices.

Local Level

Conservation Districts

Arkansas's conservation districts are the lifeblood of conservation activity at the watershed level. District board members are active leaders in the local community and are often pioneers in implementing innovative conservation practices. This "grassroots" connection is an important element in achieving sustainable nutrient reduction in priority watersheds. Conservation districts, along with many other watershed-level stakeholder groups and organizations, work with state and federal agencies to improve water quality through public policies, public outreach and education, project implementation, and water quality monitoring.

National Problem—Pollution

What is Point Source Pollution?

Point source pollution is defined as a discharge from a single, discrete point such as a pipe. The Clean Water Act (CWA) of 1972 defines a point source as any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flow from irrigated agriculture.

What is Nonpoint Source Pollution?

NPS pollution is a type of water pollution that is not confined to an end-of-the-pipe discharge but is generated by surface water runoff during rain events. Total phosphorus (TP) and total nitrogen (TN) are the focus for the ANRS. Common sources of NPS pollution in Arkansas include:

- Animal production operations and feedlots
- Agricultural activities
- Timber harvesting
- Home sewage systems
- Land development
- Urban stormwater runoff
- Streambank and shoreline erosion
- Atmospheric deposition

What are HABs?

Harmful algal blooms (HABs) occur when colonies of cyanobacteria, also known as blue-green algae, grow rapidly in response to nutrient surpluses in water. Cyanobacteria can produce toxins that can be harmful to people, pets, livestock, fish, and other animals. Toxin exposure may cause rash, nausea, vomiting, diarrhea, or numerous other effects.

Exposure occurs when people have contact with contaminated water such as surface scum or water containing high levels of toxins. Routes of exposure include:

- Ingestion or swallowing water while drinking or recreating
- Inhalation or inhaling airborne water droplets while recreating
- Skin or eye contact while recreating

What is a Watershed?

A watershed is a land drainage area that channels rainfall and snowmelt to creeks, streams, and rivers, which eventually flow to reservoirs, bays, or the ocean. U.S. watersheds are divided and subdivided into successively smaller hydrologic units. Every hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of 2 to 12 digits based on the levels of classification in the hydrologic unit system (Figure 1):

- 2-digit HUC first-level (regional level)
- 4-digit HUC second-level (subregional level)
- 6-digit HUC third-level (basin level)
- 8-digit HUC fourth-level (subbasin level)
- 10-digit HUC fifth-level (watershed level)
- 12-digit HUC sixth-level (subwatershed level)

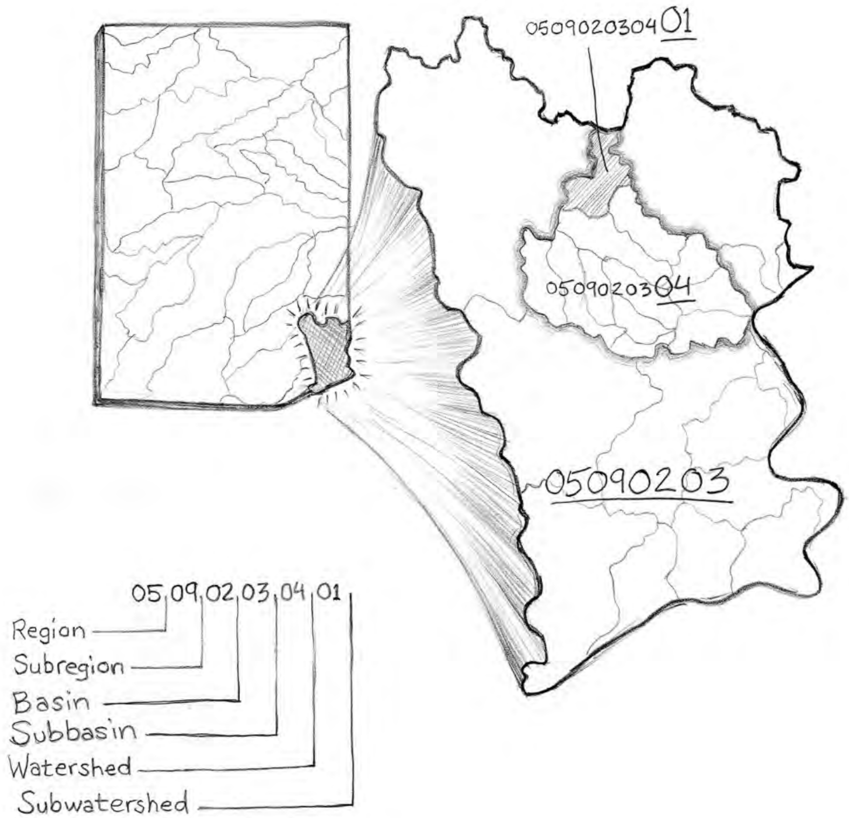


Figure 1. Hydrologic Unit System Classification.

Arkansas has 58 HUC-8 subbasin level watersheds (Figure 2).

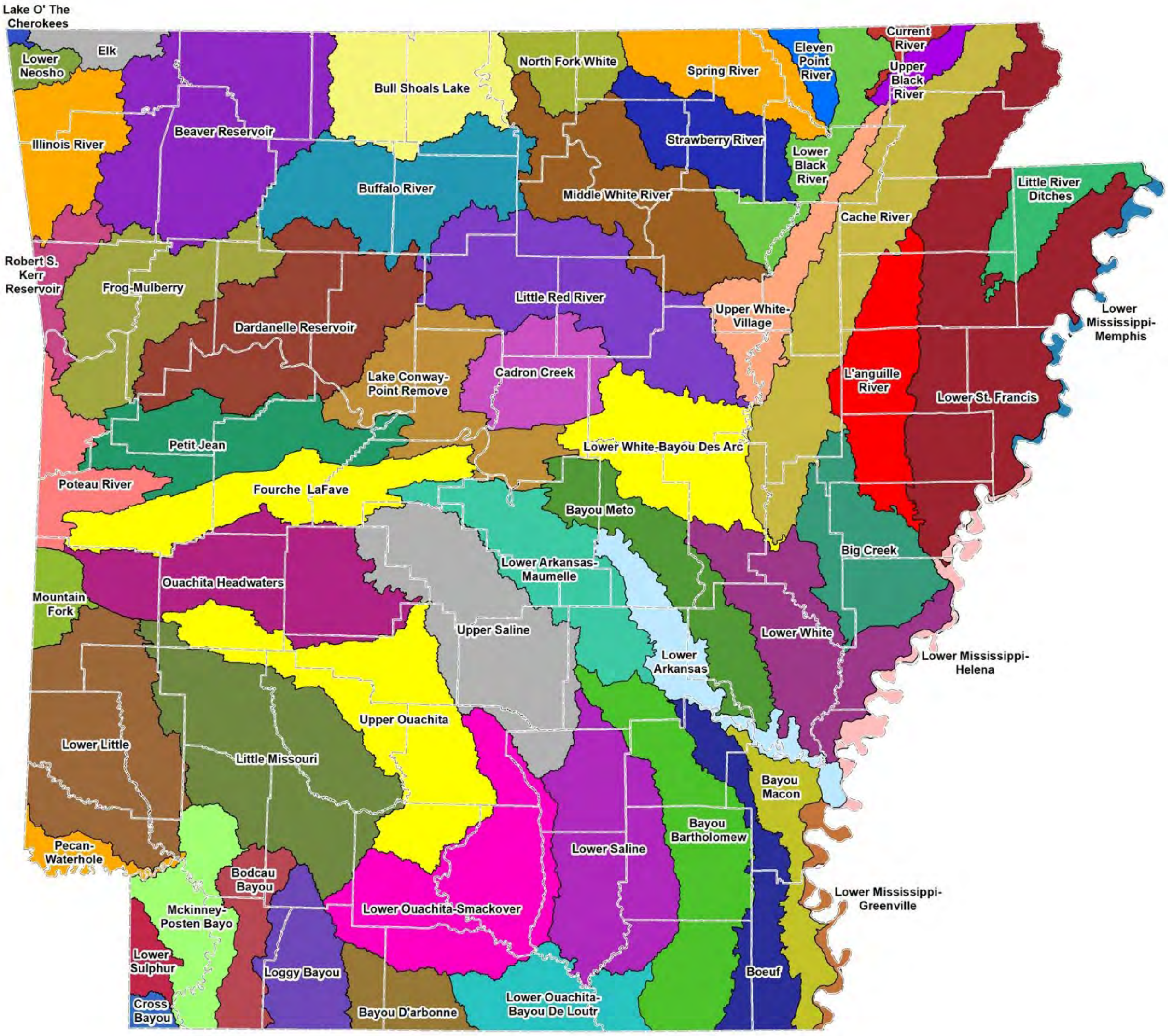


Figure 2. Arkansas Subbasin Level Watersheds.

What is the MARB?

The Mississippi/ Atchafalaya River Basin (MARB) is the third-largest river basin in the world. The Mississippi River originates in northern Minnesota (Figure 3). During a 2,350-mile journey south to the Gulf of Mexico, the Mississippi River is joined by hundreds of tributaries, including the Arkansas River. Water from 31 states drains into the Mississippi River and creates a drainage basin over 1,245,000 square miles (mi^2) in size. Before reaching the Gulf, the Mississippi meets up with the Atchafalaya River. This forms the MARB.

Figure 3. Mississippi/Atchafalaya River Basin.

What is Hypoxia?

Hypoxia means low oxygen and is a problem for freshwater, estuaries, and coastal waters. Hypoxic waters have dissolved oxygen concentrations of less than 2–3 milligrams per liter (mg/L). Hypoxia can be caused by a variety of factors, including excess nutrients, primarily nitrogen and phosphorus. These excess nutrients can promote algal overgrowth and lead to eutrophication. As dead algae sink to the bottom and decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water (Figure 4).

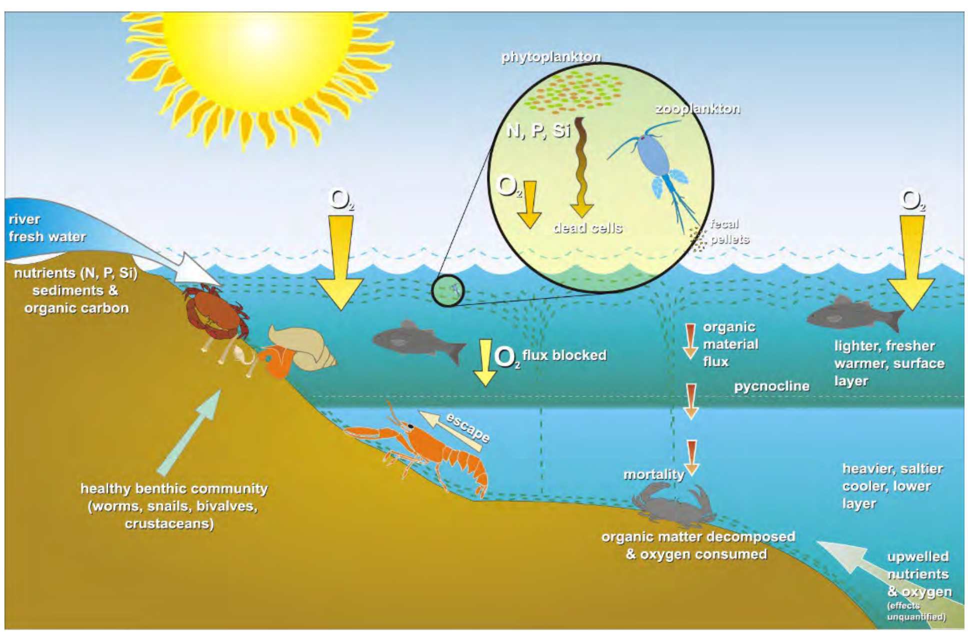


Figure 4. Hypoxia Process.

What is the Hypoxic Zone?

The Gulf of Mexico is experiencing water quality degradation in the form of hypoxia (low dissolved oxygen levels), which negatively affects aquatic communities and creates a hypoxic zone. The hypoxic zone in the Gulf of Mexico is caused by nutrient loadings from tributary streams and river basins that flow into the Mississippi River and subsequently to the Gulf of Mexico. Seasonal stratification (layering) of waters in the Gulf of Mexico prevents mixing of oxygen-rich surface water with oxygen-poor water on the bottom of the Gulf. Without mixing, oxygen in the bottom water is limited and a hypoxic condition exists. The hypoxic zone was mapped from July 25 to July 31, 2021 and estimated at 16,400 square kilometers (km^2) (6,334 mi^2) (Figure 5). The 2021 size is the 16th largest in 35 years of hypoxia data.

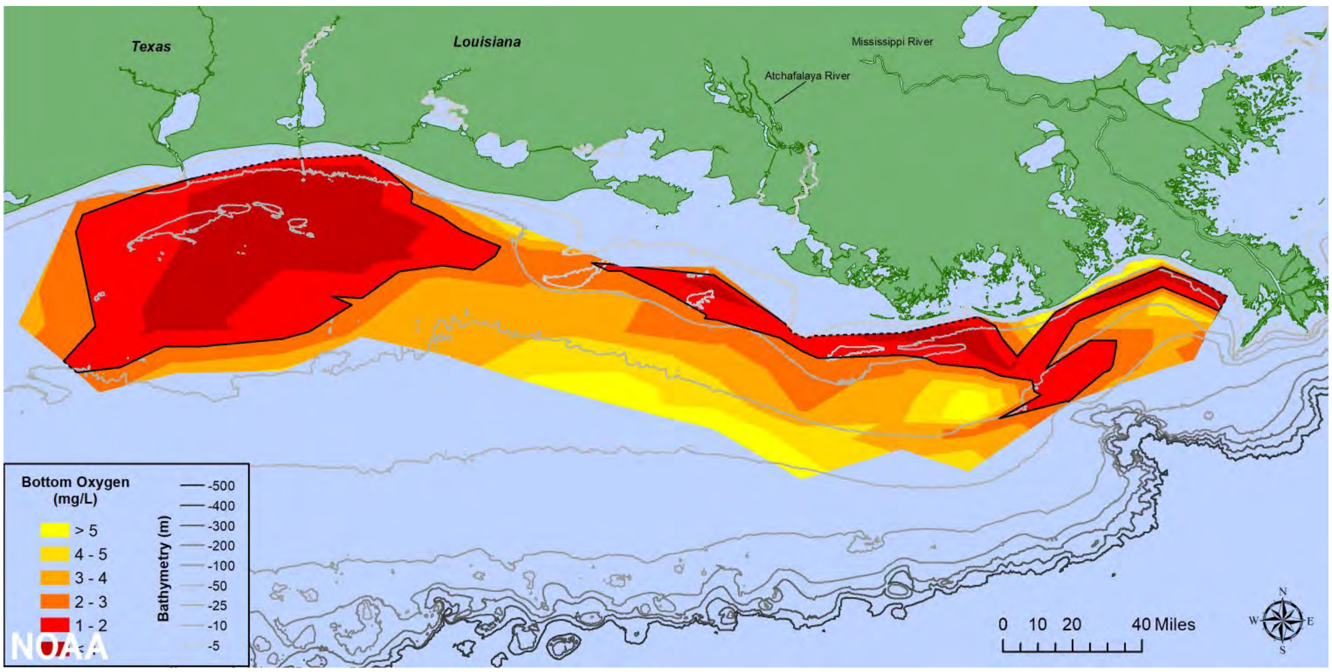


Figure 5. Hypoxic Zone: July 25 to July 31, 2021 (6,334 $miles^2$).

Hypoxia Task Force

What is the Hypoxia Task Force?

Established in 1997, the Hypoxia Task Force (HTF) brings together 12 upper and lower Mississippi River Basin states, tribes within the MARB, and five federal agencies to partner on local, state, and regional efforts to reduce nutrient pollution. The HTF convenes to discuss ongoing nutrient reduction activities that can potentially decrease Mississippi River nutrient concentrations and subsequent nutrient loadings to the Gulf of Mexico. It encourages a holistic approach that considers upstream sources and downstream impacts.

Mississippi River Gulf of Mexico Watershed Nutrient Task Force

What is the Goal?

The HTF has set a goal of limiting the dead zone to a running 5-year average of 5,000 km^2 or 1,930 mi^2 (see Figure 5). Meeting this goal will depend on nutrient load reduction (both TN and TP) to the Gulf of Mexico from the MARB. It is estimated that reductions in TN and TP loads of 48% ± 21% are required to reach HTF goals (Fennel and Laurent 2017). The HTF has set a goal of reducing nutrients to the Gulf of Mexico by 45% of baseline levels (1980–1996) by 2035 with an interim goal of 20% by 2025. Arkansas will help the HTF meet those goals.

Section 2. Strategy Development

Gulf Hypoxia Action Plan 2008

The Gulf Hypoxia Action Plan of 2008 describes a national strategy for reducing, mitigating, and controlling hypoxia in the Gulf of Mexico and improving water quality in the MARB. It calls for states to complete and implement comprehensive nitrogen and phosphorus reduction strategies. The plan also reiterates goals first adopted by the HTF in 2001 (Figure 6).

Coastal

"…Strive to reduce or make significant progress toward reducing the five-year running average areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 km^2 by 2035. Including an interim target of a 20% reduction of nitrogen and phosphorus by 2025."

Within the Basin

"To restore and protect the waters of the 31 States and Tribal lands within the MARB through implementation of nutrient and sediment reduction actions to protect the public health and aquatic life as well as reduce the negative impacts of water pollution on the Gulf of Mexico."

Quality of Life

"To improve the communities and economic conditions across the MARB, in particular the agriculture, fisheries, and recreation sectors, through improved public and private land management and a cooperative, incentive-based approach."

Figure 6. Goals of the 2008 Gulf Hypoxia Action Plan.

The 2008 plan also outlines the following overarching principles as guidance for reaching goals:

- Encourage actions that are voluntary, incentive-based, practical, and cost-effective.
- Use existing programs, including existing state and federal regulatory mechanisms.
- Follow adaptive management strategies.
- Identify additional funding needs and sources during the annual agency budget processes.
- Identify opportunities for, and potential barriers to, innovative and market-based solutions.
- Provide measurable outcomes.

The ANRS attempts to closely adhere to these same principles.

The 2008 plan estimates that significant reductions in nitrogen and phosphorus are needed to achieve the major goals of reducing the size of the hypoxic zone and improving water quality within the MARB.

2011 Memo on State Nutrient Reduction Frameworks

The Recommended Elements of a State Framework for Nutrient Reduction memorandum was released to USEPA regional offices and states in 2011 by the USEPA Acting Assistant Administrator for the Office of Water, Nancy Stoner. The recommendations included:

- Prioritizing watersheds on a statewide basis for nitrate-nitrogen and TP loading reductions.
- Setting watershed load reduction goals based on the best information available.
- Ensuring the effectiveness of the National Pollutant Discharge Elimination System (NPDES) point source permits in targeted or priority watersheds.
- Addressing agricultural sources.
- Addressing stormwater and septic system sources.
- Establishing accountability and verification measures.
- Conducting annual reporting of implementation activities and biennial reporting of load reduction and environmental impacts associated with each management activity in targeted watersheds.
- Create a work plan and schedule for numeric criteria development.

2022 Memo on Accelerating Nutrient Pollution Reductions

A memorandum was released in April 2022 by the USEPA Assistant Administrator for the Office of Water, Radhika Fox, outlining the governing principles and strategies to accelerate nutrient pollution reduction in the nation's water. The memo stated that nutrient pollution is a growing challenge impacting public health, water quality, and the economy. Excess levels of phosphorus negatively affect 58 percent of the nation's rivers and streams and 45 percent of our lakes (USEPA2022). Five governing principles will guide the Office of Water:

- Advance equity and environmental justice.
- Build and foster partnerships.
- Follow the science and invest in data-drive solutions.
- Support innovation.
- Scale successful initiatives.

Three primary strategies are outlined in the memo:

- Deepen collaborative partnerships with agriculture.
- Redouble efforts to support states, tribes, and territories to achieve nutrient pollution reductions from all sources.
- Utilize EPA's Clean Water Act authorities to drive progress, innovation, and collaboration.


Rice Fields in Arkansas

Arkansas's Role

State Nutrient Reduction Strategies are considered the cornerstone in reducing nutrient loads to the Gulf of Mexico. The State of Arkansas joined the HTF and initiated the ANRS as part of the 2014 Water Plan update. Arkansas's efforts specific to national nutrient loading and impairment of the Gulf of Mexico is participation on the Gulf of Mexico HTF, coordinated research, and implementation of nutrient reduction activities in Arkansas. There is also great local benefit by reducing nutrients to Arkansas's lakes and rivers.

The process for creating and updating the ANRS is a lengthy process (Figure 7). Some actions are continuous and ongoing like participating in the HTF and updating watershed management plans, while other actions happen less frequently, like conducting a full water quality analysis every five years. The overview of the process is a two-year cycle where information is collected, analyzed, reviewed, and updated. The first year focuses on collecting and analyzing information, and the second year focuses on goals and strategies specifically looking into watersheds that have been identified as having nutrient or monitoring issues.

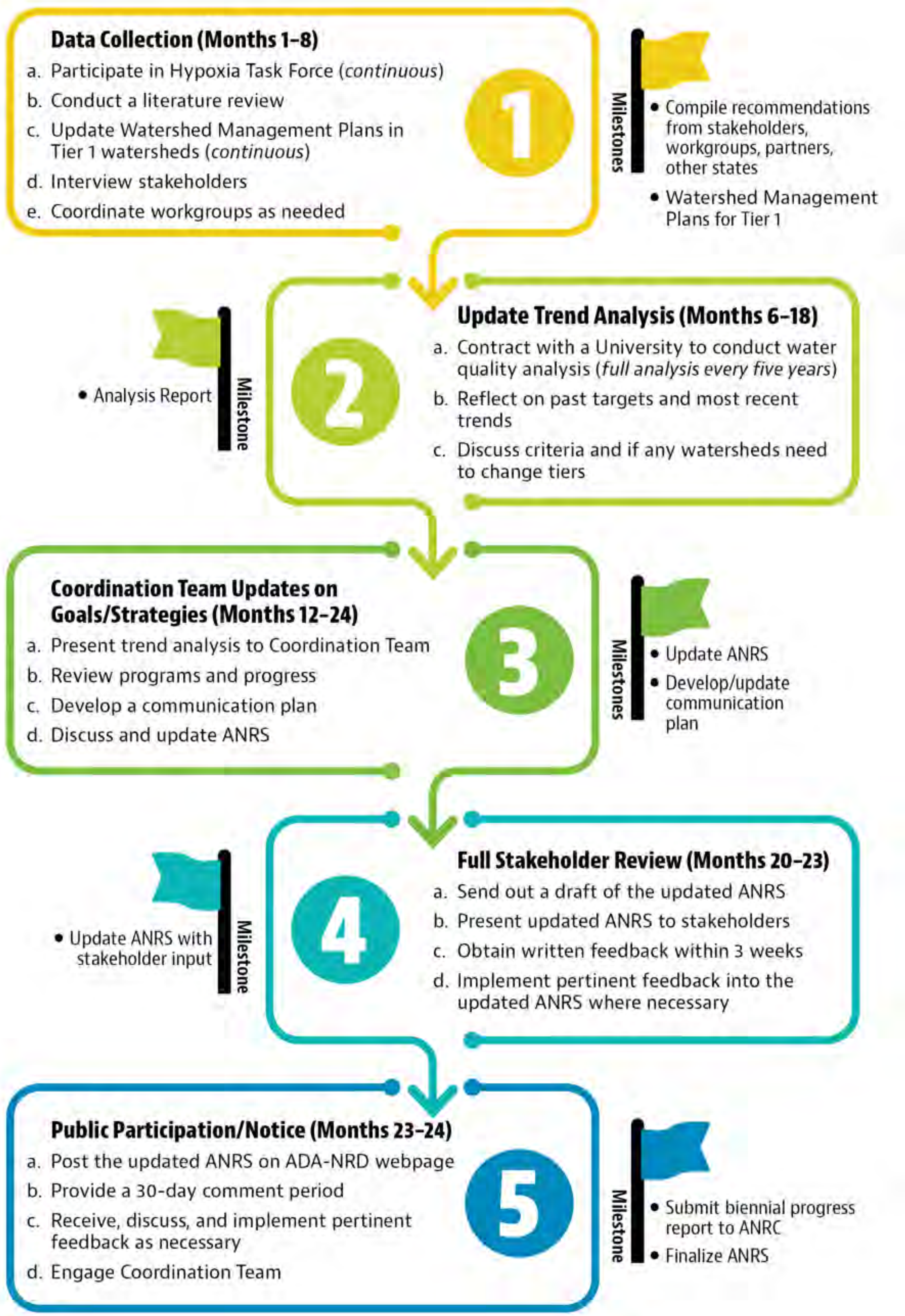


Figure 7. ANRS Development/Update Two-Year Cycle.

Interagency Collaboration

Broad agency support, coordination, and collaboration are required for the successful implementation of the ANRS. Connecting multiple key partners can help foster an adaptive management approach by providing platforms for communication, relationship building, information sharing, and stakeholder engagement. The ANRS provides an opportunity to bridge multiple entities to apply a broad adaptive framework to facilitate nutrient reduction activities.

Coordination Team

A Nutrient Reduction Strategy Coordination Team is comprised of representatives from NRD, FD, DEQ, AGFC, UADA Cooperative Extension Service, and NRCS. The state agency members of the team are ultimately responsible for making final programmatic decisions for the ANRS, updating the strategy, and collecting both public and stakeholder comments.

Guiding Principles

Implementing changes in land use or increasing investment in wastewater treatment processes require clearly defined examples of effective and economically viable opportunities. Those opportunities should demonstrate measurable or assumed benefits to the individual and surrounding watershed community. The ANRS strategic framework recognizes that reaching water quality goals requires collaborative processes that, when implemented over time, result in incremental progress toward the desired improvement goal. Those processes must be adaptable to changing conditions and should adhere to the following set of guiding principles:

- Strengthening existing programs.
- Promoting voluntary, incentive-based, cost-effective conservation and protection measures.
- Incorporating adaptive management and flexible strategic planning.
- Leveraging available financial and technical resources.
- Pursuing market-based opportunities and solutions.

Public Participation

Implementation of the nutrient reduction practices are primarily voluntary, and thus, requires sustained public interest and support. Public and stakeholder support of these guiding principles and strategic opportunities referenced throughout the ANRS is crucial to nutrient reduction in Arkansas.

Stakeholder engagement and participatory management are key components for successful implementation of the ANRS. One of the intentions of the ANRS is to understand how the attitudes, beliefs, values, interests, and behaviors of stakeholders relate to nutrient pollution and nutrient reduction activities. It also encompasses incorporating that information into strategic decision-making. At the landscape scale, processes to collect this type of information must be comprehensive, innovative, and flexible; enable integration of knowledge; and promote learning.

The ANRS framework promotes enhanced outreach and educational efforts to bolster engagement of local stakeholders in reduction activities, regular evaluation of reduction goals, and advancement of science-based technologies. This integrated approach represents a sustained multidiscipline, multisector effort to reduce point and nonpoint source nutrient loading and improve water quality through publicly supported strategies. This effort requires cooperation and communication on nutrient reduction between federal, state, and local agencies; stakeholders; and the public. Table 1 gives a list of identified stakeholders for the 2022 update of the ANRS.

Table 1. List of Identified Stakeholders

Agricultural Council of Arkansas	Arkansas Tech University	Peoples Company
American Biochar	Arkansas Wastewater Managers Association	Save Greers Ferry Lake
American Farmland Trust	Audubon Arkansas	Southeast Arkansas RC&D
Arkansas Association of Conservation Districts	Arkansas Water Works & Water Environment Association	Sierra Club – Arkansas Chapter
Arkansas Association of Conservation District employees	Bass Pro Shop	Southeast Aquatic Resources Partnership
Arkansas Cattlemen's Association	Bayou Meto Water Management District	Southwest Arkansas Economic Development District
Arkansas Chapter, Associated General Contractors	Beaver Water District	Southwest Arkansas RC&D
Arkansas Department of Health	Beaver Watershed Alliance	Southwest Arkansas Planning & Development District
Arkansas Department of Parks, Heritage, and Tourism	Buffalo River Watershed Alliance	The KKAC Organization
Arkansas Department of Transportation	Central Arkansas RC&D	The Nature Conservancy
Arkansas Division of Environmental Quality	Central Arkansas Water	The Poultry Federation
Arkansas Division of State Parks	Circle K Angus Farm	Trout Unlimited – Arkansas Chapter
Arkansas Environmental Federation	Communities Unlimited	U.S. Army Corps of Engineers
Arkansas Farm Bureau	Conservation districts*	USEPA
Arkansas Forestry Association	Delta Plastics of the South	U.S. Fish and Wildlife Service
Arkansas Game and Fish Commission	Division of Arkansas Heritage	U.S. Park Service
Arkansas Home Builders Association	Ducks Unlimited	UADA Cooperative Extension Service
	East Arkansas Planning and Development District	UADA Public Policy Center
	Equilibrium	UADA Agricultural Experiment Stations
	Eureka Springs Parks and Recreation Commission	UADA Research and Extension
	Farm Bureau Chapters	UADA Water Resources Center

Arkansas Land and Community Development Corp.

Arkansas League of Women Voters

Arkansas Municipal League

Arkansas Native Plant Society

Arkansas Natural Heritage Commission

Arkansas Natural Resources Commission

Arkansas Office of the Governor

Arkansas Oil and Gas Commission

Arkansas Ozark Waterkeeper

Arkansas Pork Producers Association

Arkansas Poultry Federation

Arkansas Public Policy Panel

Arkansas Recycling Coalition

Arkansas Resource Conservation and Development Council (RC&D)

Arkansas Rice Federation

Arkansas River Valley RC&D

Arkansas Rural Water Association

Arkansas State Plant Board

Arkansas State University

Arkansas Stream Heritage Partnership

Friends of North Fork/White River

Friends of the Ouachita Trail

FTN Associates

Illinois River Watershed Partnership

Kings River Watershed Group

L'Anguille River Watershed Coalition

Lake Fayetteville Watershed Partnership

Lakewood Property Owners' Association

Landcan

Little Red River Action Team

Lower Mississippi River Conservation Committee

McGeorge Construction

Mississippi River Network

National Fish and Wildlife Foundation

National Weather Service

Northeast Arkansas RC&D

Northwest Arkansas Land Trust

Northwest Arkansas RC&D Council

Ozark Foothills RC&D

Ozark Land Trust

Ozark Society

Ozarks Water Watch

University of Arkansas at Pine Bluff

University of Arkansas at Fayetteville

University of Arkansas at Monticello

USA Rice

USDA FSA

USDA NRCS

USGS

Watershed Conservation Resource Center

West Center Arkansas Planning & Development District

West Central Arkansas RC&D

West Fork – White River Watershed

Western Arkansas Planning & Development District

Weyerhaeuser Company

White Oak Bayou Wetlands Conservatory

White River Planning & Development District

Witt Stephens Jr. Central

* Arkansas County, Ashley County, Baxter County, Benton County, Boone County, Buffalo, Calhoun County, Carroll County, Chicot County, Clark County, Clay County, Cleburne County, Cleveland County, Columbia County, Conway County, Cossatot, Craighead County, Crawford County, Crittenden County, Crooked Creek, Cross County, Dallas County, Desha County, Drew County, Faulkner County, Franklin County, Fulton County, Garland County, Grant County, Greene County, Hempstead County, Hot Spring County, Independence County, Izard County, Jackson County, Jefferson County, Johnson County, Lafayette County, L'Aigle Creek, Lawrence County, Lee County, Lincoln County, Little River County, Logan County, Lonoke County, Madison County, Miller County, Mine Creek, Mississippi County, Monroe County, Montgomery County, Nevada County, Newton County, Ouachita County, Perry County, Phillips County, Pike County, Poinsett County, Pope County, Poteau River, Prairie County, Pulaski County, Randolph

County, Rich Mountain, Saline County, Sebastian County, Sharp County, St. Francis County, Stone County, Union County, Van Buren County, Washington County, White County, Woodruff County, Yell County

I-40 Bridge over the Mississippi River

Section 3. Water Quality

Introduction

The ANRS aims to reduce TN and TP loading to the Gulf of Mexico by targeting watersheds with the greatest protentional for reduction. A water quality data analysis of all HUC-8 subbasin level watersheds was completed in 2021 by NRD through the Arkansas Water Resources Center (Appendix A). The goal was to prioritize watersheds based on extensive, statewide water quality monitoring data.

Sufficient data status indicated that all data availability requirements for both the magnitude assessment and trend analysis were met, including data collection at a minimum of three monitoring stations each year within a HUC-8. For the magnitude assessment, three of the last five years were required to qualify with at least three active stations, while trend analysis required a minimum of 10 qualifying years. Additionally for trend analysis, at least two-thirds of years from the first to last year of a HUC-8's data record was required to meet the three active stations requirement.

Nutrient Trends by Watershed

Nutrient concentrations have mostly declined or remained stable across Arkansas watersheds in the last three decades. Previous efforts over the last 30 years to reduce nutrient concentrations seem to be successful, but many watersheds do not have enough data due mainly to a shortage of water quality monitoring sites.

Only one HUC-8 subbasin-level watershed showed increases in TN: the Spring River watershed (HUC 11010010) in northern Arkansas (Figure 8). No changes in TN were detected for five HUC-8s. The rest of the HUC-8s analyzed were decreasing in TN. There were no HUC-8 watersheds that were increasing for TP (Figure 9). Seven HUC-8s remained the same for TP. All other qualifying HUC-8s show a decreasing TP trend.

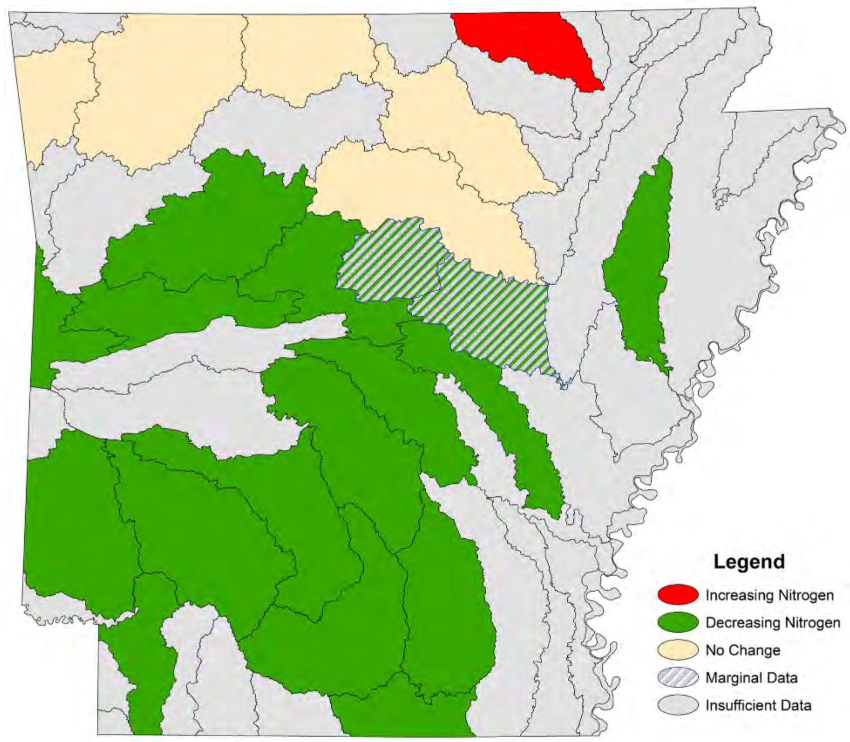


Figure 8. Trends in Watershed Total Nitrogen Concentrations, as the 75th Percentile of Annual Station Medians, 1990–2019.

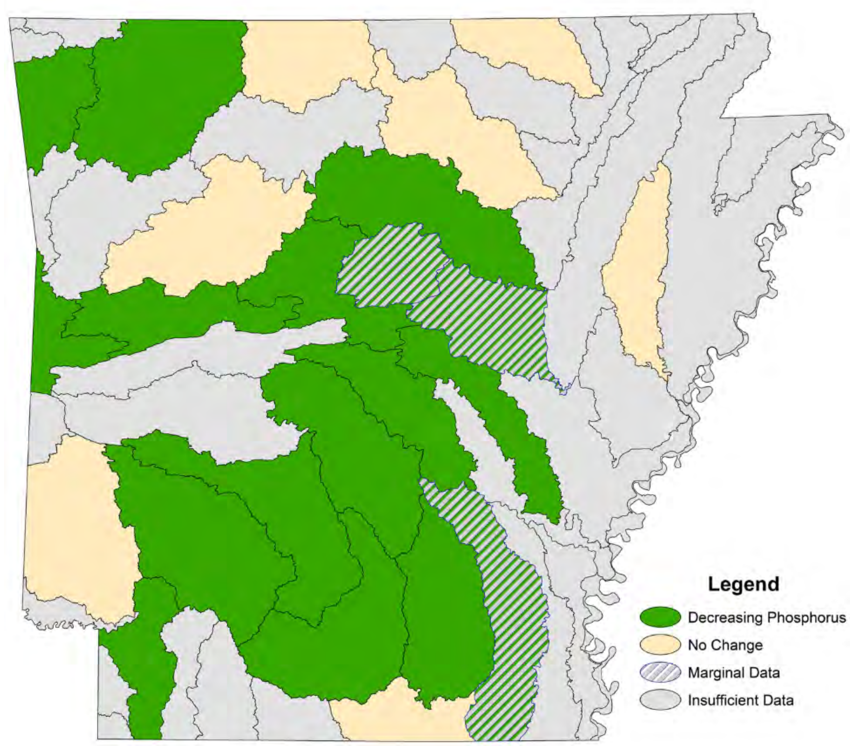


Figure 9. Trends in Watershed Total Phosphorus Concentrations, as the 75th Percentile of Annual Station Medians, 1990–2019.

HUC-8 Tiers

Arkansas's 58 watersheds were classified into four tiers (Figure 10). A four-tier framework was developed based on magnitude and trend results and data availability to assign all Arkansas's HUC-8s to following tiers:

- Tier 1 – Maximum focus for nutrient reduction activities, sufficient data.
- Tier 2 – Focus for nutrient reduction activities, needs more monitoring.
- Tier 3 – Less focus for nutrient reduction activities, needs more monitoring.
- Tier 4 – Least focus for nutrient reduction activities, sufficient monitoring.

See Appendix A for more information.

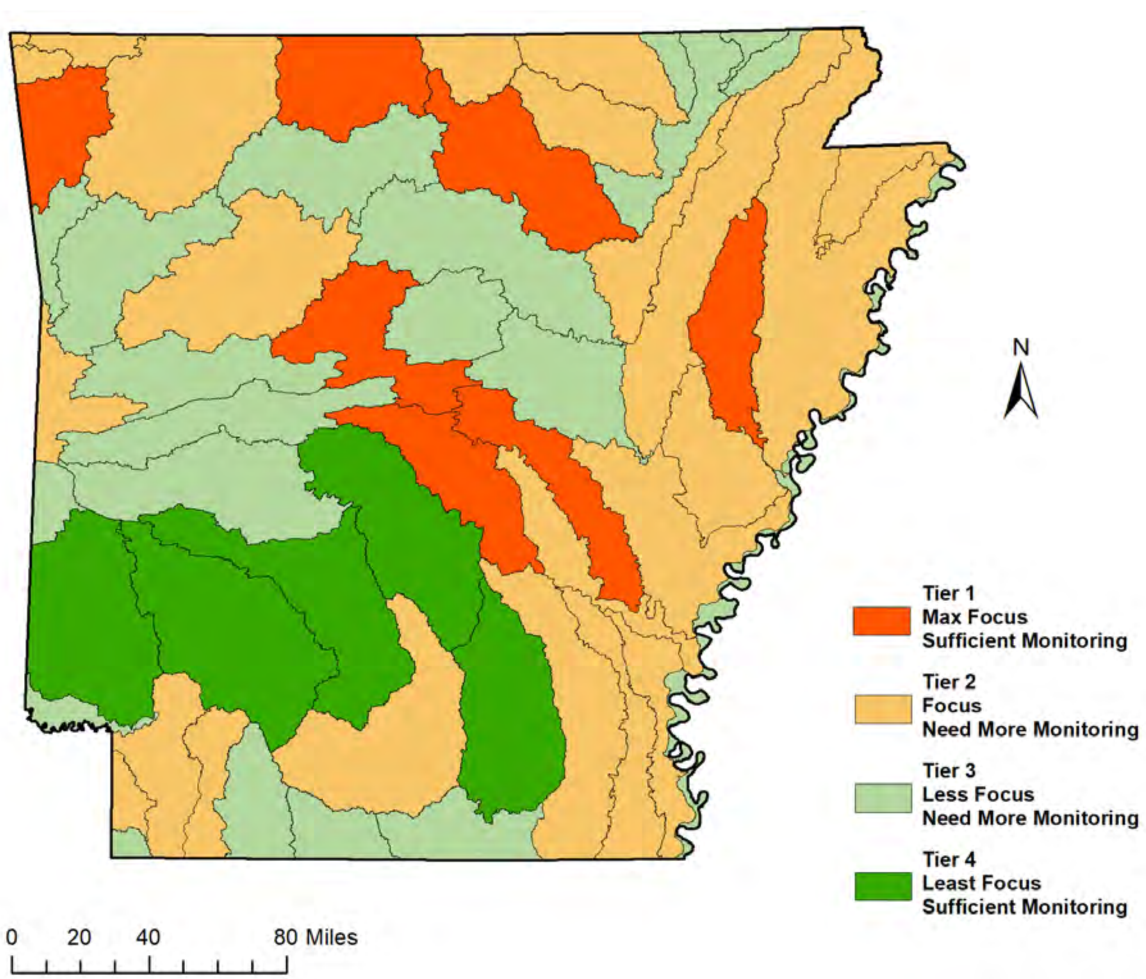


Figure 10. Four Tiers of HUC-8 Watersheds.

Tier 1 Designation

The prioritization framework identified seven Tier 1 HUC-8 watersheds for maximum focus with enough to guide a nutrient reduction strategy (Table 2; see Figure 10). Tier 1 watersheds have sufficient data and have a great potential for both TN and TP reduction. Total nutrient magnitudes (years 2015–2019) were the primary driver (see Appendix A).

Table 2. Tier 1 Watersheds

11110203 – Lake Conway-Point Remove
11110103 – Illinois
08020205 – L'Anguille
08020402 – Bayou Meto
11010004 – Middle White
1110207 – Lower Arkansas-Maumelle
11010003 – Bull Shoals Lake

Most of these watersheds had other substantiating factors for prioritization, including nutrient levels that were not changing at the HUC-8 level (11010004 – Middle White, 11010004 – Bull Shoals Lake, and 11110103 – Illinois), a majority of sites with increasing nutrients (11010004 – Bull Shoals Lake), NRCS Mississippi River Healthy Watersheds Basin Initiative (MRBI) priority watershed (08020205 – L'Anguille, 08020402 – Bayou Meto), nutrient surplus area priority watershed (11010003 – Bull Shoals Lake and 11110103 – Illinois), or prioritization under Arkansas's 2018–2023 Nonpoint Source Pollution Management Plan (08020205 – L'Anguille, 11110103 – Illinois, 11110203 – Lake Conway-Point Remove).

Tier 1 strategies will be implemented under Goal 1.

Tier 2 Designation

A total of 23 HUC-8s were assigned to Tier 2 focus status. Tier 2 focuses on future monitoring program investments due to demonstrated nutrient reduction needs, data limitations, or both. Tier 2 HUC-8s were grouped by four subcategories that summarize the level of nutrient reduction need suggested by the data analysis, data availability, and partner priority status (Table 2). Subcategories are: (2a) equivalent evidence for nutrient reduction need to Tier 1, but with insufficient data for quantitative assessment and goal setting; (2b) evidence of nutrient reduction need, but less than qualifying criteria for Tier 1, with sufficient data; (2c) evidence of nutrient reduction need, with limited data; and (2d) a partner priority (MRBI or nutrient surplus area) for nutrient reduction focus, but with insufficient data for assessment in any component of the data analysis (Table 3).

Tier 2 strategies will be implemented under Goal 2.

Table 3. Tier 2 Subcategories

Tier 2a: Max. Focus, Enhance Monitoring	Tier 2b: Focus, Continue Monitoring	Tier 2c: Focus, Enhance Monitoring	Tier 2d: Likely Focus, Design Monitoring
Lower St. Francis	Lower Ouachita-Smackover	Dardanelle Reservoir	Lake O' The Cherokees

Tier 2a: Max. Focus, Enhance Monitoring	Tier 2b: Focus, Continue Monitoring	Tier 2c: Focus, Enhance Monitoring	Tier 2d: Likely Focus, Design Monitoring
Lower Sulphur	Beaver Reservoir	Little River Ditches	Lower Neosho
Mckinney-Posten Bayous	Spring	North Fork White	Upper White-Village
Bodcau Bayou	Poteau	Cache	Big
Bayou Bartholomew		Strawberry	Lower White
Elk			Lower Arkansas
			Boeuf
			Bayou Macon

Tiers 3 and 4 Designation

Tiers 3 and 4 were designed to encompass HUC-8s with the fewest lines of evidence suggesting nutrient reduction need, acknowledging that data-limited HUC-8s merit greater prioritization in Tier 3 from the perspective of investment in future data collection efforts. All HUC-8s that did not qualify for Tier 1 or Tier 2 status were assigned to Tier 3 or Tier 4 based on data availability, with data-limited HUC-8s assigned to Tier 3 and HUC-8s with sufficient data assigned to Tier 4.

Tier 3 and Tier 4 strategies will be implemented under Goal 3.

Challenges to a Statewide Prioritization Framework

Uneven coverage in the state's ambient water quality monitoring data sets was the primary challenge to a statewide HUC-8 prioritization framework. Approximately one-third of Arkansas HUC-8s did not qualify for analysis. In many cases, data-deficient HUC-8s may not represent the appropriate scale for ANRS prioritization. Some are data-limited because only a small area is in Arkansas—most notably 11140105 – Kiamichi, of which only 0.13 mi^2 lies within Arkansas.

Beaver Lake

Section 4. Measuring Environmental Impacts

Water Quality Monitoring

Water quality monitoring provides data to support decision-making on health and environmental issues like nutrient pollution. Monitoring is used to inform us about current, ongoing, and emerging problems within Arkansas's waters. Several agencies and organizations are collecting data that can be incorporated into the strategic framework outlined here in the ANRS.

Challenges of Water Quality Monitoring

The monitoring of ecosystems poses several scientific, technical, and policy challenges. Challenges must be minimized or overcome for monitoring to be successful and to provide the information necessary to address questions the study was designed to answer.

The effectiveness of best management practices (BMPs) can vary greatly within and among watersheds, and the cumulative effects of combinations of practices can produce results that are different than the sum of their individual reductions (Sharpley et al. 2009; Francesconi et al. 2014). Areport prepared by the Northeast-Midwest Institute in collaboration with the USGS (Betanzo et al. 2015) lists and discuss the following challenges:

- It takes time for management practices to be implemented at the watershed scale with a density that results in water quality change.
- Land management practices and land use are constantly changing.
- Legacy nutrients, specifically phosphorus, in soil and sediment can continue to be released after conservation practices have been implemented.
- Precipitation and streamflow vary from year-to-year, which can affect the length of time required to measure water quality change.

- The lack of long-term monitoring or the challenge of maintaining an adequate and appropriate long-term monitoring program to document results.
- Data on BMP and conservation practice implementation and maintenance are sometimes not available.

Ambient Water Quality Monitoring Network

DEQ monitors Arkansas's surface water in streams and lakes by collecting samples. Chemical, physical, and biological data obtained from the samples are used for water quality assessments, designated use attainment decisions, and special projects. DEQ currently monitors around 175 permanent, ambient monitoring stations (Figure 11). The ambient monitoring stations are sampled twice a quarter and analyzed for selected parameters. Nutrient data typically collected includes TP, orthophosphate, nitrate-nitrogen, TN, ammonia nitrogen, and total Kjeldahl nitrogen on selected waterbodies.

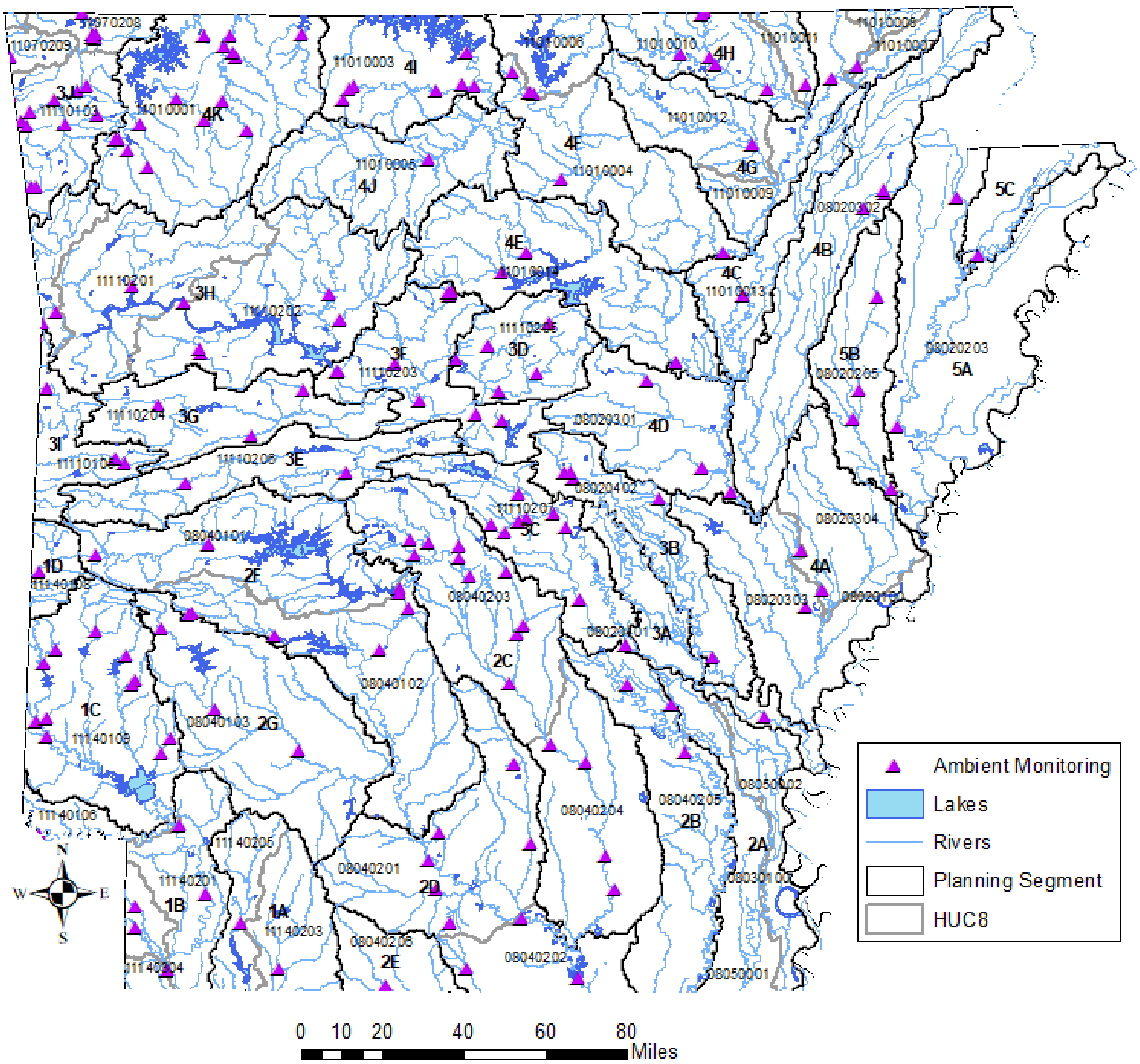


Figure 11. DEQ Water Quality Monitoring Stations.

Lake Water Quality Monitoring Program

The DEQ monitors the water quality of 23 of Arkansas's public lakes for designated use assessment and trend analysis. Lakes are sampled quarterly, and water samples are collected for ambient monitoring parameters.

Ground Water Quality Monitoring

DEQ operates the Ground Water Quality Monitoring Network, which currently uses a network of approximately 250 water supply wells and springs in 11 designated areas. Samples taken for laboratory analyses differ for each location, but nutrients include constituents like that of the ambient monitoring stations.

NRD works closely with other state and federal agencies to monitor a water well network of over 1,200 sites for water level and quantity information. Each spring, approximately 400 wells are monitored in the Alluvial aquifer and approximately 200–300 wells are monitored in the Sparta/Memphis aquifer. The number of wells monitored vary from year to year depending on the resources available, well accessibility, and other factors.

Arkansas Masterwell Program

The USGS maintains the Arkansas Masterwell Program, which supplies long-term groundwater quality monitoring.

Source Water Quality Monitoring

ADH monitors approximately 62 drinking water sources in Arkansas. Most sites are lakes, with some rivers and a few springs. Samples are taken on a quarterly basis, and laboratory analysis includes several constituents, but parameters associated with nutrients include TN and TP. The ADH also provides technical assistance to public water systems to enable their own monitoring for nutrients.

Water Quality Standards

Designated Uses

The CWA requires states to develop water quality standards to protect surface waters for aquatic life, recreation, human health, and other uses. DEQ develops proposed water quality standards for Arkansas that are published in Arkansas Pollution Control and Ecology Commission Rule 2. Water quality standards are designed to enhance the quality, value, and beneficial uses of the surface waters of Arkansas. They aid in the prevention, control, and abatement of water pollution. Water quality standards provide for the protection and propagation of fish and wildlife, while ensuring that water recreation is safe. Standards must consist of three elements: designated uses, criteria to protect those uses, and an anti-degradation policy.

Designated uses, also referred to as beneficial uses, are appropriate water uses to be achieved and protected for specific water bodies. Water quality standards are ecoregion-based. Water within each of the six ecoregions of the state has standards that were developed from data from the least-disturbed streams within each ecoregion.

List of Designated Uses

- **Extraordinary Resource Waters:** This beneficial use is a combination of the chemical, physical, and biological characteristics of a waterbody and its watershed that is characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential, and intangible social values.
- **Ecologically Sensitive Waterbody:** This beneficial use identifies segments known to provide habitat within the existing range of threatened, endangered, or endemic species of aquatic or semi-aquatic life forms.
- **Natural and Scenic Waterways:** This beneficial use identifies segments that have been legislatively adopted into a state or federal system.
- **Primary Contact Recreation:** This beneficial use designates waters where full body contact is involved.
- **Secondary Contact Recreation:** This beneficial use designates waters where secondary activities like boating, fishing, or wading are involved.
- **Aquatic Life:** This beneficial use designates waters which provide for the protection and propagation of fish, shellfish, and other forms of aquatic life.
- **Domestic Water Supply:** This beneficial use designates water that will be protected for use in public and private water supplies.
- **Industrial Water Supply:** This beneficial use designates water that will be protected for use as process or cooling water.
- **Agricultural Water Supply:** This beneficial use designates waters that will be protected for irrigation of crops and/or consumption by livestock.
- **Other Uses:** This category of beneficial use is generally used to designate uses that are not dependent upon water quality, such as hydroelectric power generation and navigation.

Impaired Waters

Section 303(d) of the CWA requires states to identify waters where current pollution control technologies alone cannot meet the water quality standards set for that waterbody. DEQ maintains a list of impaired waters—those water bodies that are not meeting water quality standards and/or designated uses based on DEQ assessments.

Impairment of a waterbody from excess nutrients is dependent on natural characteristics such as stream flow, residence time, stream slope, substrate type, canopy, riparian vegetation, primary use, season of the year, and ecoregion water chemistry. Because nutrient water column concentrations do not always correlate directly with stream impairments, impairments are assessed by a combination of factors, such as: water clarity; periphyton or phytoplankton production; dissolved oxygen values; dissolved oxygen saturation; diurnal dissolved oxygen fluctuations; pH values; aquatic-life community structure; or other factors as identified by DEQ. Point source discharges into the watersheds containing DEQ's CWA section 303(d)-listed waters (due to phosphorus) shall be governed by the limits listed in Table 4.

For discharges from point sources that are greater than 15 million gallons per day (mgd), reduction of phosphorus below 1 mg/L may be required based on the magnitude of the phosphorus load (mass) and the type of downstream waterbodies (e.g., reservoirs, Extraordinary Resource Waters). Additionally, any discharge limits listed in Table 4 may be further reduced if it is determined that these values are causing impairments to special waters such as domestic water supplies, lakes or reservoirs, or Extraordinary Resource Waters.

Table 4. Point Source Phosphorus Discharge Limits

Facility Design Flow	Total Phosphorus Discharge Limit
Equal or greater than 15 mgd	Case by case
3 to less than 15 mgd	1.0 mg/L
1 to less than 3 mgd	2.0 mg/L
0.5 to less than 1 mgd	5.0 mg/L
Less than 0.5 mgd	Case by case

DEQ establishes minimum qualifications, standards, and procedures for issuance of permits for concentrated animal feeding operations (CAFOs) using liquid animal waste management systems within Arkansas and for the issuance of permits for land application sites within the state. An individual permitting program (site-specific permits) exists to regulate the operation of hog, poultry, or dairy farms or other confined animal operations using liquid animal waste management systems. Facility management, operation, and maintenance are managed through a waste and nutrient management plan developed in consideration of type of waste, on-site soils, and geological surveys. Both state NPDES and CAFO regulations stipulate additional nutrient management planning and certification requirements in nutrient surplus watersheds. Continual monitoring and reporting are necessary to ensure individual permit conditions are being met.

Nutrient Surplus Area

Three laws were enacted in 2003 in Arkansas that affect Arkansas's agricultural producers located within watersheds of concern. The goal of this legislation is to preserve water quality in Arkansas without creating an unnecessary burden on agricultural interests. Arkansas's commercial poultry farmers, as well as any livestock, forage, and crop production operations utilizing poultry litter, are required to follow provisions of these laws:

- Act 1059, AN ACT TO CERTIFY SOIL NUTRIENT MANAGEMENT PLANNERS AND SOIL NUTRIENT APPLICATOR. Microsoft Word – ACT1059.doc (state.ar.us).
- Act 1060, ARKANSAS POULTRY REGISTRATION ACT. Microsoft Word – ACT1060.doc (state.ar.us).
- Act 1061, ARKANSAS SOIL NUTRIENT APPLICATION AND POULTRY LITTER UTILIZATION ACT. Microsoft Word – ACT1061.doc (state.ar.us).

Others impacted by the regulations are agricultural operators and landowners of more than 2.5 acres operating in nutrient surplus areas and any agricultural producers using state or federal funds for creating or implementing nutrient management plans, whether they are within designated nutrient surplus areas. Specifically, the new regulations require:

- Certifying all those who apply nutrients to crops or pastureland.
- Certifying nutrient management plan writers.
- Registering all poultry feeding operations.
- Developing and implementing nutrient and poultry litter management plans for those operating in nutrient surplus areas.

Designated nutrient surplus areas as identified in the enabling Arkansas legislation include the following watersheds (Arkansas Code Annotated § 15-20-1104; Figure 12):

- Illinois River
- Spavinaw Creek
- Honey Creek
- Little Sugar Creek
- Poteau River
- Mountain Fork of the Little River
- Upper Arkansas River, including Lee Creek and Massard Creek
- Upper White River, above its confluence with the Crooked Creek

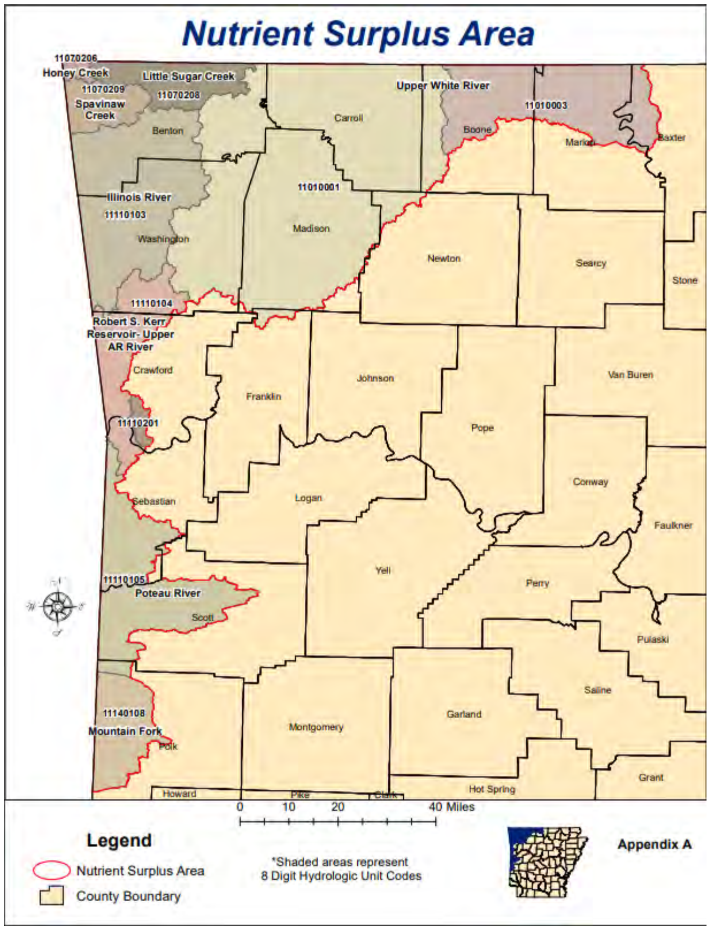


Figure 12. Nutrient Surplus Areas in Arkansas.

Waters in existing or subsequently designated nutrient surplus watersheds may be included if activities provide a significant phosphorus contribution in the nutrient surplus watersheds.

Urban stormwater runoff has been identified as a source of contamination in DEQ's most current (2018) List of Impaired Waterbodies. DEQ regulates this runoff through issuance of: (1) NPDES General Permits for construction, industrial, and municipal separate storm sewer systems (MS4); (2) Non-Stormwater NPDES General Permits for car washes, water treatment; and (3) No-Discharge Permits for land application and oil and gas activities. All permitted MS4s must develop and implement stormwater management plans that address these minimum control measures:

(1) Public education and outreach

(2) Public participation/ involvement

(3) Illicit discharge detection and elimination

(4) Construction site runoff control

(5) Post construction stormwater management and pollution prevention

(6) Pollution prevention/ good housekeeping for municipal operations

For urban areas, development and landscaping techniques that reduce or slow rates of runoff are well publicized and documented. These techniques and practices help mitigate the effects of impermeable surfaces by incorporating filtration and retention capacities within the urban setting. Urban pollution prevention programs can become more effective by incorporating initiatives that:

- Advance planning and establishment of runoff pollution prevention goals.
- Increase government and community interaction.
- Prioritize pollution prevention over source treatment.
- Establish sustainable funding sources.
- Increase public education, monitoring and reporting, and enforcement participation.
- Develop strategies relevant to local issues.
- Adapt policies and programs as needed to improve pollution prevention.

Nutrient Trends by Source Category

In order to understand and identify the sources of nutrients that are contributing to the HABs in our local waterbodies and the Gulf of Mexico Hypoxic Zone, we used the USGS SPARROW model. The SPARROW (Spatially Referenced Regression on Watershed attributes) model is a popular watershed modeling technique that integrates water quality data with landscape information. Sources of nitrogen and phosphorus include agricultural, urban, and natural (Figure 13). Agricultural sources include fertilizer, manure, and nitrogen fixing crops (Table 5). Urban sources include atmospheric deposition, urban land runoff, and municipal wastewater discharges. Natural sources include natural sources like phosphorus from dead plant or animal debris.

As seen in Table 5 the biggest contributing source of nitrogen is atmospheric deposition followed by manure, nitrogen fixing crops, and farm fertilizer. The largest contributing source of phosphorus is farm fertilizer followed by manure, natural sources, and urban land. Knowing the sources of nutrients will help to guide conservation practices and ultimately, help to reduce nutrients in our waters.

Table 5: Sources of Nitrogen and Phosphorus (2012 Delivered Aggregated Loads)

Source	Nitrogen	Phosphorus
Agricultural Sources		
Manure	22%	28%
Nitrogen fixing crops	15%	-
Farm fertilizer	14%	48%
Urban Sources		
Urban land	2%	8%
Municipal wastewater discharges	2%	4%
Atmospheric deposition	45%	-
Natural Sources		
Natural sources	-	12%

Arkansas is known as the Natural State for good reason. As Figure 13 shows, about half of Arkansas is wooded or has open fields, with less than 6% of Arkansas designated as urban or developed land according to USDA NASS 2021. About 30% of Arkansas land is cropland or pastured. Arkansas is a top producer of many crops in the U.S. Soybean production uses about half the share of cropland, and rice occupies about a quarter of croplands. The rest of the cropland is mainly made of up corn, cotton, and hay. Figure 13 shows land use and types of crops grown in Arkansas, and it also shows the sources of nitrogen and phosphorus as being contributed by agricultural, urban, or natural sources. Table 5 breaks down sources into more specific groups.

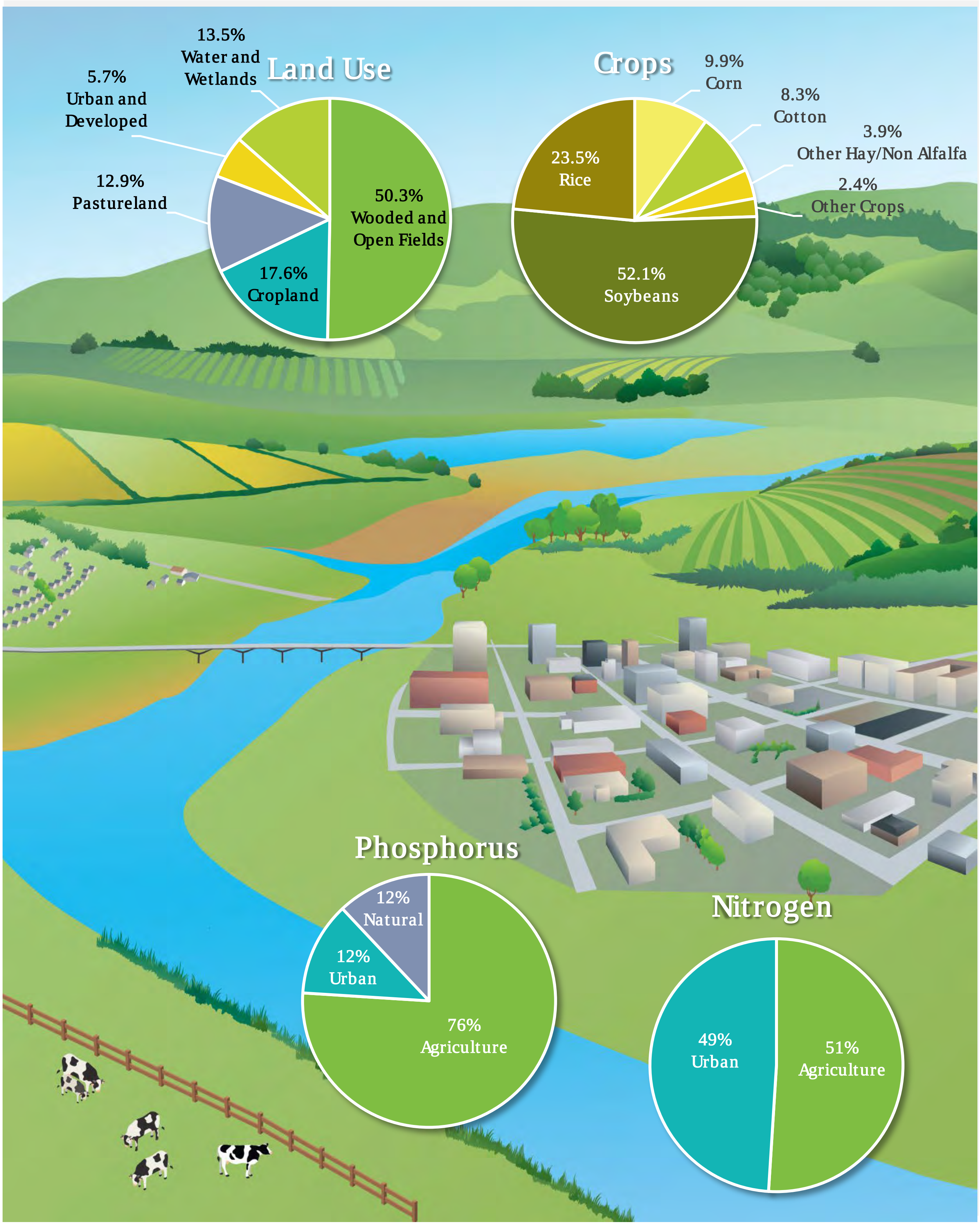


Figure 13. Nitrogen and Phosphorus Loads to Arkansas Waters
(Source: 2012 Delivered Aggregated Loads: Robertson and Saad 2019; Land Uses: USDA NASS 2021).

Monitoring Nutrients

Financial support for comprehensive monitoring is sometimes inadequate and in direct competition for limited monies available for "on-the-ground" reduction practices. How much monitoring is needed should be based on watershed-specific characteristics, water quality data, observation, and professional judgment. Data policies should be adopted that allow aggregation of monitoring and program data and that can be made available for use by resource professionals without compromising the integrity of personal information.

On the agricultural landscape, implementation of individual edge-of-field or farm-scale reduction practices may not translate to immediate and measurable water quality improvements downstream. The larger the watershed, the greater the potential for localized reduction effects to become distorted (immeasurable) downstream. Potential lag times between initial implementation of reduction practices and improvement of water quality downstream, along with the environment's capacity to assimilate the nutrient load, must be understood when evaluating reduction progress. To fully evaluate and document reduction progress requires a network of monitoring locations determined by analyses of conditions in the watershed. A comprehensive monitoring network should include edge-of-field, subwatershed, watershed, and basin level sampling locations. However, financial support for such comprehensive monitoring is often inadequate and can be in competition with the limited funding available for implementation of "on-the-ground" reduction practices. The amount of monitoring effort adequate to document impacts and reduction progress will be based on watershed characteristics, water quality data, previous observation, and professional judgment from water quality and natural resource professionals.

Landscape features (e.g., land use, land cover, soils, hydrography and inundation, wetlands, geology, geomorphic setting, conservation practices) influence lag time, assimilation capacity, and overall reduction. Demonstration projects and technical studies can provide valuable insight regarding lag time and the chemical and biological processes that are influencing nutrient uptake and assimilation. Similarly, geographic information system (GIS) decision-support programs and watershed models can identify landscape influences beyond the individual farm level and can serve as powerful tools for resource managers and regulators. These tools should be fully utilized wherever possible to establish realistic and achievable reduction goals and to track the progress of implementation and nutrient-reduction efforts.

Data on local, state, and federal programs involving permitting and incentive-based, voluntary activities are not always readily available or easily transferred to a compatible format for use. In some instances, policies designed to protect private landowner information prevents the sharing of data related to the location and extent of "on-the-ground" changes resulting from regulatory and voluntary conservation programs. Lack of data on these changes can severely limit the scope of watershed planning. Data policies should be adopted that allow aggregation of program information for use by resource managers without compromising the privacy of individual personal information.

Total Maximum Daily Load

Atotal maximum daily load (TMDL) is a calculation developed for some waters that are not meeting or are at risk of not attaining water quality standards. The TMDL calculates the maximum amount of constituent a waterbody can receive and still meet the standards. When establishing TMDLs, the DEQ considers all point and nonpoint sources of a pollutant, existing scientific uncertainty, potential community growth, and the effects of seasonal variation.

Nutrient Criteria Development

In 2001, EPApublished recommended water quality criteria for nutrients under section 304(a) of the CWA (USEPA2001). This document was to serve as a starting point for states, tribes, interstate commissions, and others to develop refined nutrient criteria (EPA2001). According to EPA, nutrients cause adverse effects on humans and domestic animals; impairment to aesthetics; interference with human use; negatively effects on aquatic life; and impacts to downstream systems. The challenge with EPA's 1998 National Strategy for the Development of Regional Nutrient Criteria is that the strategy is a "one number fits all" approach. The Regional Nutrient Criteria does not consider the dynamic characteristics of streams and rivers and their ability to assimilate nutrient impacts. These characteristics include, but are not limited to: flow; gradient; canopy cover; substrate type; water clarity; pH; dissolved oxygen; channel stability; temperature; season; trophic status; and other factors. In addition, large, generalized data sets, such as EPA's Nutrient Ecoregions Approach, do not account for the natural state of streams and rivers, nor do they determine levels for predicting excessive levels of benthic algae.

In response to EPA's guidance, DEQ has adopted the following approaches to nutrient criteria development:

- Develop nutrient criteria that fully recognize localized conditions and protect specific designated uses, using the process outlined in the USEPAtechnical guidance manuals.
- Use other scientifically defensible methods and appropriate water quality data to develop criteria protective of designated uses.

The Upper Saline Watershed was used as a pilot study by DEQ to test methods for developing and utilizing a three-level nutrient criteria development approach for Arkansas's rivers/streams. The Level I Assessment was performed to screen sites for potential nutrient impairment. The Level II and Level III Assessments were performed at sites where potential nutrient impairment exists. It was intended that, after completion of the pilot study and verification of assessment methodology, the approach derived from the Upper Saline Watershed pilot project would transfer to other rivers/streams in Arkansas. Completion of the Upper Saline River Pilot Study brought forth intrinsic study design flaws. During the pilot study, lack of severely nutrient impacted reaches and modified calculation of 25th and 75th percentiles, macroinvertebrate assemblages exhibited little spatial or temporal differences, while fish assemblages among groups were highly variable. The small sample size of the Upper Saline pilot study prevented identification of nutrient concentration thresholds among biotic assemblages using regression modeling.

Beaver Reservoir, a large drinking water source for Northwest Arkansas, was a pilot study area for the development of nutrient criteria for Arkansas's lakes/reservoirs. It was intended that, after completion of the pilot study and verification of assessment methodology, the tools and processes derived for the Beaver Reservoir pilot project would be transferable to other lakes/reservoirs in Arkansas. Completed in 2008 and based on weight-of-evidence approach, findings from the study recommend effects based numeric water criteria for Hickory Creek on Beaver Lake for growing season geometric mean chlorophyll a concentration of 8 micrograms per liter (µg/L), annual average Secchi depth of 1.1 meters (m), and nutrient targets for TP and TN of 0.04 mg/L and 0.4 mg/L, respectively.

Lake criteria have been developed for Beaver Lake only (Table 5). This criterion was adopted in February 2014 into Regulation #2 by the Arkansas Pollution Control and Ecology Commission. Data collection is ongoing for potential future use in nutrient criteria development.

Table 6. Lake Site-Specific Nutrient Standard

Lake	Chlorophyll a (µg/L) **	Secchi Transparency (m) ***
Beaver Lake *	8	1.1

** These standards are for measurement at the Hickory Creek site over the old thalweg, below the confluence of War Eagle Creek and the White River in Beaver Lake.*

*** Growing season geometric mean (May–October)*

**** Annual Average*

Currently, Arkansas maintains the following narrative nutrient standard, Reg. 2.509 in Rule # 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas:

> "Materials 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 use of the waterbody."

Section 5: Nutrient Reduction Practices

Point Source Management

Point source nutrient loading is small relative to statewide NPS contributions. However, during low streamflow conditions, loadings from point sources can be a significant portion of the total nutrient load. Depending on location and specific conditions, a point source may be the primary contributor to nutrient impairment on a seasonal or year-round basis. Point source nutrient loading can be reduced in influent to treatment facilities, in wastewater effluent, in stormwater discharges, or in other concentrated discharge sources.

Point source loadings and associated impairments are assessed regularly through stream and effluent water quality data. Additional watershed and hydrologic modeling, water quality and mass balance analysis, and other assessments may be necessary to understand the stream and lake environments where improvement efforts are ongoing or being considered. The assessments for point source loading should be led by state water quality regulators in cooperation with other water resource agencies involved in nutrient reduction. Where nutrient impairment is present, the necessary level of water quality monitoring should be determined on an individual watershed basis and may vary based on site-specific conditions. Monitoring may be appropriate at both the discharge point (end of pipe) and further downstream to assess overall nutrient effects on the aquatic environment from the point source(s). Locations of existing stream flow and water quality monitoring stations should be evaluated to take advantage of opportunities to add water quality sampling at stream flow stations and to leverage multiple sources of funding.

In nutrient surplus area watersheds, NPDES permitting requirements for phosphorus removal have been strengthened. DEQ bases regulations on the design flow (treatment capacity) of facilities in nutrient surplus area watersheds. NPDES phosphorus limits are referenced in Table 4 of this report. Treatment costs for phosphorus removal can be costly and prohibitive in some cases. Smaller wastewater treatment systems that do not have adequate nutrient reduction treatment or revenue sufficient to support expensive nutrient removal processes may benefit from regionalization of treatment capacity.

The potential for multisystem collection and waste flow to regionally operated treatment facilities should be analyzed where there is little opportunity for smaller, individual treatment facilities to meet NPDES requirements and nutrient-reduction goals. New wastewater treatment facilities, whether partially or fully financed through state-funded, low-interest loan and grant programs, must be approved and receive certification of compliance with the Arkansas Water Plan. This certification process provides an opportunity to review factors that can affect nutrient reduction, environmental, and economic needs on a regional basis.

General Practices

There are many point source implementation practices that agencies can implement and coordinate to reduce nutrients in aquatic systems (Table 6). Leveraging financial support and resources from multiple programs where beneficial opportunities exist is basic to the state's multidiscipline, multiagency strategic approach to nutrient reduction.

The long-term reduction goal in priority watersheds is to remove impairment risks caused by nutrient point sources and maintain beneficial uses. Potential interim target or percent reduction goals are to be evaluated on a watershed-by-watershed basis.

DEQ encourages potential new or expanding facilities to request an evaluation of preliminary NPDES permit limits during the design of the treatment system. The preliminary limit evaluation provides an opportunity for new or expanding facilities to design nutrient reduction to consistently meet any preliminary nutrient limits. DEQ normally responds to preliminary limits requests in a response letter sent to the facility and/or consulting engineer.

Table 7. Point Source Implementation Practices

Adopt effective, innovative, and economical treatment technologies
Monitor and assess watershed impacts from point sources
Incorporate NPDES nutrient limits for major treatment facilities in priority watersheds
Increase the knowledge of available treatment processes and reduction effectiveness
Expand watershed-based monitoring networks where possible
Enhance reporting and analysis of trends in nutrient loading and reduction
Increase public participation in urban nutrient-reduction programs and practices
Improve nutrient assimilation and uptake capacities in riparian, lake, and wetland areas
Incorporate regional planning when developing new or upgraded treatment systems
Promote and increase implementation of effective urban stormwater management programs

Nonpoint Source Management

Nutrient Management

Nutrient management is the science and practice that links soil, crop, weather, and hydrologic factors with BMPs and conservation practices to achieve optimal nutrient use efficiency while protecting aquatic environments. Nonpoint sources of nutrients can originate from commercial fertilizers, animal manure and litter, urban stormwater runoff, home sewage, sediment, or other contributing sources. Managing nutrient inputs (e.g., fertilizer, manure, litter application) and potential runoff, as well as increasing the assimilation capacity of land and aquatic environments (e.g., riparian buffers, wetlands), is necessary to affect measurable reduction at the watershed-level scale.

Landscapes have undergone modifications that change the way water moves across the land. Examples of these changes include subsurface drainage; removal of wetlands, riparian corridors, and floodplains; construction of roads, buildings, and other impervious surfaces; and stream channelization, dredging, and relocation. As large flow events occur more frequently and local drought and flood cycles are intensified, it can result in increased nutrient loading, more sedimentation, increased water temperatures, lower dissolved oxygen, and degradation of aquatic ecosystems in Arkansas's water bodies. Restoring landscapes to a more natural hydrology by encouraging drainage water management is recommended.

Arkansas Phosphorus Index

The Arkansas Phosphorus Index (API) was developed as part of farm nutrient management planning process (Sharpley et al. 2010). The term phosphorus index is used to describe the level of risk for potential movement of phosphorus across the landscape. The API assesses the risk of phosphorus loss in runoff from pastures and hayland as a function of source potential (phosphorus from the soil and manure application), transport potential (risk of phosphorus movement offsite as affected by runoff and erosion, field slope, grazing intensity and proximity to streams) and any additional BMPs implemented between the application site and potential receiving waters.

For a specific set of field conditions, the index associates a phosphorus runoff risk value to a specific manure or biosolids application rate. The classification of this value into a risk range determines if the application is environmentally acceptable. If acceptable, the nutrient management plan specifies this application rate as the maximum rate for the combination of phosphorus source and field in question. During the implementation of a nutrient management plan, application rates up to the specified maximum can be applied. Lower application rates are generally assumed to have lower environmental phosphorus runoff risk and therefore also acceptable. UADA's publication, Using the 2010 Arkansas Phosphorus Index, describes the API and how to interpret the assigned risk, and it provides example calculations. The API addresses seven site characteristics that are grouped into either Source Factors or Transport Factors. The first two site characteristics are Phosphorus Source Factors: (1) soil test phosphorus and (2) soluble phosphorus application rate. The other five site characteristics are Phosphorus Transport Factors: (3) soil erosion, (4) soil runoff class, (5) flooding frequency, (6) application method, and (7) timing of phosphorus application. In addition to management practices that influence site characteristics, there are additional BMPs that can be considered to reduce phosphorus runoff risk (Table 7). Currently, the API is also being updated to integrate the risk of phosphorus runoff from row crops.

Table 8. Approved BMPs for Use in the Arkansas Phosphorus Index

Diversion
Fencing
Field borders
Filter strip and/or fenced filter strip
Grassed waterway
Pond and/or fenced pond
Riparian forest buffer and/or fenced riparian forest buffer
Riparian herbaceous cover and/or fenced riparian herbaceous cover

NRD adopted the revised API and requires that it be used when preparing nutrient management plans in designated nutrient surplus watersheds (Figure 12). NRCS has also adopted the API as part of its nutrient management conservation practice standards (NRCS Practice Code 590).

Agricultural Practices

In Arkansas, nonpoint sources of pollution are primarily addressed through the application of BMPs and conservation practices. BMPs and conservation practices can often be specified as individual practices or as suites of practices that best address the resource of concern.

Agricultural landscapes provide the greatest opportunity for significant NPS nutrient and sediment reduction. NRCS defines several management techniques and practices. NRCS recommends a systems approach to NPS pollution management that targets core and supporting conservation practices and BMPs to address water quality concerns due to nutrient and sediment runoff. The systems approach concept is referred to as Avoiding, Controlling, and Trapping (ACT). Primarily agriculture-based, ACT provides an approach to help producers avoid pollution by reducing the amount of agricultural nutrients available in runoff or leaching into water bodies; to control pollution by preventing the loss of pollutants; and to trap pollution as a last line of defense against potential pollutants at edge-of-field or in facilities that capture and assimilate nutrients before entering water bodies.

It is known that implementing single reduction practices alone may not yield the desired reductions at the watershed or basin-level scale. Proving to be more effective are advanced farm planning and land management techniques that avoid, control, and trap nutrients by using combinations of practices to sustain long-term reduction. Whole-farm planning, which encourages farmers to identify long-term farm, environmental, and production goals, is helping to focus on longer-term planning objectives. The 4R nutrient stewardship concept advocates the use of the right fertilizer, at the right rate, at the right time, and in the right place (Figure 14). When the 4R principles are combined with BMPs on the land, maximum nutrient reduction is achieved while also meeting crop requirements.

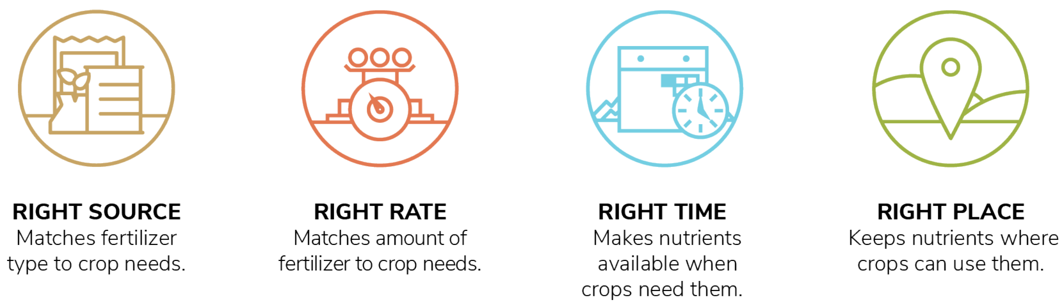


Figure 14. 4R Principles of Nutrient Stewardship. (Source: The Fertilizer Institute)

Knowledge gained from implementing these types of farm planning strategies and reduction practices should be used to guide future incentives and reduction activities while protecting the economic livelihood of local stakeholders whose voluntary actions over time are critical to successful nutrient reduction. Innovative methods and technologies that optimize nutrient reduction and water efficiencies should be promoted and incorporated wherever possible (Table 8). Refer to Appendix B for more information on conservation cropping systems.

Table 9. Nonpoint Source Implementation Practices

Promote research of innovative and effective market-based nutrient reduction practices
Demonstrate farming practices that increase reduction effectiveness and economic viability
Increase participation in nutrient reduction practices and programs
Expand the use of nutrient-inhibiting supplements
Increase adoption of improved grazing and pasture management practices
Explore the feasibility and viability of nutrient trading programs
Increase riparian buffer zones and functioning wetland areas
Enhance watershed assessment and modeling tools, web-based information, and reporting
Establish regular reporting on nutrient-reduction activities and progress
Promote public and private sector partnerships
Promote low impact development (LID)and other nutrient reduction strategies and programs in urban

Expected Nutrient Reduction Efficiencies

In late 2018 and early 2019, an expert panel consisting of 25 people with expertise in nutrient management met multiple times to identify nutrient reduction practices in Arkansas row crop and animal production systems. The panel's goal was to reach a consensus on expected reduction efficiencies for identified practices. The panel was made up of representatives from federal agencies (USEPA, USDA NRCS, USDA Agricultural Research Service); state agencies (NRD, DEQ); state universities (UADA Cooperative Extension Service; University of Arkansas, Department of Crop, Soil, and Environmental Sciences; Arkansas State University); and nongovernment natural resources organizations (Illinois River Watershed Partnership, The Nature Conservancy, Arkansas Farm Bureau). Practice suites and individual practices are listed along with their expected nutrient reduction efficiencies in Table 9 and Table 10, respectively. All nutrient reduction efficiencies represent expected annual reductions in TP or TN loads.

Table 10. Expected Nutrient Reduction Efficiencies for Practice Suites

Practice Suite	TP Reduction (%)	TN Reduction (%)
Irrigation Water Management Practices Suite	40	55
Tailwater Recovery Practices Suite	35	50
Reduced Irrigation Water Use Practices Suite	5	5
Row Crop Soil Nutrient Management Practices Suite	25	15
Conservation Tillage and Cover Crop Suite	55	50
Pasture Management Practices Suite	65	45

Table 11. Expected Nutrient Reduction Efficiencies for Individual Practices

Individual Management Practice	USDA Practice Code	TP Reduction (%)	TN Reduction (%)
No-till/conservation tillage	329/345	20	10
Cover crops	340	30	25
Nutrient management plan	104	15	10
Tailwater recovery system	447	20	25
Forested riparian buffer – cropland	391	45	30
Forested riparian buffer – pasture	391	35	35
Grassed riparian buffer – cropland	390	45	20
Grassed riparian buffer – pasture	390	35	35
Prescribed grazing	528	15	10
Stream exclusion/access control	472	15	10
Watering facility	614	15	10
Heavy use area protection	561	15	10

The expected nutrient reduction efficiencies will help inform the Arkansas Nutrient Reduction Reporting/ Tracking Framework that is being developed in 2022. The Arkansas Nutrient Reduction Reporting/ Tracking Framework will inventory the implementation of practices (and suites of practices) and measure NPS nutrient reduction in Arkansas.

Forestry Practices

Forestry BMPs

Forestry practices can help safeguard water quality during forestry operations from forestry landowners, logging contractors, and forest industry. Forestry BMPs include structural and nonstructural controls, operations, and maintenance procedures that can be applied before, during, and after silvicultural activities (AFC 2018). FD, in collaboration with the NRD, DEQ, the Sustainable Forest Initiative, and others, have developed and endorsed voluntary BMPs to effectively protect water quality. Example BMPs for forestry operations include, but are not limited to, streamside management zones, active road planning to minimize stream crossings, inactive road revegetation and/or stabilization, soil stabilization, and preparing sites with methods that minimize the disturbance of soil while meeting desired objectives.

FD conducts surveys on the voluntary implementation of BMPs for water quality protection in Arkansas. The most recent results from 2017–2018 found the BMP implementation rate on sites monitored was 93% (AFC 2018). Implementation of BMPs was highest on public and forestry land sites and lowest on private nonindustrial sites. See the State Forest Action Plan for more information.

Homeowners and Businesses

At the individual level, homeowners and businesses can use fertilizer responsibly, refrain from overwatering gardens and yards, and landscape with native plants that promote nutrient absorption. Limiting fertilizer use is key to reducing nutrient loading in runoff. When fertilizer is needed, reach for phosphorus-free lawn fertilizer by only buying fertilizer in which the center number is '0'. A free soil test is the best way to decide what the soil needs. Homeowners can reduce nutrient use both outdoors and indoors.

Outdoor Nutrient Reduction

- Test soil. Arkansans are able to get a free soil test. It is important to limit nutrients, especially phosphorus.
- Disconnect downspouts and install rain barrels to catch water collected from the roof to reduce runoff. This water can be used to water plants and gardens during non-rainy weather.
- Plant rain gardens. Rain gardens increase soil porosity and the ground's capacity to absorb rainwater. Using rain gardens has proven to reduce overall water runoff into our sewers.
- Plant native plants. To combat nutrient runoff, using native plants in your garden is the most effective method of reducing need for fertilizers. Native plants are naturally adapted to the native climate and once established, can be grown without the need to fertilize or water.
- Plant trees. Trees are increasingly recognized for their importance in managing runoff. Their leaf canopies help reduce erosion caused by falling rain. They also provide surface area where rainwater lands and evaporates. Roots take up water and help create conditions in the soil that promote infiltration.

Indoor Nutrient Reduction

- Inside your home, be sure to double check that your liquid dish soap, laundry detergent, and dishwater detergents are all phosphate free.
- Excessive private water usage can keep sewage treatment plants from operating most efficiently. To reduce your indoor water use, consider the following to help you save money along with Earth's most precious resource: (1) purchase low-flow shower heads; (2) use shower timers; (3) turn off faucets when brushing teeth; and (4) check your indoor pipes for leaks.

Low Impact Development and Green Infrastructure

There are a variety of ways to address urban stormwater runoff at the city, local, and individual levels.

In urban and suburban parts of Arkansas, much of the land surface is covered by buildings and pavement, which does not allow rain and snowmelt to absorb into the ground. These impervious surfaces make it easier for stormwater to pick up, absorb, and carry pollutants directly to Arkansas's waterways where they can harm water quality. Pollutants in stormwater may include:

- Fertilizers, pesticides, and other chemicals from gardens, homes, and businesses
- Nutrients and bacteria from pet waste and failing septic systems
- Sediment from construction areas
- Grease, oil, and heavy metals from cars

One of these solutions is to utilize low impact development (LID). LID is a term to describe systems and practices that use natural processes that result in infiltration, evapotranspiration, or use of stormwater to protect water quality. LID tries to manage stormwater as close to the source as possible. The most common examples of LID are rain gardens, bioretention gardens, bioswales, pervious pavement, green roofs, and rain harvesting.

Green infrastructure (GI) is an approach to water management that protects, restores, or mimics the natural cycle. At both the site and regional scale, LID/GI practices aim to preserve, restore, and create green space using soils, vegetation, and rainwater harvest techniques. Although the terms LID and GI can sometimes be used interchangeably, LID is often considered to be a subset of GI.

Outreach and Education

Public education and support are vital to long-term NPS nutrient reduction. Local participation and involvement in urban pollution prevention activities such as LID (e.g., rain gardens; infiltration and open space areas; riparian buffers; residential and subdivision stormwater management; local ordinances), should be fostered through public workshops and educational training, field days, advertisements, restoration, and demonstration projects.

Local watershed groups should be supported and encouraged as they can positively influence public participation and interest in pollution prevention activities. Opportunities to involve youth in local pollution prevention projects and education programs should be promoted to local administrators and program managers as a necessary component for long-term nutrient reduction success.

Organized Arkansas Watershed Community Efforts

Community-based watershed groups come together around water issues. They may coordinate projects, educate residents, and promote stewardship of their watershed. On-the-ground projects encompass a wide variety of issues but often include a strong education and outreach component. Projects may include water quality monitoring, habitat restoration, stormwater management, and rain gardens. Example Arkansas watershed groups include:

- Arkansas Ozark Waterkeeper
- Beaver Watershed Alliance
- Buffalo River Watershed Alliance
- Friends of the Mulberry River Watershed
- Friends of the North Fork and White Rivers
- Illinois River Watershed Partnership
- Kings River Watershed Partnership
- Lake Fayetteville Watershed Partnership
- Little Red River Action Team
- Lower Mississippi River Conservation Committee
- Ozarks Water Watch
- Save Greers Ferry Lake
- White Oak Bayou Wetlands Conservancy

Other Nonprofit Groups

Arkansas Soil Health Alliance

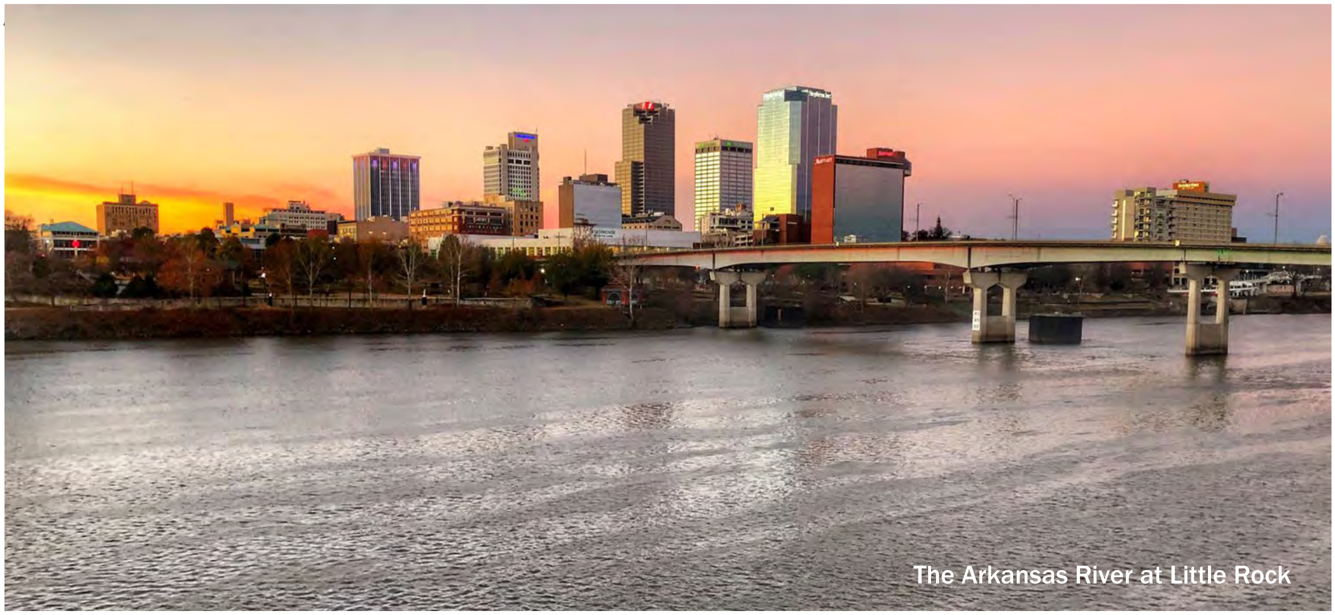
The Arkansas Soil Health Alliance (ASHA) is a nonprofit 501(c)3, led by farmers to drive adoption of soil health practices through educating farmers on the benefits of soil health. The alliance is supported by NRCS, Arkansas Association of Conservation Districts, Arkansas Grazing Lands Coalition, University of Arkansas, Arkansas State University, and the Soil Health Institute.

Individual Home Sewage Systems

Septic systems are intended to treat and dispose of relatively small volumes of wastewater effluent produced by homes and small businesses in areas not served by centralized sewer systems. There are a variety of individual and cluster treatment systems that process home and commercial sewage including, but not limited to, traditional septic tanks, chamber treatment systems, drip distribution systems, and aerobic treatment systems. These systems are regulated by ADH.

Properly managed septic systems can protect human health and preserve water quality. However, old; undersized; or poorly designed, installed, operated, or maintained systems can have adverse health and environmental impacts.

Documented issues with compromised septic systems include contamination of surface waters and ground water with disease-causing pathogens (i.e., Escherichia coli) and nutrients (i.e., nitrogen and phosphorus). NRD and partner organizations are exploring a program that coordinates resources to remediate failing individual home sewage systems in prioritized watersheds.



The Arkansas River at Little Rock

Section 6: Programs, Projects, and Initiatives Supporting Nutrient Reduction

Point Source Pollution Management

National Pollutant Discharge Elimination System Program

Federal and state laws require permits and place limits on businesses, cities, and industries that discharge water containing pollutants that may flow to a river, stream, or lake. Limits are set at levels protective of both human health and aquatic ecosystems. Point source discharges in Arkansas are managed through NPDES permits regulated by DEQ.

The NPDES permit program helps address water pollution by regulating point sources that discharge pollutants to water bodies. In Arkansas, wastewater, construction, stormwater, and pretreatment are managed through the NPDES permit program. DEQ also operates NPDES compliance inspections. This is to verify compliance with effluent limitations and to evaluate the permittee self-monitoring program. The DEQ has authority from USEPA to issue permits that control the discharge of treated wastewater into Arkansas waterways. Active NPDES sites are shown in Figure 15.

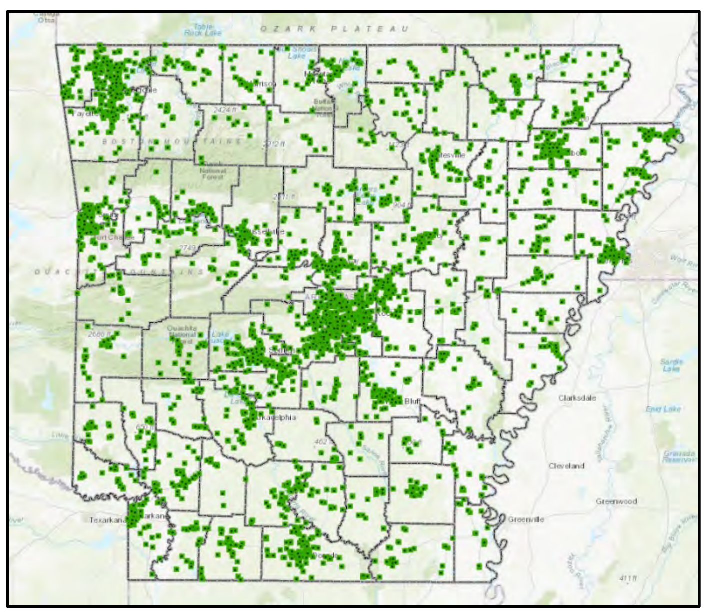


Figure 15. Active NPDES Sites.

DEQ can prepare two different types of permits within the discharge permit program: individual and general. An individual permit is prepared for a specific facility with unique permit limits and general permits are used for those facilities with similar operations. DEQ organizes its general permits as stormwater and non-stormwater. General stormwater permits may cover activities associated with construction, industry, and MS4s. General non-stormwater permits may cover operations related to sanitary landfill ponds; noncontact cooling water, cooling tower blowdown, and boiler; aggregate facilities; nonindustrial individual treatment systems; filter backwash wastewater from municipal drinking water supply plants; hydrostatic testing; car/truck wash; groundwater cleanup; and pesticide coverage.

DEQ also has a pretreatment program as a component of the NPDES program. DEQ works with closely with municipalities to protect water quality from potential pollutants discharged into publicly owned treatment works (POTWs). POTWs may be designed to treat domestic sewage, but treatment plants also have industrial customers that may be discharging harmful pollutants.

Nonpoint Source Pollution Management

NRD is responsible for developing and implementing the state's NPS Pollution Management Program. This program is a cooperative effort of many local, state, and federal agencies. Each year the NPS Management Section receives federal monies from EPA to fund projects associated with the abatement, reduction, or control of NPS pollutants. Projects may include implementation of BMPs, demonstrations of effective techniques, technical assistance, education, and monitoring. The NPS program uses the federal CWA section 319 guidance and their NPS Program Management Plan as part of the criteria for selecting grant recipients. Recipients must provide a minimum of 43% nonfederal match (in-kind or cash). Recipients eligible for funding must be nonprofit (documented and recognized), state/local government agencies, or academic institutions.

Nutrient reduction often involves changing historic land use practices, and the value of these changes may or may not be initially understood or embraced by local communities. For this reason, benefits of nutrient reduction must be clearly defined and demonstrable. Showcasing successful projects and programs can be an effective way to promote reduction benefits and increase participation in reduction activities. Universities and research centers should not only study those factors that impact reduction and reduction effectiveness, but also the economic consequences to individuals participating in reduction activities. The economic livelihood of stakeholders must be protected because they are part of the local economy, and their voluntary actions over time are critical to successful nutrient reduction.

Because nutrients can be transported in a dissolved form, proper application combined with water management can reduce loading and increase water efficiency—outcomes that are supported by many local, state, and federal programs. Capture, storage, and reuse of surface water and retention of sediment is a priority component of comprehensive water resources planning efforts ongoing in agriculture areas of east

Arkansas. The most current and innovative technologies that optimize nutrient reduction and water efficiencies should be widely promoted and incorporated into normal agricultural practices wherever possible.

Arkansas can be described in terms of regional nutrient causes and impacts. In northwest, north, and southwest Arkansas, excess nutrients (phosphorus) from animal agriculture and increased sediment loading from urbanization are the primary sources of loading. Throughout east Arkansas, nutrient loads are the result of increased sediment and runoff from row-crop agricultural areas.

The 2018–2023 Nonpoint Source Pollution Management Plan

The Arkansas Natural Resources Commission names 11 priority watersheds in the 2018–2023 Nonpoint Source Pollution Management Plan (Figure 16). The priority watersheds were designated using a risk assessment matrix process. Most of the funding goes toward those priority watersheds.

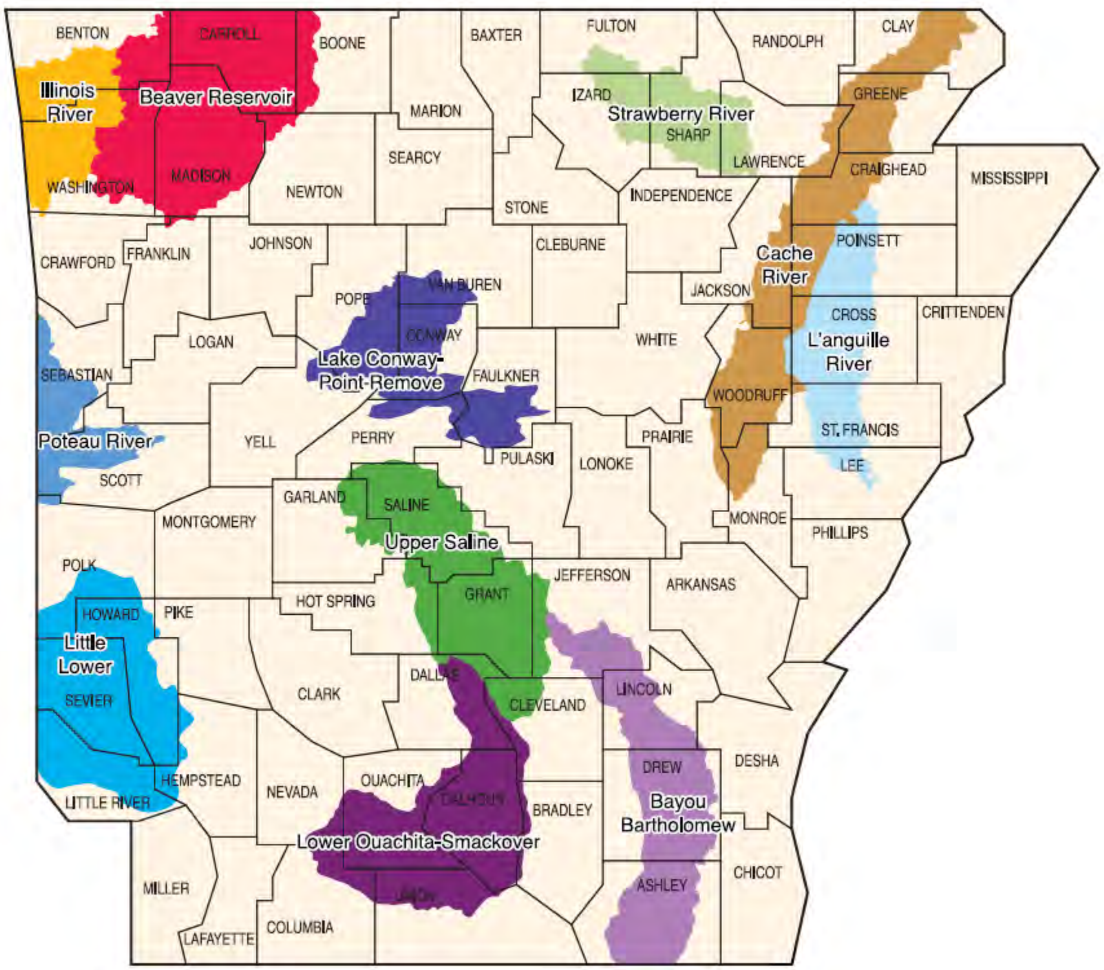


Figure 16. NPS Management Program Priority Watersheds.

Federal Management Programs, Projects, and Initiatives

Arkansas Natural Resources Division has a long-standing partnership with local USDA staff and through cooperation across multiple programs we hope to continue efforts to improve water quality. Release of EPA's April 2022 nutrient memo *Accelerating Nutrient Pollution Reductions in the Nation's Waters* further encourages states to broaden relationships, not only with USDA, but also the broader water sector across agriculture and industry. The Arkansas NRD is committed to this endeavor and highlights the following USDA programs where the ANRS can help support nutrient reduction projects.

USDA Farm Bill

The Farm Bill provides support, certainty, and stability to a variety of Arkansas's sectors by enhancing farm support programs and promoting and supporting voluntary conservation. The USDA offers a variety of programs to support operations. NRCS and FSA implement Farm Bill programs related to conservation and improving water, including:

- Environmental Quality Incentives Program (EQIP) – EQIP provides financial and technical assistance to agricultural producers to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation, and improved or created wildlife habitat (Figure 17).

- Conservation Stewardship Program (CSP) – CSP helps agricultural and forestry producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.

- Agricultural Conservation Easement Program (ACEP) – ACEP helps landowners, land trusts, and other entities protect, restore, and enhance wetlands, grasslands, and working farms and ranches through conservation easements.

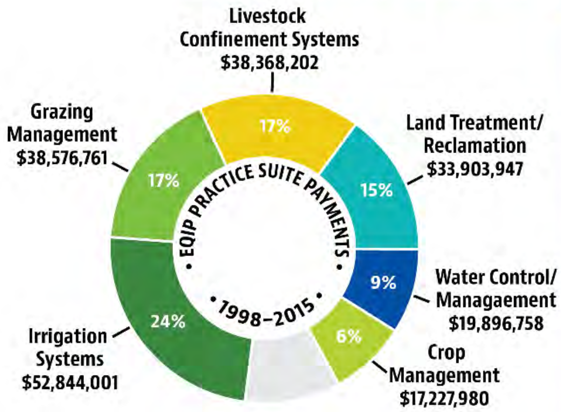
- Regional Conservation Partnership Program (RCPP) – RCPP promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. NRCS aids producers through partnership agreements and RCPP conservation program contracts (Figure 18).

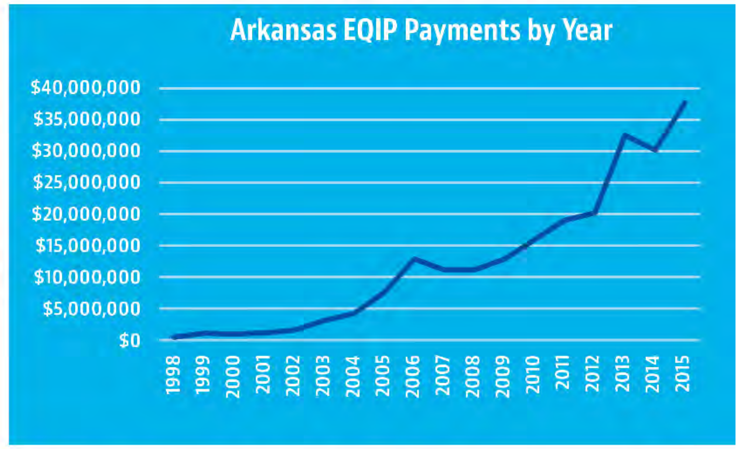
- Conservation Reserve Program (CRP) – CRP is a land conservation program administered by FSA. In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality.

- Agricultural Conservation Easement Program (ACEP) – ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands. Under the Agricultural Land Easements component, NRCS helps Indian tribes, state and local governments, and nongovernmental organizations protect working agricultural lands and limit nonagricultural uses of the land. Under the Wetlands Reserve Easements component, NRCS helps to restore, protect, and enhance enrolled wetlands.

- Mississippi River Basin Healthy Watersheds Initiative (MRBI) – Launched by NRCS in 2009, the 13-state MRBI uses several Farm Bill programs, including EQIP, CSP, and ACEP. These programs help landowners sustain natural resources through voluntary conservation. MRBI funding is made available in small priority watersheds (HUC-12s) and is delivered through multiyear implementation plans for individual projects in priority watersheds. These implementation plans are developed by NRCS and local partners. Implementation plans document annual targets for conservation treatments and must be informed by watershed assessments that identify critical source areas related to nutrient and sediment loss. Implementation plans must also contain quantifiable interim metrics for each watershed related to the primary water quality concerns that can be reported annually. The overall goals of MRBI are to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands. There are numerous MRBI projects ongoing in Arkansas (see Figure 19).

EQIP-Funded Conservation Practices in Arkansas





Conservation practices (i.e., best management practices), are an important tool for reducing nutrients and improving water quality. USDA's Environmental Quality Incentives Program (EQIP) is one way to fund conservation practices in Arkansas (EWG Conservation Database).

EQIP Payments: Arkansas is ranked 8th of all states in total EQIP payments received ($223,587,960). Payments have increased considerably throughout the years, starting with $454,377 in 1998 and growing to $37,698,760 in 2015.

Practice Suites: From 1998–2015, irrigation systems (24%), grazing management (17%), livestock confinement systems (17%), land treatment/reclamation (15%), water control/management (9%), and crop management (8%) made up 90% of EQIP payments.

Resource Concerns: EQIP-funded projects addressing water quality made up 35% of payments through the years.

Source: Environmental Working Group's (EWG's) Conservation Database

USDA EQIP is supporting the following conservation practices on Arkansas farms during 2015–2024:

EQIP Data Provided by USDA NRCS in 2019/2020

Figure 17: EQIP Funded Conservation Practices in Arkansas.

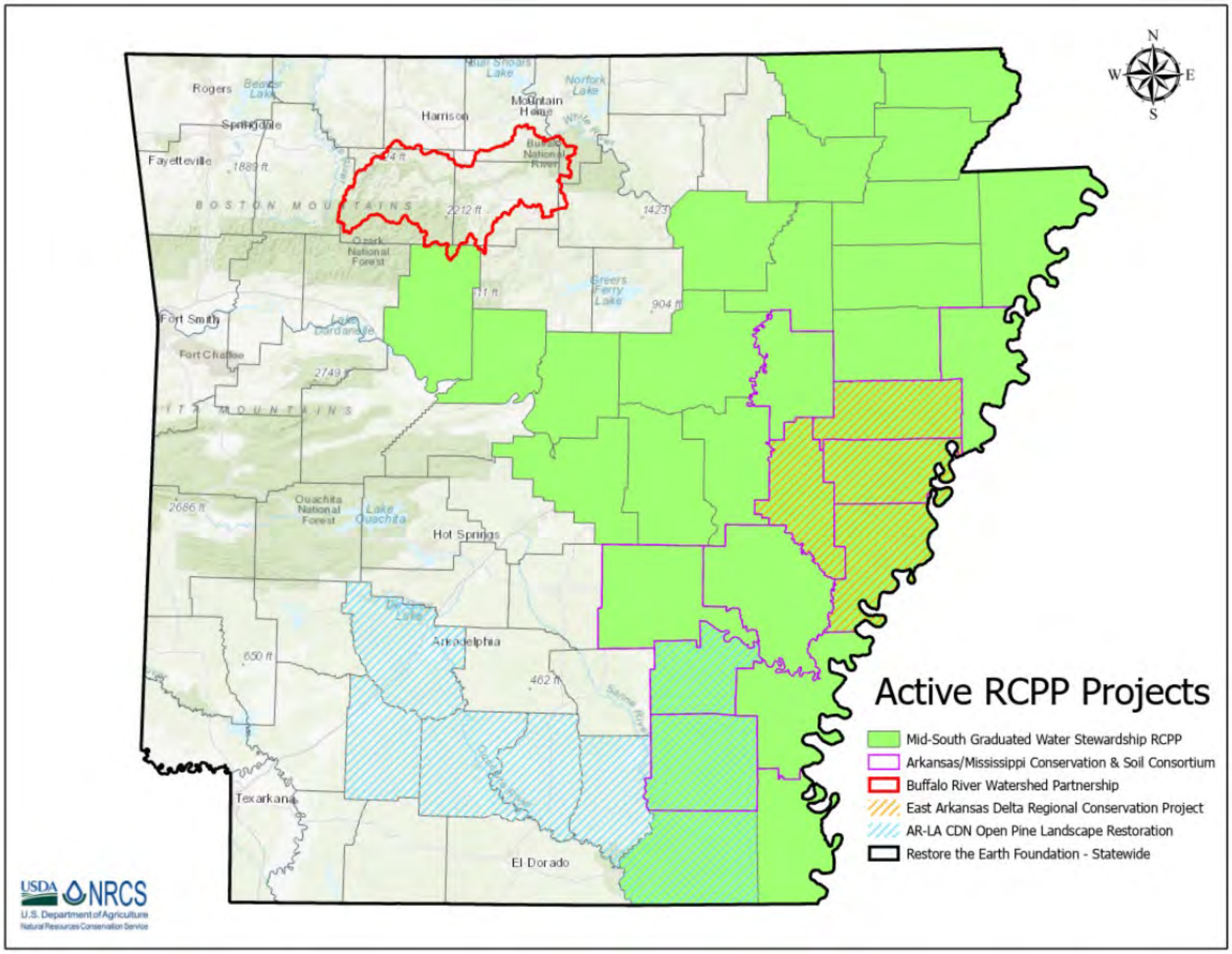


Figure 18. Regional Conservation Partnership Program Priority Areas Map.

National Water Quality Initiative

Launched in 2012, the National Water Quality Initiative (NWQI) is a partnership among NRCS, state water quality agencies, and USEPA to identify and address impaired water bodies through voluntary conservation. Arkansas has several NWQI projects (Figure 19). NRCS provides targeted funding for financial and technical assistance in small watersheds most in need and where farmers can use conservation practices to make a difference. Conservation systems include practices that promote soil health, reduce erosion, and lessen nutrient runoff, such as filter strips, cover crops, reduced tillage, and manure management. These practices not only benefit natural resources but also enhance agricultural productivity and profitability by improving soil health and optimizing the use of agricultural inputs.

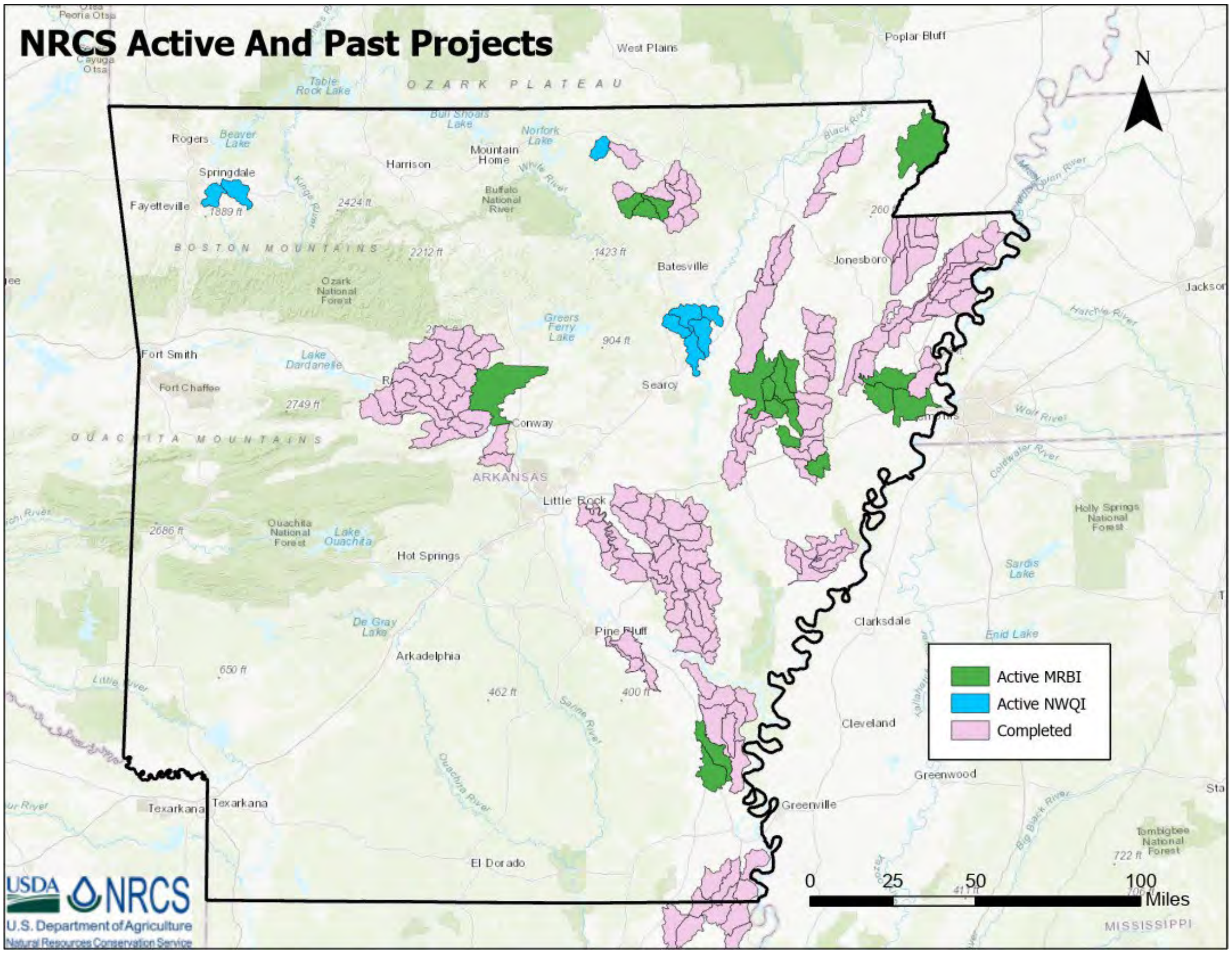


Figure 19. Natural Resources Conservation Services Initiatives.

Joint Chiefs' Landscape Restoration Partnership

The USDA Forest Service and NRCS are working together to improve the health of forests where public forests and grasslands connect to privately owned lands. Through the Joint Chiefs' Landscape Restoration Partnership, the two USDA agencies are restoring landscapes, reducing wildfire threats to communities and landowners, protecting water quality, and enhancing wildlife habitat.

Conservation Lands Program

Ducks Unlimited, acting primarily through its land-holding subsidiary, Wetlands America Trust, works with willing landowners to protect land through several means, including acquisitions, conservation easements, and planned gifts. Conservation easements are a valuable tool in estate planning for landowners wanting to preserve the land/habitat they have spent their life managing for future generations. Ducks Unlimited also maintains a Habitat Revolving Fund accessible for target acquisitions and purchases of development rights within their Landscape Conservation Priority Areas.

Measuring Conservation Practices

Edge-of-field water quality monitoring on agricultural lands in targeted watersheds throughout Arkansas is available through MRBI and NWQI. Producers can use the data from water quality monitoring and evaluation to measure the effectiveness of conservation practices and systems such as nutrient management, cover crop, and irrigation water management. Evaluation of conservation practice effectiveness through edge-of-field monitoring will lead to a better understanding of nutrient and sediment loading and will assist NRCS and participants in adapting or validating the application of conservation measures.

State Programs

Nutrient Management Program

NRD operates the Nutrient Management Program, which includes certification programs for consultants, compliance activities, and education programs necessary to implement state nutrient law. The certification programs include the Nutrient Management Planner Certification and the Nutrient Management Applicator Certification. Planners prepare nutrient management plans to indicate how nutrients should be applied to fields and other land for crop production while protecting ground water and surface water from excessive nutrient enrichment. Applicators apply nutrients from litter or commercial fertilizer to land within nutrient surplus areas (see Figure 12).

The program also requires poultry feeding operations where 2,500 or more poultries are housed or confined on any given day to register annually with the NRD. The NRD administers the registration program for the purpose of collecting information on the number of poultry, type of poultry, and practices of poultry feeding operations in Arkansas. It is designed to preserve Arkansas's economy and water quality through registration, training, and research.

Arkansas and federal partners fund water quality technicians to help facilitate the development and the implementation of nutrient management plans within nutrient surplus watersheds. The technicians also develop voluntary nutrient management plans outside of nutrient surplus watersheds. In 2021, there were more than 1,000 nutrient management plans written or updated throughout Arkansas.

Arkansas Unpaved Roads Program

The Arkansas Unpaved Roads Grant Program was established in 2015 by Act 898 of the 90th General Assembly of Arkansas. The program will fund more than $300,000 worth of projects annually in Arkansas counties. The goals of the program are to: (1) fund safe, efficient, and environmentally sound projects for the maintenance of dirt and gravel roads that have been identified as sources of sediment or dust, (2) provide training to road maintenance professionals on techniques of dirt and gravel road maintenance that minimizes negative impacts to water and air quality, and (3) conduct demonstrations of new and innovative techniques of dirt and gravel road construction and maintenance to assist in training of road crews and to more broadly share BMPs.

Nonpoint Source Cost Share Program

NRD administers the voluntary Nonpoint Source Cost Share Program for the State of Arkansas. NRD cooperates with conservation districts, other state agencies, academic institutions, nonprofit organizations, and local watershed groups to implement BMPs to help reduce NPS pollution. Common BMPs include:

- Brush management
- Cover crop
- Cross fencing
- Firebreak
- Forage and biomass planting
- Forest stand improvement
- Heavy use area protection
- Herbaceous weed treatment
- Irrigation and livestock pipeline
- Pond (certain sizes may require specifications)
- Prescribed burning
- Silvopasture
- Tree/shrub establishment
- Watering facility

Wetlands and Riparian Zone Tax Credit

Wetlands and riparian zones provide significant benefits to Arkansans, including flood control, water quality enhancement, fish and wildlife habitat, recreational opportunities, and groundwater recharge. Arkansas Code Annotated §26-51-1501 et seq., the "Arkansas Wetland and Riparian Zone Creation, Restoration, and Conservation Tax Credits Act," allows a state income tax credit to be taken by taxpayers who engage in the development, restoration, or conservation of wetland and riparian zones through projects approved by the Private Lands Restoration Committee. The program promotes an increase in biological and ecological integrity through voluntary restoration or conservation of Arkansas's important environmental landscapes.

Projects that restore and improve riparian zones, create wetlands, or conserve riparian habitat are generally determined to be eligible for the program by the Private Lands Restoration Committee. Project applications must be approved by the Private Lands Restoration Committee before project activities occur to qualify for the tax credit program. Some project activities that qualify for tax credits are:

- Procuring professional services for site development and project maintenance
- Preparing the site
- Establishing permanent vegetation
- Stabilizing stream banks and controlling erosion
- Constructing berms
- Installing water control structures

Specific criteria for eligibility are included in Title XIII rules governing this program.

Groundwater Protection and Management Program

The Natural Resources Division is Arkansas's water resources planning and management agency. NRD is responsible for state level planning, management, and protection of our groundwater resources. This is accomplished through monitoring of aquifer water levels and water quality, the implementation of BMPs, conservation, enforcement of the proper construction of water wells, and education.

Water and Wastewater Funding

NRD has available funding for water and wastewater projects from both state and federally funded programs. Each of these programs has its own requirements and limitations. Our purpose here is to provide an overview of what can be done without getting into specifics of each program.

Types of projects NRD's commission funds:

- Public water supply, treatment, and distribution systems
- Sewer collection and treatment systems
- Solid waste collection or disposal
- Irrigation (water conservation)
- Flood control and drainage
- Erosion and sediment control
- Agricultural BMPs (NPS pollution prevention)

Eligible entities:

- Cities
- Towns
- Counties
- Rural development authorities
- Public facilities boards
- Water associations
- Improvement districts
- Regional water distribution districts
- Levee and drainage districts
- Conservation districts
- Regional solid waste authorities
- Regional wastewater treatment districts

Funds may be used for new or existing systems. Generally, funds must be used for capital improvement projects and not maintenance projects. NRD's commission has funded projects for $5,000–$60,000,000.

Agricultural Water Quality Loan Program

The NRD, in conjunction with conservation districts and participating banks, provides low-interest loan money to agricultural landowners for installing conservation practices that reduce NPS pollution impacts to water quality. Approved applicants are eligible to have up to $250,000 in outstanding loan balance. Eligible practices include constructing tail water recovery systems, irrigation reservoirs, stacking sheds, ponds, and livestock fencing; purchasing no-till drills; and leveling land areas.

Arkansas Water Plan

The Arkansas Water Plan is the state's policy for long-term water management. The plan includes all previous plan updates and is a dynamic framework updated to meet the state's changing needs. The Arkansas Water Plan brings data, science, and public input together to define water demands, water supplies, issues, and potential solutions to meet future needs.

Forest Legacy Program

The purpose of the Forest Legacy Program is to protect forest areas that are threatened by conversion to non-forest uses. The protection is accomplished through fee simple title or conservation easement purchases. The conservation easement allows the seller to retain the right to manage the forest and sell timber while protecting the forest from conversion to non-forest uses. The Forest Legacy Program provides federal funding for up to 75% of the cost of conservation easements or fee acquisition.

Forest Stewardship Program

The Forest Stewardship Program recognizes and rewards landowners that are managing their forestlands according to a multiple-use concept. The Forest Stewardship Program is also a means by which a landowner has access to resource professionals to assist them in obtaining a written forest management plan addressing multiple-use management.

Private Lands Program

Many federal, state, and nongovernmental programs are available for private lands. AGFC offers many programs, technical assistance, and advice on managing wildlife on private lands.

Arkansas Discovery Farm Program

There are currently 14 Discovery Farm sites around the state (Figure 20). Production systems selected for study are crop and livestock-based, representing the diversity of operations in Arkansas. Knowledge gained from the Arkansas Discovery Farm Project will help farmers, natural resource managers, and decision-makers develop more effective science-based practices to address water resources issues. The Arkansas Discovery Farm Program is supported by a host of sponsors and industry stakeholders who ensure research addresses the needs of Arkansas farmers in a proactive manner. Several Discovery Farm sites are in Tier 1 watersheds.

The objectives of the Arkansas Discovery Farm Program are to:

- Conduct on-farm research and monitoring to assess the need for and effectiveness of BMPs.
- Provide on-farm verification and documentation of conservation practices to ensure sound environmental land stewardship.
- Develop and deliver educational programs from data collected on-farm to help producers achieve both production and environmental goals, thus increasing the overall sustainability of Arkansas's farming enterprises.

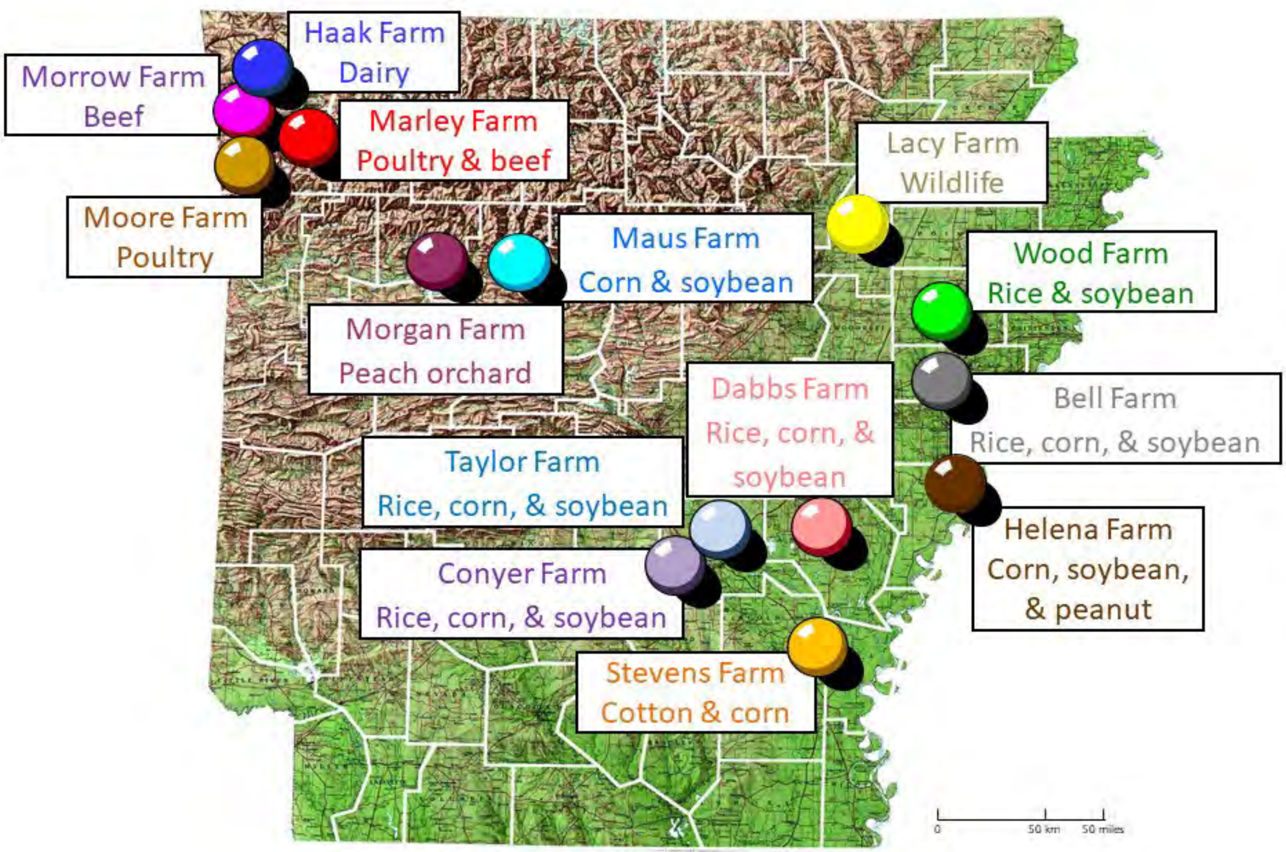


Figure 20. Discovery Farm Sites.

Pilot Project – Septic Remediation

In many rural areas throughout Arkansas, residential wastewater is treated using septic systems. Inadequate or poorly maintained septic systems are often ineffective and can leak nutrients such as nitrogen and phosphorus. Arkansas has a pilot project to help homeowners replace old, failing septic systems in two targeted watersheds: the Beaver Reservoir Watershed and the Illinois River Watershed. These watersheds in northwest Arkansas are a priority for the State of Arkansas. They are both in the nutrient surplus area and are on the priority list for the 2018–2023 Nonpoint Source Pollution Management Plan.

The septic remediation pilot project offers financial assistance in the form of a grant and/ or loan to qualifying homeowners in the two targeted watersheds. Funding is only for repair or replacement of an existing septic system as determined by the ADH. Grant assistance is based on a sliding income scale of the homeowner. Grants are usually paired with a no-interest 10-year loan. For instance, an income level less than $20,828 receives 90% grant funding and a 10% loan, and an income level of $62,486–$83,314 receives 10% grant funding and a 90% loan. A 0% interest loan for all income levels above $83,315 is also available. Financial assistance to homeowners does not exceed $30,000, with funding usually between $5,000 and $10,000 per failing septic tank.

The pilot project began in 2021. It will run for three years and will then be evaluated. Local watershed managing organizations oversee the septic remediation pilot project. The managing organization is responsible for determining eligibility, reviewing applications, and ensuring the projects are implemented correctly.

Section 7: Strategic Framework

The Framework

The strategic framework lays out the specific actions and strategies to take to achieve the overall goals and purpose of the ANRS. The strategic framework identifies potential opportunities for nutrient reduction and water quality improvement. It is a coordinated and adaptive management strategies that leverage collaborative, integrated approaches to nutrient reduction and goal setting.

The ultimate desired goal is to remove nutrient impairment from all waterbodies. The purpose of the ANRS is to reduce nutrient concentrations in Arkansas's watersheds, providing local benefits and helping to shrink the Gulf Hypoxic Zone. This goal will be accomplished by working closely with our stakeholders to adaptively manage and implement relevant practices and programs to safeguard state and regional economic prosperity, environmental quality, and recreational opportunities for current and future generations.

The three main goals of ANRS are:

1. Increase or maintain downward nutrient trends in Tier I watersheds.
2. Enhance water quality monitoring and increase or maintain downward nutrient trends in Tier 2 watersheds.
3. Continue efforts to reduce nutrients in all watersheds.

Overview of Goals

Interim target reduction levels for Tier 1 watersheds will be identified on a watershed-specific basis but must be based on sufficient data (i.e., physical, chemical, and biological); existing policies, regulations, and public support; watershed planning; and any other factors appropriate for establishing a reduction goal. If numeric nutrient reduction goals cannot be established at present or are undeterminable due to insufficient data, qualitative goals that describe implementation of nutrient reduction activities and water quality improvements will be used to track incremental progress resulting from reduction efforts.

Technical and nontechnical factors affecting nutrient goals are to be fully discussed and disclosed to all local stakeholders. Protecting the economic and environmental benefits for land and water users should be a priority for all entities involved in nutrient-reduction efforts and activities. Focusing on the protection of these benefits provides the opportunity to better understand conditions within individual watersheds and the stressors that are most affecting those conditions. Increased understanding of land uses and water quality relationships in the watershed will help identify solutions that more effectively reduce nutrient loading and leverage limited financial resources. Learn more about how the ANRS goals and strategic framework work together (Figure 21).

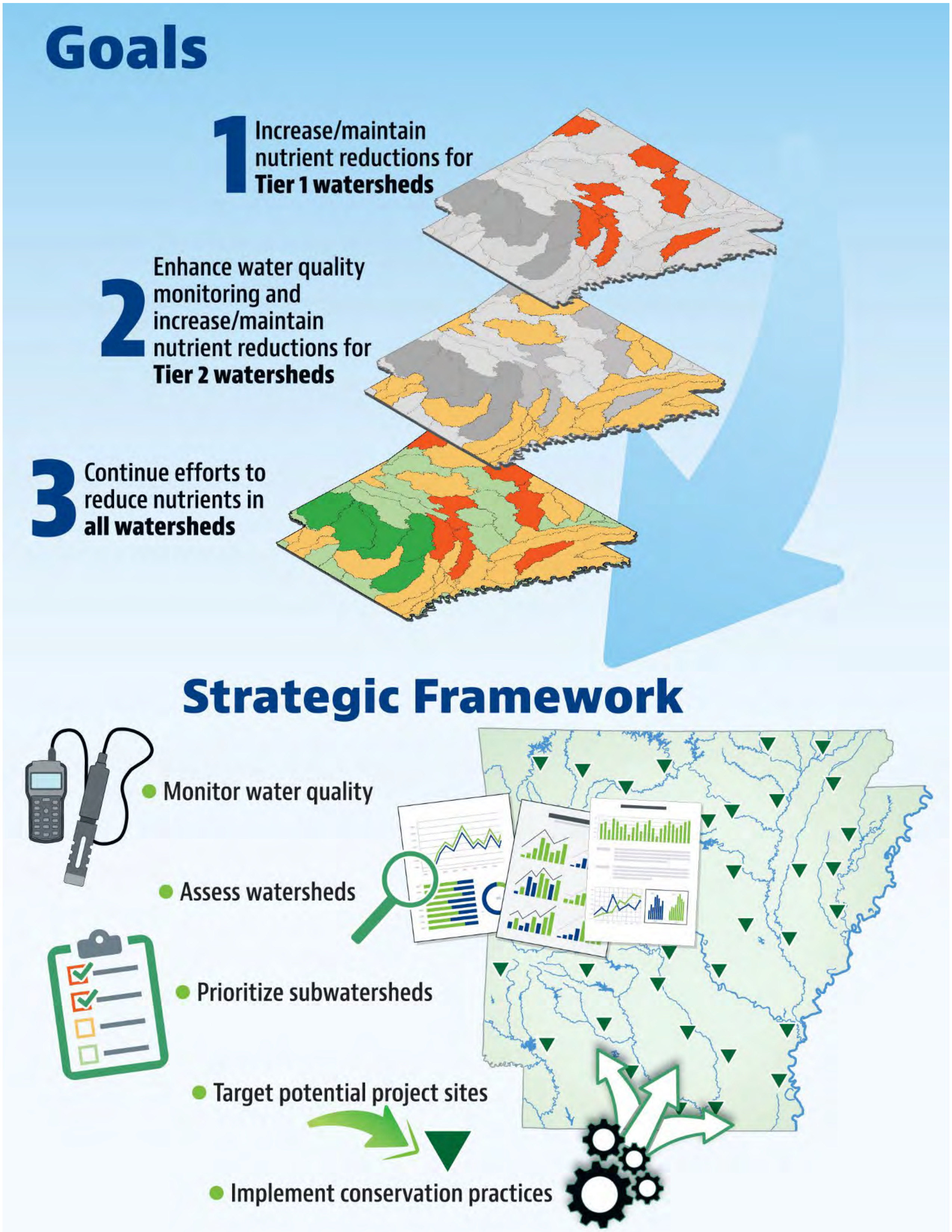


Figure 21. ANRS Goals and Strategic Framework.

Goal 1: Increase or Maintain Downward Trends for Tier 1 Watersheds

Objective A. By 2029, NRD will update watershed management plans for all Tier 1 watersheds.

1. By 2023, NRD will update, review, and compare strategies for Tier 1 Watershed Management Plans for Middle White, Bayou Meto, and Lake Conway-Point Remove.
2. NRD will evaluate need to update watershed management plans for Tier 1 watersheds by the following dates:
    a. By 2024: Illinois River watershed
    b. By 2025: L'Anguille
    c. By 2026: Bull Shoals Lake
    d. By 2027: Lower Arkansas-Maumelle
3. Maintain current watershed management plans by updating the plans for Tier 1 watersheds every seven years.

Objective B. By 2025, NRCS will reduce nutrients by implementing conservation practices on agricultural and forest lands within Tier 1 watersheds.

1. Implement Farm Bill programs, federal water quality-based initiatives, and state-level programs within watersheds by providing conservation technical assistance to operators and landowners as well as offering the opportunity to compete for financial assistance dollars.
    a. Identify nutrient resource concerns present on individual farms when working with operators and landowners.
    b. Determine the objectives of the operators and landowners to develop the strategy for implementation to reduce nutrients at a field-scale level as well as watershed level.
    c. Develop conservation plans, nutrient management plans, irrigation water management plans, and forestry plans to help landowners meet conservation goals on their operations while reducing nutrients.
    d. Implement those plans at the field scale with landowners to reduce nutrients.
    e. Evaluate results of conservation practice implementation in reducing nutrient loads.

Objective C. By 2025, NRD will review the pilot Septic Tank Removal Program.

1. Gather information from Illinois River Watershed Partnership (IRWP) and Ozark Water Watch (OWW) about lessons learned.
2. In conjunction with IRWP and OWW, perform a strengths, weaknesses, opportunities, and threats (SWOT) analysis of Septic Tank Removal Program. Based on the outcome of the SWOT analysis, develop strategic planning implementation for future Tier 1 watersheds.
3. Present findings to the ANRC in a report on or before the ANRC's November 2024 meeting.

Objective D. By 2023, NRD will develop and implement a communication plan to engage partners and stakeholders in Tier 1 watersheds.

1. Inform those Tier 1 conservation districts that have most of their district in a Tier 1 watershed about the ANRS and begin working with them.
2. Develop a communication plan for each individual Tier 1 watershed during watershed management plan updates.
3. Accumulate knowledge on the communication practices that are most effective and review these with the ANRS team.

Goal 2: Enhance Water Quality Monitoring to Inform Nutrient Trends for Tier 2 Watersheds

Objective A. By 2023, NRD, DEQ, and ADH will improve communication among water quality monitoring agencies to reduce overlap and enhance spatial coverage.

1. DEQ will review Arkansas's water quality monitoring efforts during development of the state's Integrated Report to:
    a. Identify agency monitoring data objectives.
    b. Determine if improvements are needed.
    c. Implement improvements as needed.
2. By 2023, the ANRS team will prioritize water quality monitoring efforts in data-limited watersheds.
    a. Use the following Tier 2 subcategories to help prioritize areas of need:
        i. Tier 2a: insufficient data for quantitative assessment and goal setting
        ii. Tier 2b: low priority because has sufficient data
        iii. Tier 2c: limited data
        iv. Tier 2d: insufficient data for assessment in any component of the data analysis, but a partner priority (MRBI or nutrient surplus area)
    b. Evaluate strategic development of monitoring networks and new station placement on a case-by-case basis:
        i. Evaluate spatial extent of Tier 2 watersheds to determine monitoring scale.
        ii. Develop clear thresholds for data analysis needs per watershed and per Tiers 2a, 2c, and 2d.

Objective B. By 2025, NRCS and NRD will reduce nutrients by implementing conservation practices on agricultural and forest lands within Tier 2 watersheds with HTF or CWA section 319 funds.

1. Implement Farm Bill programs, federal water quality-based initiatives, and state-level programs within watersheds by providing conservation technical assistance to operators and landowners as well as offering the opportunity to compete for financial assistance dollars.

   a. Identify nutrient resource concerns present on individual farms when working with operators and landowners.
   b. Determine the objectives of the operators and landowners to develop the strategy for implementation to reduce nutrients at a field-scale level as well as watershed level.
   c. Develop conservation plans, nutrient management plans, irrigation water management plans, and forestry plans to help landowners meet conservation goals on their operations while reducing nutrients.
   d. Implement those plans at the field scale with landowners to reduce nutrients.
   e. Evaluate results of conservation practice implementation in reducing nutrient loads.

Goal 3: Continue Efforts in all Watersheds

Objective A. By 2024, NRD will incorporate data and analysis into biennial progress reports as needed when sufficient data is obtained.

1. Recently updated watershed management plans will be reviewed to seek out ways to inform and improve the ANRS.
2. Communication plans for the ANRS will be reviewed and updated.
3. Outreach and education strategies will be reviewed to include how to best utilize the Arkansas Conservation Partnership.
4. The following will also be reviewed and reported if available:
   a. Recommendations for new studies
   b. Progress from the HTF
   c. Literature review
   d. Stakeholder interviews
   e. Information from workgroups

Objective B. By 2023, NRD will develop the nutrient reduction reporting/ tracking framework to quantify reductions from adopted BMPs across the state and communicate results to the public.

1. Preliminary results will be reviewed and analyzed.
2. NRD will review how best and how often to communicate results to the public.

Objective C. By 2024, NRD will issue a report on the ANRS to the agency's commission by or in November every other year.

1. The update will include implementation of strategic actions from the previous 24 months.
2. The update will include a summary of the outcomes of the current programs that support nutrient-reduction activities.

3. Comments and feedback will be solicited to improve implementation, strengthen collaborative partnerships, and identify additional opportunities for promoting effective nutrient-reduction activities.

Objective D. By 2028, NRD will perform a full analysis of nutrient concentrations for all Tiers.

1. Have a contractor analyze water quality data and produce a report.
2. Present data to the ANRC on or by November 2028.
3. Increase data by prioritizing monitoring site locations.

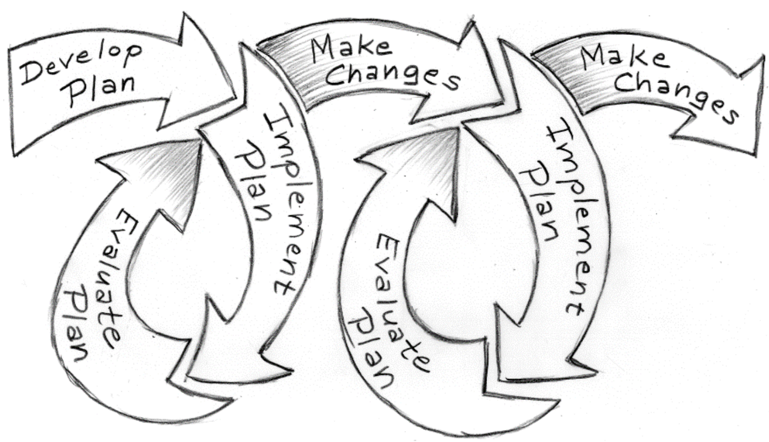
Objective E. By 2028, NRD and a team of scientists will update and analyze expected nutrient reduction efficiencies from practice suites and individual practices.

1. A team of scientists will be assembled to review the original expected nutrient reduction efficiencies.
2. A framework to analyze expected nutrient reduction efficiencies will be developed.

Section 8. Measuring Progress

Adaptive Management

The ANRS is based on scientific analysis with input from the public and governmental agencies. However, the ANRS will need to continually be improved and refined based on new information and input from stakeholders, scientists, and key partners. The ANRS will be evaluated and periodically updated every two years using a process of planning, implementing, assessing, and adapting the plan. This is referred to as accountability and explicitness. The adaptive management approach assumes that knowledge will be gained through implementation and observation of nutrient reduction strategies, projects, and programs.



These activities are evaluated on a watershed-by-watershed basis to determine what can be achieved and maintained through regulatory processes and with voluntary grassroots participation and support. Reduction goals for Tier 1 watersheds are attained through individual watershed management plans. Plans are regularly assessed to determine what is working, what improvements should be made, and what policies are supported by the public. These factors will change over time as technology and programs evolve to improve nutrient management and adapt to social, political, and economic changes in the future.

Coordinated and adaptive management strategies that leverage collaborative, integrated approaches to nutrient reduction and goal setting will help the ANRS to evolve to continually meet the nutrient reduction requirements needed in Arkansas. The ANRS is a framework that identifies potential opportunities for nutrient reduction and water quality improvement.

A key to long-term water quality improvement is commitment from both public and private sectors. This commitment can be realized through a variety of means such as:

- Mobilization and coordination of available resources.
- Consistent interpretation and implementation of water management policies.
- Long-term support at local, state, and national levels.
- Improvement in science-based assessment of nutrient reduction techniques and practices.

To maximize benefits from these commitments necessitates that limited resources be targeted for water quality improvement activities that provide the most environmental, social, and economic "bang-for-the-buck."

Nutrient Reduction Tracking

The ANRS defines success based in terms of improved environmental indicators; more specifically, by observing decreasing trends in nutrient concentrations at the HUC-8 scale. Nutrient-reduction activities and initiatives must contribute to the achievement of on-the-ground water quality objectives and need to demonstrate progress toward Arkansas's water quality goals.

Analysis may be performed every two years and incorporated into biennial progress reports. This project will provide a continued assessment of water quality trends across the State of Arkansas, as well as help the state decide which HUC-8 watersheds need targeted for nutrient-reduction efforts.

Reporting Progress

Reporting the progress of nutrient-reduction efforts is an important component of the strategic framework. Communication among entities involved in reduction activities and the public is essential to maintaining transparency of program implementation and to evaluating and reporting progress toward reaching reduction goals.

Biennial reporting that compiles the implementation of strategic actions from the previous 24 months will be developed by the date of the November board meeting of NRD's commission every other year. The outcomes of the current programs that support nutrient-reduction activities will be summarized in general for the state and by Tier 1 watershed management plans. The report will be presented every other year by or in the November meeting of the Commission, as well as posted on the ANRD website. Comments and feedback will be solicited to improve implementation, strengthen collaborative partnerships, and identify additional opportunities for promoting effective nutrient reduction activities.

Future Efforts

Research and demonstration projects provide insight on the economics and effectiveness of nutrient reduction activities and programs. Such organizations as the UADA, the USDA Agricultural Research Service, the Arkansas Water Resources Center, the Center for Advanced Spatial Technologies, and others contribute invaluable knowledge through research and demonstration of agricultural practices, watershed modeling, economic and GIS analysis. These efforts will continue to inform nutrient-reduction work in the future. Education is provided to landowners and public officials by many levels of government. However, the local conservation districts are and should remain the primary network for coordination of outreach efforts.

References

Arkansas Forestry Commission. 2018. *Best Management Practices for Water Quality Protection*. Arkansas Department of Agriculture's Forestry Division. Little Rock, AR.

Arkansas Admin Rules 138.00.05-004. https://casetext.com/regulation/arkansas-administrative-code/agency-138-arkansas-natural-resources-commission/rule-1380005-004-title-22-rules-governing-the-arkansas-soil-nutrient-and-poultry-litter-application-and-management-program

Arkansas Code Annotated § 15-20-1104. https://law.justia.com/codes/arkansas/2019/title-15/subtitle-2/chapter-20/subchapter-11/section-15-20-1104/.

Arkansas Code Annotated § 26-51-1501. https://www.agriculture.arkansas.gov/wp-content/uploads/2020/05/title_13-rules.pdf.

Alexander, R.B., R.A. Smith, G.E. Schwarz, E.W. Boyer, J.V. Nolan and J.W. Brakebill. 2008b. Share of the nutrient flux (mass per time) delivered to the Gulf of Mexico from States in the Mississippi and Atchafalaya River Basins. *Environmental Science & Technology, 42* (supplemental material).

Arkansas Department of Environmental Quality, Office of Water Quality. 2016. *Integrated Water Quality Monitoring Assessment Report* [PDF File]. Retrieved from https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/final-2016-305b-report.pdf.

Arkansas Natural Resources Commission. 2018. *2018–2021 Nonpoint Source Pollution Management Plan*. Arkansas Natural Resources Commission. Little Rock, AR. https://www.agriculture.arkansas.gov/natural-resources/divisions/water-management/nonpoint-source-management/.

Arkansas Pollution Control and Ecology Commission. 2018. *Regulation No.2: Regulation Establishing Standards for Surface waters of the State of Arkansas*. Retrieved from https://www.adeq.state.ar.us/regs/files/reg02_final_190120.pdf.

Betanzo, E.A., A.F. Choquette, K.H. Reckhow, L. Hayes, E.R. Hagen, D.M. Argue, and A.A. Cangelosi. 2015. *Water data to answer urgent water policy questions: Monitoring design, available data and filling data gaps for determining the effectiveness of agricultural management practices for reducing tributary nutrient loads to Lake Erie*. Northeast-Midwest Institute Report. Retrieved March 17, 2016. http://www.nemw.org/.

Conservation Technology Information Center. 2006. *Getting Paid for Stewardship: An Agricultural Community Water Quality Trading Guide* [PDF File]. Retrieved from http://ctic.org/media/users/lvollmer/pdf/GPfS_final(1).pdf.

Fennel, K. and A. Laurent. 2017. N and P as ultimate and proximate limiting nutrients in the northern Gulf of Mexico: implications for hypoxia reduction strategies. Biogeosciences, 15:3121-3131.

Francesconi, W., D. Smith, D. Flanagan, C. Huang, and X. Wang. 2014. Modeling conservation practices in APEX: from the field to the watershed. Paper presented at Soil and Water Conservation Society, 69th International Annual Conference, July 27–30, 2014, Lombard, Illinois.

Jacobson, C. and A.L. Robertson. 2012. Landscape Conservation Cooperatives: Bridging entities to facilitate adaptive co-governance of social-ecological systems. *Human Dimensions of Wildlife* 17:333–343.

Jarvie, H.P., A.N. Sharpley, B. Spears, A.R. Buda, L. May, and P.J.A. Kleinman. 2013a. Water quality remediation faces unprecedented challenges from "legacy phosphorus." *Environmental Science and Technology* 47:8997–8998.

Jarvie, H.P., A.N. Sharpley, P.J.A. Withers, J.T. Scott, B.E. Haggard, and C. Neal, C. 2013b. Phosphorus mitigation to control river eutrophication: Murky waters, inconvenient truths, and "postnormal" science. *J. Environ. Qual.* 42:295–304.

Robertson, D.M., and D.A. Saad. 2019. *Spatially Referenced Models of Streamflow and Nitrogen, Phosphorus, and Suspended Sediment Loads in Streams of the Midwestern United States*. U.S. Geological Survey Scientific Investigation Report 2019-5114. https://doi.org/10.3133/sir20195114.

Sharpley, A., H. Jarvie, A. Buda, L. May, B. Spears, and P. Kleinman. 2013. Phosphorus legacy: Overcoming the effects of past management practices to mitigate future water quality impairment. *J. Environ. Qual.* 42:1308–1326.

Sharpley, A.N., P.J.A. Kleinman, P. Hordan, L. Bergstrom, and A.L. Allen. 2009. Evaluating the success of phosphorus management from field to watershed. *J. Environ. Qual.* 38:1981–1988.

Sharpley, A., M. Daniels, K. Vandevender, P.A. Moore, Jr., B. Haggard, N. Slaton, and C. West. 2010. *Using the 2010 Arkansas Phosphorus Index* [PDF File]. Retrieved from https://www.uaex.edu/publications/PDF/MP487.pdf.

Turner, R.R., N.N. Rabalais, and D. Justic. 2006. Predicting summer hypoxia in the northern Gulf of Mexico: riverine N, P, and Si loading. *Marine Pollution Bulletin* 52(2):139–148.

University of Arkansas Cooperative Extension Service. 2010. *Arkansas Phosphorus Index* [PDF File]. Retrieved from https://www.uaex.edu/publications/PDF/FSA-9531.pdf.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2021. *CropScape – 2020 Cropland Data Layer for Arkansas*. Accessed February 3, 2022. https://nassgeodata.gmu.edu/CropScape/.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2019. *2018 Arkansas Annual Report: At-a-Glance* [PDF File]. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/ar/newsroom/factsheets/.

U.S. Environmental Protection Agency. n.d. The Mississippi/Atchafalaya River Basin (MARB). Retrieved from https://www.epa.gov/ms-htf/mississippiatchafalaya-river-basin-marb.

U.S. Environmental Protections Agency. n.d. Urban Runoff: Low Impact Development. Retrieved from https://www.epa.gov/nps/urban-runoff-low-impact-development.

U.S. Environmental Protection Agency. 2001. *Nutrient Criteria Development; Notice of Ecoregional Nutrient Criteria*. 66 Fed. Reg. 1671. 01-569.pdf (govinfo.gov)

U.S. Environmental Protection Agency. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* [PDF File]. Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/2008_04_18_nps_watershed_handbook_handbook-2.pdf.

U.S. Environmental Protection Agency. 2012. *Water Quality Trading Policy to Promote Market-Based Mechanisms for Improving Water Quality* [PDF File]. Available from https://www.epa.gov/sites/production/files/2019-02/documents/trading-policy-memo-2019.pdf.

U.S. Environmental Protection Agency. 2022. Accelerating Nutrient Pollution Reductions in the Nation's Waters [PDF File]. Available from https://www.epa.gov/nutrient-policy-data/2022-epa-nutrient-reduction-memorandum

Walkenhorst, E. 2016, November 27. States, including Arkansas, miss goal; Gulf's 'dead zone' unchecked. *Arkansas Democrat-Gazette*. Retrieved from https://www.arkansasonline.com/news/2016/nov/27/states-miss-goal-gulf-s-dead-zone-unche/.

White, K.L., B.E. Haggard and I. Chaubey. 2004. Water Quality at the Buffalo National River, Arkansas, 1991–2001. *Transactions of the ASAE* 47(2):407–417.

Appendix A. Watershed prioritization to reduce nutrient export: A framework for the State of Arkansas based on ambient water quality monitoring data

Project #20-2000 ANRS-100 – Final Report

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EXECUTIVE SUMMARY

The annual formation of the Northern Gulf of Mexico hypoxic zone is driven by nutrient loading from the Mississippi-Atchafalaya River Basin (MARB). Member States of The Mississippi River/Gulf of Mexico Hypoxia Task have developed statewide strategies to identify priorities and opportunities for nutrient export reduction in the MARB. In 2014, the State of Arkansas joined the Task Force and initiated an Arkansas Nutrient Reduction Strategy (ANRS), which currently prioritizes ten Hydrologic Code 8 (HUC-8) watersheds (ANRD, 2014). These priority watersheds were not selected based on measured in-stream nutrient concentrations or trends, which impedes quantitative assessment, goal setting, and linking investments to nutrient reduction progress. The ANRS is currently under revision to address these concerns, and the goal of this project was to develop a prioritization framework for the State of Arkansas based on robust statistical analysis of extensive, statewide ambient water quality monitoring program data sets.

This study used available data sets to calculate HUC-8 75th percentiles of site median total nutrient (total nitrogen, or TN, and total phosphorus, or TP) concentrations (subsequently, screening levels) on an annual basis as inputs to HUC-level analyses of nutrient magnitude and trend. The magnitude assessment compared screening levels to screening thresholds that were based on ecological responses to nutrient gradients to identify nutrient reduction needs, identifying 21 HUC-8s for TN and

18 for TP. Trend analysis provided the context of directional change in screening levels over time, suggesting that total nutrient concentrations are widely decreasing and near total absence of increasing trends. Each HUC-8 was also characterized by level of data availability (insufficient, marginal, or sufficient) for each component of the overall analysis, with approximately 1/3 of Arkansas HUC-8s having insufficient data to qualify for any component. A four-Tier framework was developed based on synthesis of magnitude and trend results and data availability to assign all Arkansas HUC-8s to priority Tiers.

The prioritization framework identified seven HUC-8s for maximum focus in Tier 1 as the priority watershed candidates for the ANRS update:

- 08020205 – L'Anguille
- 08020402 – Bayou Meto
- 11010003 – Bull Shoals Lake
- 11010004 – Middle White
- 11110103 – Illinois
- 11110203 - Lake Conway-Point Remove
- 11110207 – Lower Arkansas-Maumelle

Tier 1 criteria targeted Arkansas HUC-8s with multiple lines of evidence (TN and TP) from the data analysis supporting prioritization, as well as sufficient data availability. Thus, these Tier 1 HUC-8 recommendations hone in on a select set of HUC-8s with the greatest demonstrated nutrient reduction need based on analysis of measured ambient nutrient concentrations in Arkansas waterbodies, paired with the level of data availability required to support a quantitative and goal-oriented ANRS.

The prioritization framework identified 23 Arkansas HUC-8s for focus status in Tier 2. Tier 2 criteria also targeted Arkansas HUC-8s with demonstrated nutrient reduction need, including equivalent lines of evidence to Tier 1, but without sufficient data for quantitative assessment and goal setting, as well as needs demonstrated by fewer lines of evidence, both with and without sufficient data. The HUC-8s with insufficient data for any component of the analysis, but that were partner priorities in programs with stated nutrient reduction goals also fell in Tier 2. All Arkansas HUC-8s that were not assigned to Tier 1 or Tier 2, were divided between Tier 3 (less focus) and in Tier 4 (least focus), depending on data availability. Tier 3 assignments acknowledge that HUC-8s with relatively less weight of evidence suggesting nutrient reduction need, but with data limitations, require a greater focus status, with the goal of investing in monitoring programs. Twenty-three data-limited HUC-8s were assigned to Tier 3, while five HUC-8s with sufficient data were assigned to Tier 4.

INTRODUCTION

Coastal and estuarine seasonal hypoxic zones are a global environmental challenge and have increased in size and scale over the last half century (Diaz and Rosenberg, 2008). Marine hypoxic zones are areas of low oxygen availability resulting from an interplay of natural density stratification due to salinity or temperature gradients and excessive algal growth due to nutrient enrichment (Rabalais et al., 2002). The largest marine hypoxic zone in the United States coastal waters is in the Northern Gulf of Mexico and is also one of the largest in the world. Though nutrient enrichment and oxygen minimum zones occur naturally through processes such as upwelling, the source of nutrient enrichment to the Gulf of Mexico is excessive nutrient loading from the Mississippi-Atchafalaya River Basin (MARB; Turner et al., 2006). The MARB drains approximately 40% of the contiguous United States, and nutrient loading to the Gulf of Mexico has increased over the last century or more (Turner and Rabalais, 1991; Justic et al., 1995).

The Gulf of Mexico hypoxia task force was formed to advance understanding of the drivers of hypoxic zone formation, as well as possible mitigations. The task force has set a goal of limiting the dead zone to a running 5-year average of 5000 km^2 (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). Meeting this goal will hinge on nutrient load reduction to the Gulf of Mexico from the MARB in both total nitrogen (TN) and total phosphorus (TP), which both potentially limit the primary production fueling the eutrophication cycle in the Gulf of Mexico hypoxic zone, depending on temporally and spatially variable conditions (Dodds, 2006; Turner and Rabalais, 2013; Fennel and Laurent, 2017). Long-term data continues to support observations that nutrient load drives the extent of the Gulf of Mexico hypoxic zone (Rabalais et al., 2007), with estimated reductions in TN and TP loads of $48 \pm 21\%$ required to reach task force goals (Fennel and Laurent, 2017).

The task force also coordinates federal, state, and tribal agencies in developing plans to reduce nutrient export to the Gulf of Mexico from the MARB. State Nutrient Reduction Strategies are considered the cornerstone in reducing nutrient loads to the Gulf of Mexico. The State of Arkansas joined the Task Force and initiated a Nutrient Reduction Strategy (ANRS) as part of the 2014 Water Plan update (ANRC, 2014). The goal of the ANRS is to improve overall aquatic health and viability in Arkansas waters for recreational, economic, environmental, and human health benefits. Identifying priority watersheds and waterbodies is a key component of the ANRS and is foundational for maximizing the impact of available resources. Currently, ten priority watersheds are identified under the ANRS. Designation as a priority watershed considered the priority areas of conservation and nutrient reduction programs in the state, waterbody impairments, interstate cooperative efforts, local conservation district goals, and nutrient export model estimates for the MARB (Spatially Referenced Regression on Watershed attributes, or SPARROW).

However, the prioritization of Arkansas watersheds under the ANRS was not based on measured in-stream nutrient concentrations or trends (i.e. directional change). This missing piece feeds into other concerns related to updating and advancing the ANRS, including no defined methods to evaluate progress or lack of progress, challenges to documenting clear links between resource expenditures and water quality improvement, and no clearly defined goal or water quality target. The ANRS is currently under revision to address these concerns, with emphasis on demonstrating a need for nutrient reduction using measured data and targeting watersheds where data are sufficient to allow quantitative assessment and goal setting.

The goal of this project was to develop a framework for the State of Arkansas to prioritize watersheds based on robust statistical analysis of extensive, statewide ambient water quality monitoring program datasets to identify trend and central tendency in nutrient concentrations. Project objectives were:

1. Develop a statewide water quality database using ADEQ ambient water quality monitoring program data from 1990 – 2019.
2. At the watershed (Hydrologic Unit Code, or HUC-8) scale, assess magnitude of 75th percentiles of TN and TP concentration annual site medians against screening thresholds for levels of ecological concern.
3. At the HUC-8 scale, assess 75th percentiles of TN and TP concentration annual site medians for trend over time.
4. Assign HUC-8s to prioritization categories based on synthesis of HUC-8 level trend and magnitude assessment results, data availability, and priorities of select Arkansas programs with a nutrient export reduction focus.
5. At the site-level, within priority category 1 HUC-8s, assess total nutrient concentrations for trend over time.

METHODS

Database development

The primary data source for this project was the Arkansas Department of Environmental Quality (ADEQ) ambient water quality monitoring database accessed via the water quality monitoring data portal (https://www.adeq.state.ar.us/techsvs/env_multi_lab/water_quality_station.aspx). All observations for focus nutrient parameters were downloaded for the time period January 1, 1990 – December 31, 2019. Focus parameters were Nitrite+nitrate-nitrogen (mg/L; NOx-N), Total Kjeldahl nitrogen (mg/L; TKN), Total Nitrogen (mg/L; TN), and Total Phosphorus (mg/L; TP). The parameters NOx-N and TKN were used to calculate TN for sites and time intervals with no direct TN measurements. Calculated TN and direct TN measurements were merged into a single TN dataset, with priority given to direct measurements of TN when available.

Datasets from the Natural Resources Division's Section 319(h) Nonpoint Source Pollution Management Program (subsequently, 319) were added as a secondary data source after initial analyses showed limited coverage of HUC-8s in the Mississippi Alluvial Plain, a key agricultural region in Arkansas, by the ADEQ's ambient water quality monitoring network. Many Section 319(h) monitoring projects target these HUC-8s, and analyzed nutrient parameters were compatible between the data sources. Therefore, datasets from projects from across the state were compiled and organized for inclusion in HUC-8 level analyses of recent TN and TP concentration magnitudes to address the ADEQ data gap.

Prior to analysis, database formats were standardized for compatibility with statistical software using R 4.0.4 (R Core Team, 2021) and the packages tidyverse (Wickham et al. 2019) and lubridate (Grolemund and Wickham, 2011). Non-numeric information accompanying observation values was separated from numeric information and stored in supplemental information columns. Data were most commonly flagged because an analyte was not detected at concentrations above reporting limits. Non-detections were recorded as the value of the provided reporting limit and flagged as non-detections in a supplemental information column. Data were screened for potential outlier values or transcription errors and a subset of data were flagged in the final database as out of quality control compliance including 1) values that were an order of magnitude out of range of typical values for that parameter and HUC-8, 2) values flagged as non-detections that were out of range of typical reporting limits for that parameter, 3) values flagged with "?", and 4) zero or negative values. These observations were not included in analysis and were not used to calculate TN. The final water quality database was reviewed according to quality assurance and quality control protocols by checking 10% of database entries for accuracy against original data files following an approved secondary data quality assurance project plan.

Annual TN and TP concentration site medians were calculated for all monitoring stations in the ADEQ and 319 databases. For site years with only one observation, the median was equal to the single measured value. Where multiple values were recorded for a single day, values were averaged prior to median calculation. In cases of overlapping monitoring locations between data sources, sites were treated as separate and unique. Two iterations of frequency distributions of annual site medians were then calculated for each HUC-8 and year combination with at least three site medians. The first iteration included both ADEQ and 319 monitoring stations with a five-year focus period (2015 – 2019) in order to target current nutrient levels for assessing HUC-8 nutrient magnitudes. The second iteration included only ADEQ monitoring stations and analyzed data for the full study period (1990 – 2019) for the purpose of trend analysis. The 319 data were not included in percentiles for trend analysis because of limited monitoring duration (typically < 5 years) compared to ADEQ stations, which would introduce new sources of variability unevenly through time and potentially reduce the probability of detecting trends. The resulting frequency distribution data sets consisted of HUC-8 percentile estimates for each year in which data availability requirements were met (i.e. up to 5 years or up to 30 years for the first and second iterations of percentiles, respectively).

HUC-8 nutrient magnitude assessment

For the nutrient magnitude assessment, the average of 75th percentiles of site medians (ADEQ and 319 sites; 2015 – 2019) was selected as the measure (subsequently, screening level) of HUC-8 nutrient concentrations to be compared to screening thresholds. Screening thresholds in TN and TP concentrations were derived by calculating frequency distributions of nutrient thresholds for biological response compiled from a review of stressor-response studies in the scientific literature (see Table S1 and accompanying References in Supplementary Materials). The compiled nutrient thresholds were identified for responses in a wide range of algal, aquatic macroinvertebrate, and fish indicator species, functional groups, and communities. Response thresholds were grouped based on geospatial characteristics of the studied systems, including size (ex: wadeable or non-wadeable) and dominant watershed agricultural land use types (ex: row-crop or pasture). Frequency distributions of TN and TP thresholds were calculated for geospatial groupings based on these characteristics and across all studies. Many included studies analyzed statewide, regional, or even global datasets, representing spatial scales that could not be linked to a single dominant land use type. Thresholds from these studies were included in frequency distribution calculations for any relevant geospatial grouping.

For both TN and TP, two screening scenarios were developed, each selecting one or more concentrations as screening thresholds (Table 1). Multiple scenarios were used to identify a gradient in nutrient concentrations and allow flexibility in bringing together magnitude assessment results for TN and TP with trend results into a final priority categorization framework. The primary difference between scenarios was the degree to which the selected thresholds were tailored to HUC-8 characteristics that reflect Arkansas's diverse geography and land use (Figure 1A). Seven Omernik, 1987 Level III ecoregions are present in Arkansas: Arkansas Valley (ARV), Boston Mountains (BOSM), Mississippi Alluvial Plain (MAP), Mississippi Valley Loess Plains, Ouachita Mountains (OUAM), Ozark Highlands (OZKH), and South Central Plains (SCP). Each HUC-8 was assigned to a dominant ecoregion based on the location of the greatest percentage of monitoring sites in the database (Figure 1B). In most cases, a clear majority (i.e. >2/3 of sites) were located in a single ecoregion. However, sites in 11110207 – Lower Arkansas-Maumelle were split across four ecoregions, with only 42% of sites in the dominant ecoregion (OUAM), and sites in 08040102 – Upper Ouachita were near evenly divided between 2 ecoregions (56% in the OUAM and 44% in the SCP). No monitoring sites were located in the Mississippi Valley Loess Plains.

Table 1. Scenarios for screening HUC-8 total nutrient concentration magnitudes for levels of ecological concern.

Scenario	Parameter	Ecoregion	Screening Threshold (mg/L)	Explanation
1	TN	All ecoregions	1.0	Median all systems
2	TN	Miss. Alluvial Plain	0.81	Median row-crop, non-wadeable systems
		All other ecoregions	0.66	Median pasture, non-wadeable systems
1	TP	Miss. Alluvial Plain	0.14	Median row-crop non-wadeable systems
		All other ecoregions	0.10	Median pasture, non-wadeable systems
2	TP	Forested uplands	0.07	Median pasture, wadeable systems

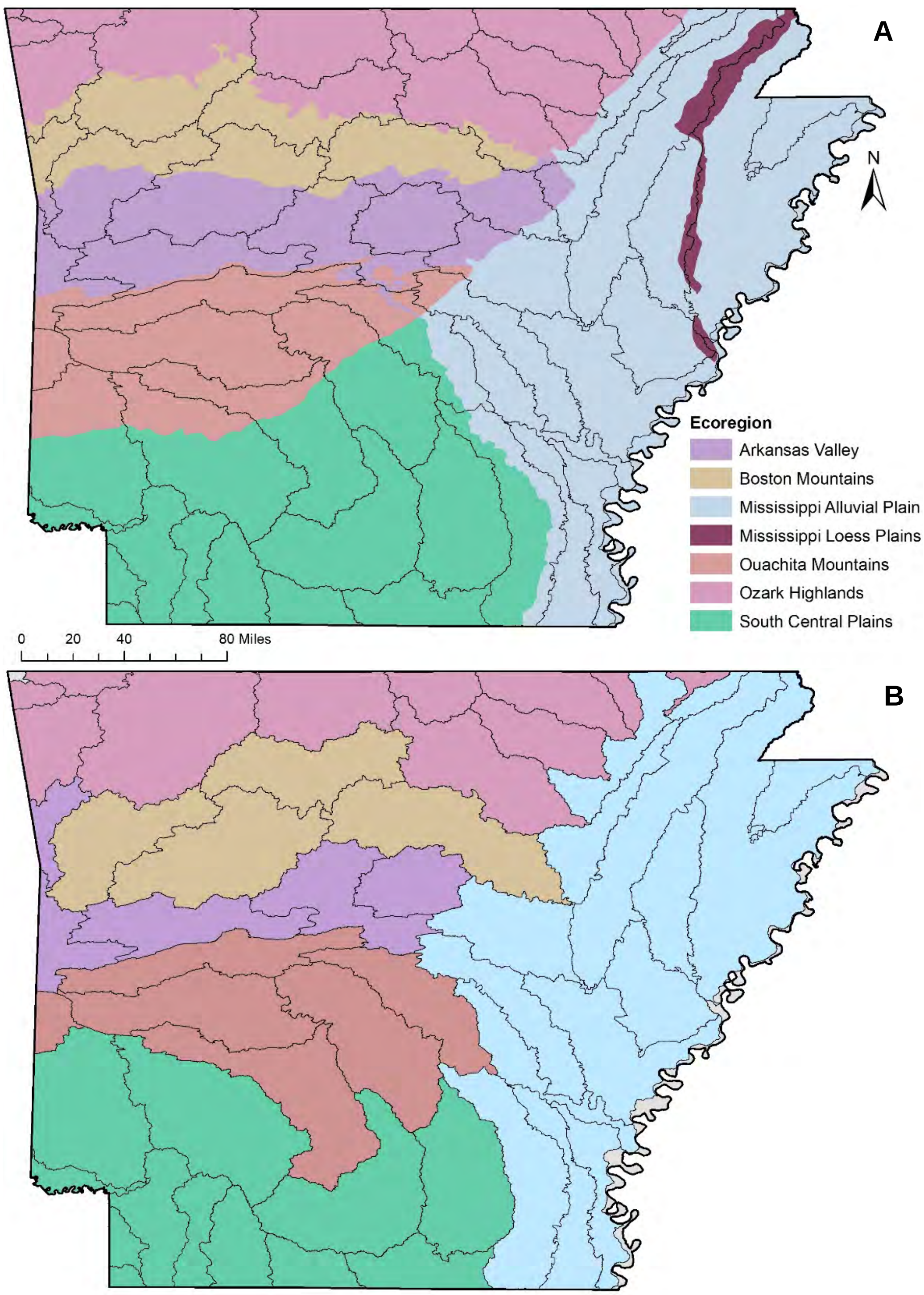


Figure 1. Omernik Level III ecoregions in Arkansas A) overlying Arkansas HUC-8s and B) as assigned to individual HUC-8s based on analysis of the ecoregion in which the greatest number of sites were located.

Under TN scenario 1, a single screening threshold (TN = 1.0 mg/L) was selected for comparison with TN screening levels for all Arkansas HUC-8's and was approximately the median of all compiled TN stressor-response thresholds. For TN, scenario 2 set separate screen thresholds for the MAP, Arkansas's primary row-crop production region, and all other ecoregions, which were the medians of thresholds derived for non-wadeable systems with row-crop watershed influence (TN = 0.81 mg/L) and pasture watershed influence (TN = 0.66 mg/L), respectively. For TP, scenario 1 also set separate screen thresholds for the MAP and all other ecoregions, which were also equivalent to the median of thresholds derived for non-wadeable systems with row-crop watershed influence (TP = 0.14 mg/L) and pasture watershed influence (TP = 0.10 mg/L), respectively. For TP, scenario 2 set the median of thresholds derived for wadeable systems with pasture influence (TP = 0.070 mg/L) as the screening threshold for HUC-8s in Arkansas's three forested upland ecoregions (BOSM, OUAM, and OZKH). The scenario 1 screening thresholds were applied for all other ecoregions under scenario 2. The degree of geospatial specificity differed between TN and TP scenarios, reflecting that many compiled studies estimated thresholds for TP only and considerably less information was available for dividing and analyzing TN thresholds by geospatial groupings.

For each scenario, all HUC-8s with a TN or TP screening level that was greater than the relevant screening threshold were identified as having nutrient concentrations at levels of potential ecological concern. These HUC-8s were flagged as candidate HUC-8s in need of nutrient reduction based on the magnitude component of the overall categorization framework. Asubset of HUC-8s was flagged as having marginal data availability in the magnitude assessment if 75th percentile estimates were available for fewer than three years of the five-year focus period or if the median number of site medians used to calculate a 75th percentile each year was less than four per year (2015 – 2019).

HUC-8 Trend Analysis

Trend analysis was conducted on the second iteration of HUC-8 75th percentiles of site median TN and TP concentrations (ADEQ sites only) using linear regression analysis (LR) and the Mann-Kendall test (MK) to detect monotonic change in concentrations over time. The analyses were carried out in R 4.0.4 using the rkt package for MK (Marchetto, 2017). Trend analysis data availability requirements were at least ten years of 75th percentile estimates, with at least 50% of years in a HUC-8's period of record represented. A subset of HUC-8s was assigned marginal data availability status if less than 2/3 of years in a HUC-8's period of record were represented, the total number of years with 75th percentiles was less than 15 years, or if the median number of site medians used to calculate a 75th percentile each year was less than four per year (1990 – 2019).

Results were typically in agreement between LR and MK, but MK results were used for determining statistical significance due to the limited sample size (i.e. maximum one 75th percentile per year, or $n_{max} = 30$). Statistical significance was interpreted as follows: for $p \geq 0.20$, trend was unlikely; for $0.10 \geq p < 0.20$, trend may exist; for $0.05 \geq p < 0.10$, trend was likely; and for $p < 0.05$, trend was very likely. Positive and negative Sen line slopes reflected increasing and decreasing trends, respectively; a slope with magnitude less than 0.01% in either direction was considered not changing, regardless of significance. The HUC-8s where increasing nutrient concentrations were detected were flagged as candidates in need of nutrient reduction based on the trend component of the overall categorization framework.

Site-level trend analysis

Trend analysis was also conducted on TN and TP concentrations at qualifying ADEQ monitoring sites ($n \geq 50$) located in HUC-8s that were flagged as candidates in need of nutrient reduction based on magnitude or trend for at least one nutrient (scenarios 1 and 2). For site-level trends, a focus period of 2000 – 2019 was targeted, and the seasonal Kendall test (SKT) was used in addition to LR and MK. When results of the three analyses were not in agreement, added weight was given to SKT results, because SKT corrects for common sources of outside variability in ambient monitoring datasets, such as seasonality, missing data, and irregular sampling intervals. Further, the site-level trend analysis results shown in state maps and summary tables are SKT results. More selective thresholds for statistical significance were applied for site-level analyses since the number of observations was less limited. The statistical significance of site-level trend analysis results was interpreted, as follows: for $p \geq 0.10$, trend was unlikely; for $0.05 \geq p < 0.10$, trend was likely; and for $p < 0.05$, trend was very likely. Positive and negative Sen line slopes reflected increasing and decreasing trends, respectively; a slope with magnitude less than 0.01% in either direction was considered not changing regardless of significance.

HUC-8 priority categorization

The prioritization framework divided HUC-8s into four tiers: 1) maximum focus for nutrient reduction, with sufficient monitoring; 2) focus for nutrient reduction, with more monitoring needed; 3) less focus, with more monitoring needed; and 4) least focus, with sufficient monitoring. Tiered rankings correspond to the level of demonstrated nutrient reduction need in synthesis with assessment of available data. HUC-8s were considered data-limited if flagged for marginal data availability for any component of analysis, or if the HUC-8 did not qualify for one or both components. The framework also considered select substantiating prioritization layers (National Resources Conservation Service Mississippi River Basin Initiative, or MRBI, priority watersheds and Nutrient Surplus Areas under AR Code § 15-20-1104, 2019) as an approach to separate data-deficient HUC-8s into categories with more or less evidence of nutrient reduction need. Designations as MRBI priority watershed (Figure 2A) or Nutrient Surplus Area (Figure 2B) are not based directly on measured in-stream nutrient concentrations, but nutrient export reduction is a stated goal.

The framework was designed to capture a limited number of HUC-8s in Tier 1 in order to focus investment of limited resources in nutrient reduction strategies and maximize returns by targeting HUC-8s with both the most evidence for nutrient reduction need and sufficient baseline data for quantitative assessment and goal setting. Specific qualifying criteria for Tier 1 were identification as a nutrient reduction focus for both TN and TP (scenarios 1 and 2 qualify), with sufficient data to assess both trend and magnitude.

In contrast, Tier 2 was set up to focus on a number of identified concerns that were not eligible for prioritization in Tier 1 due to data limitations or because the observed evidence of nutrient reduction need did not cumulatively meet Tier 1 criteria, or both. The primary goal under the ANRS for Tier 2 was investment in evaluating and meeting monitoring needs to support assessment under future ANRS updates. Qualifying criteria for Tier 2 were: 1) magnitude greater than scenario 1 threshold for one nutrient with sufficient data to assess both trend and magnitude; 2) identification for increasing trend for one nutrient; 3) identification for two nutrients (scenario 1 and 2 qualify) with limited data to assess; 4) identification for one nutrient under scenario 1 with limited data to assess; and 5) insufficient data to assess, but MRBI or NSA status.

Tier 3 and 4 were designed to encompass HUC-8s with the fewest lines of evidence suggesting nutrient reduction need, acknowledging that data-limited HUC-8s merit greater prioritization in Tier 3 from the perspective of investment in future data collection efforts. All HUC-8s that did not qualify for Tier 1 or 2 status were assigned to Tier 3 or 4 based on data availability, with data-limited HUC-8s assigned to Tier 3 and HUC-8s with sufficient data assigned to Tier 4.

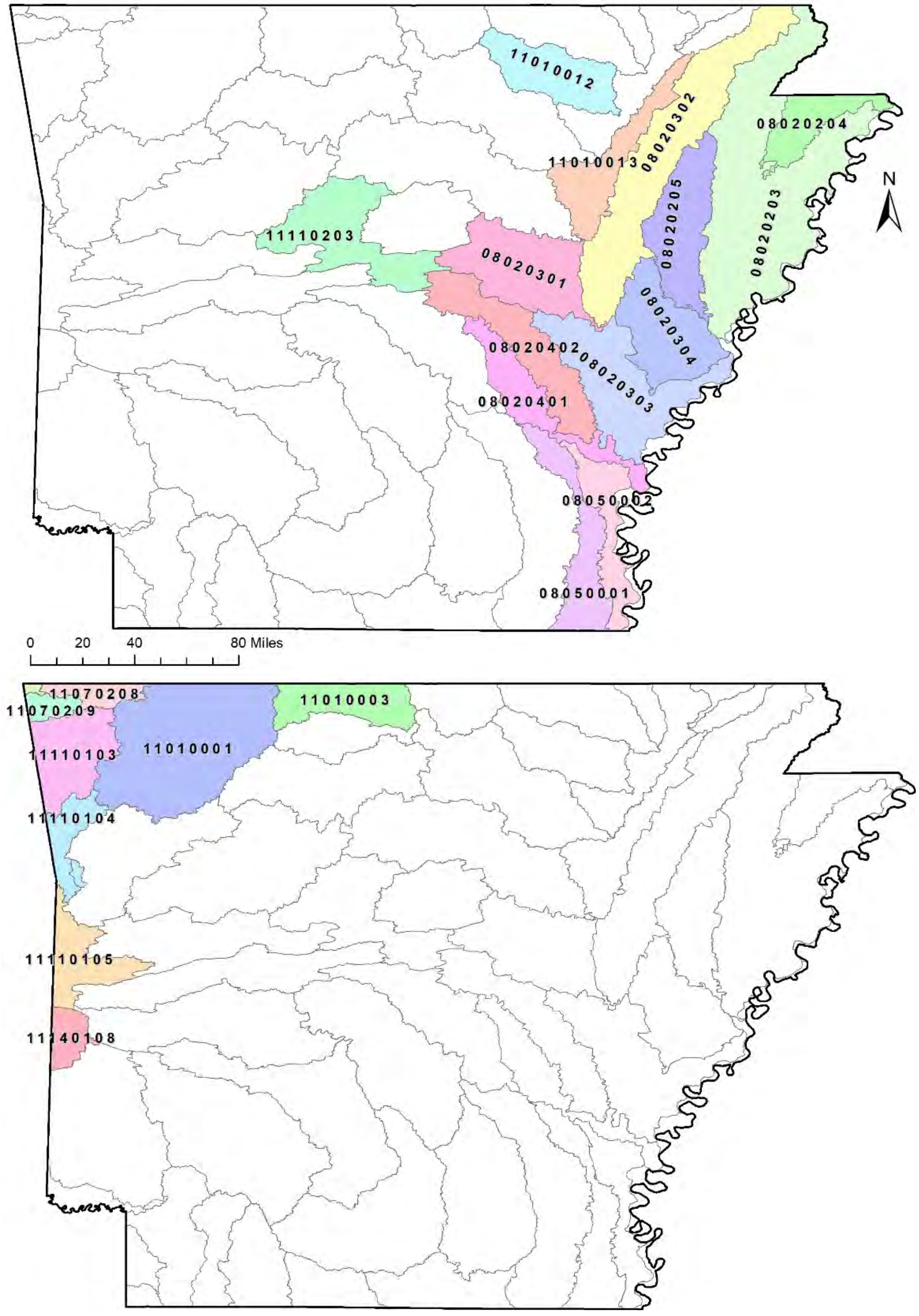


Figure 2. Arkansas HUC-8s designated as A) Mississippi River Basin Initiative (MRBI) priority watersheds and B) Nutrient Surplus Areas by AR Code § 15-20-1104, 2019.

RESULTS AND DISCUSSION

Nutrient magnitudes by Arkansas ecoregion

The TN and TP magnitude screening levels varied across the state (Figure 3A-B; Table S2-3). The HUC-8 TN screening levels were greatest in the OZKH, where the median level was greater than the scenario 1 screening threshold (TN = 1 mg/L). For HUC-8s in the ARV, MAP, and SCP, the upper quartile of screening levels was also greater than 1 mg/L. The median screening levels for MAP, ARV, and SCP HUC-8s were greater than the applicable scenario 2 screening threshold (TN = 0.81 mg/L for MAP; TN = 0.66 mg/L for all other ecoregions). The OUAM and BOSM HUC-8 TN screening levels were the lowest in central tendency and range. However, the upper quartile of OUAM HUC-8 TN screening levels was greater than 0.66 mg/L, while all Boston Mountain TN screening levels were less than the screening thresholds.

In contrast to TN, the greatest HUC-8 TP screening levels were observed in the MAP, with the median screening level ~2x greater than the scenario 1 screening threshold (TP = 0.14 mg/L). The OZKH HUC-8 median TP screening level and upper quartile of screening levels for the ARV, BOSM, and SCP were greater than the applicable scenario 1 screening threshold (TP = 0.10 mg/L). For both ARV and SCP HUC-8s the median TP screening level was close in range with 0.10 mg/L. As with TN, the TP screening levels were lowest range in the BOSM and OUAM HUC-8s. However, the range in TP screening levels for BOSM HUC-8s was far greater for TP than for TN, with the 75th percentile screening level > 0.10 mg/L, but the median less than the scenario 2 screening level (TP = 0.070 mg/L). The upper quartile of OUAM HUC-8 TP screening levels was greater than 0.070 mg/L, but the median was ~2x less.

Magnitude assessment of HUC-8 total nutrient 75th percentiles

The magnitude assessment identified a number of HUC-8s where nutrient screening levels were greater than screening thresholds, representing the HUC-8s with the greatest potential for nutrient reduction (Figure 4A-B). A total of 21 HUC-8s were flagged for TN reduction based on the magnitude component (13 under scenario 1; 8 under scenario 2); while 18 HUC-8s were flagged for TP (15 under scenario 1; 3 under scenario 2). The magnitude assessment results reflect the regional gradient (Figure 3A-B) in nutrient levels among qualifying Arkansas HUC-8 watersheds, with flagged HUC-8s clustered in the OZKM and MAP ecoregions. This pattern was especially apparent for HUC-8s that were flagged under the less restrictive scenario 1, which were the HUC-8s with the highest nutrient levels relative to the screening thresholds.

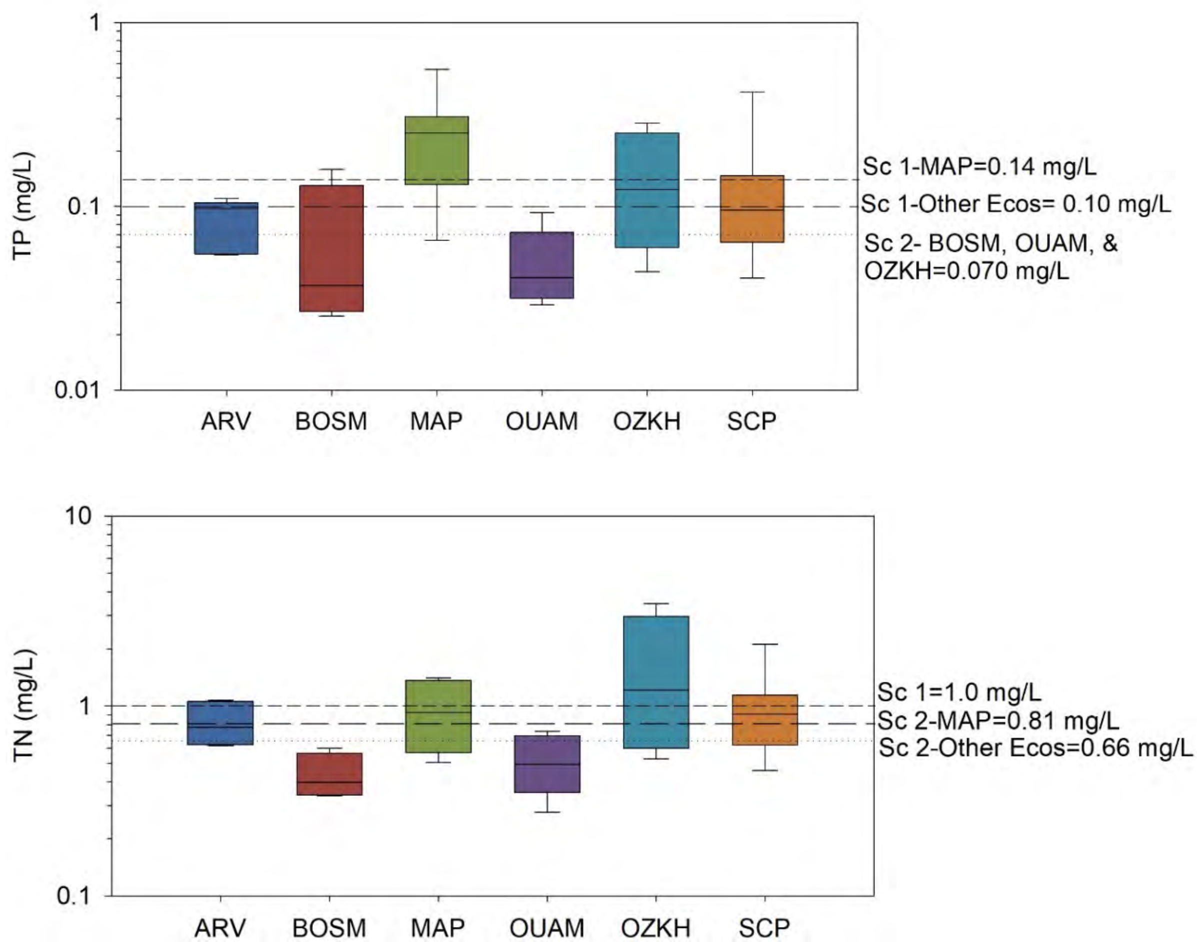


Figure 3. Boxplots showing the A) TN and B) TP concentration frequency distribution of the HUC-8 averages of 75th percentiles of site medians from 2015 - 2019 (i.e. HUC-8 screening levels) by ecoregion.

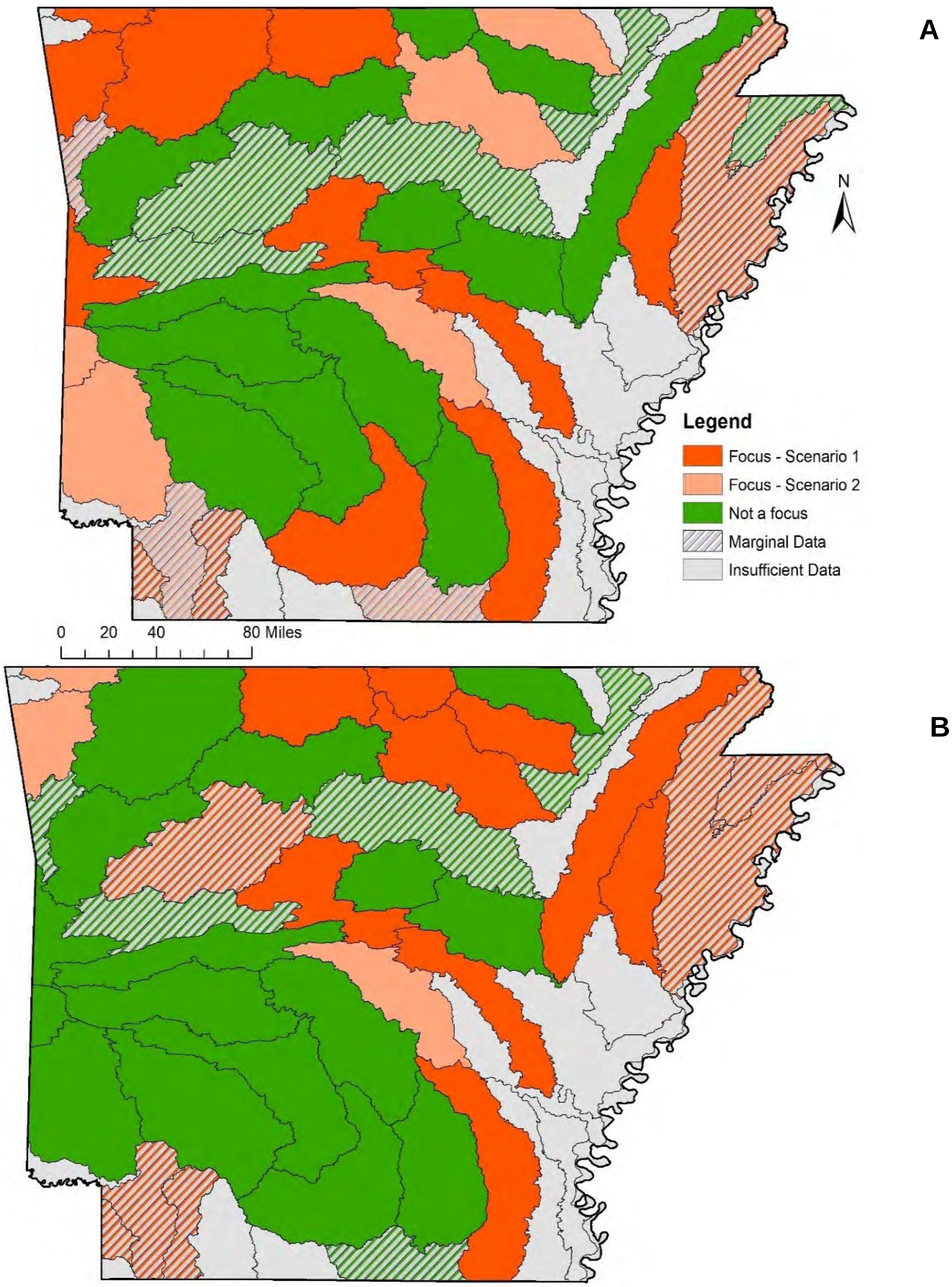


Figure 4. Results of HUC-8 magnitude assessment on A) total nitrogen and B) total phosphorus 75th percentile of site median concentrations for the period 2015 - 2019.

Approximately 2/3 of HUC-8s met data availability requirements for the magnitude assessment, but 19 were not included due to data limitations. Of qualifying HUC-8s, 11 were flagged for marginal data availability to assess magnitude for either TN or TP, or both. The main limitation on data availability was spatial coverage, or having too few active monitoring sites (n<3) within a HUC during the focus period 2015 – 2019. However, some HUC-8s were flagged for marginal data availability based on limited temporal coverage, or having <3 years of 75th percentiles. These HUC-8s were 11110104 – Robert S. Kerr Reservoir, 11010009 – Lower Black, 11140205 – Bodcau Bayou, 11140302- Lower Sulpher, and 08020203 Lower St. Francis.

Trend analysis on HUC-8 total nutrient 75th percentiles

Anotable study finding is that 75th percentiles of site median nutrient concentrations have widely declined or remained stable across Arkansas HUC-8s (Figure 5A-B; Table S4-5). This finding suggests that the State of Arkansas has seen a return on investment in nutrient reduction strategies made over the last 30 years. In fact, trend analysis results suggested increasing nutrient concentrations in only one HUC-8 (i.e. TN in 11010010 – Spring). For TP, increases in 75th percentiles of site medians were not detected in any HUC-8. No changes were detected for 5 HUC-8s for TN and for 7 HUC-8s for TP. For all other qualifying HUC-8s, trend analysis results suggested that 75th percentiles of site median total nutrient concentrations are decreasing.

However, data availability was insufficient for trend analysis for approximately half of Arkansas HUC-8s; therefore, it was not possible to determine if this finding applies statewide, including for the majority of MAP HUC-8s, a substantial number of which were flagged for nutrient levels greater than screening thresholds. The lack of increasing trends and inability to assess trends statewide with this approach had practical implications for the HUC-8 focus categorization process. Namely, the categorization process was largely based on the magnitude assessment.

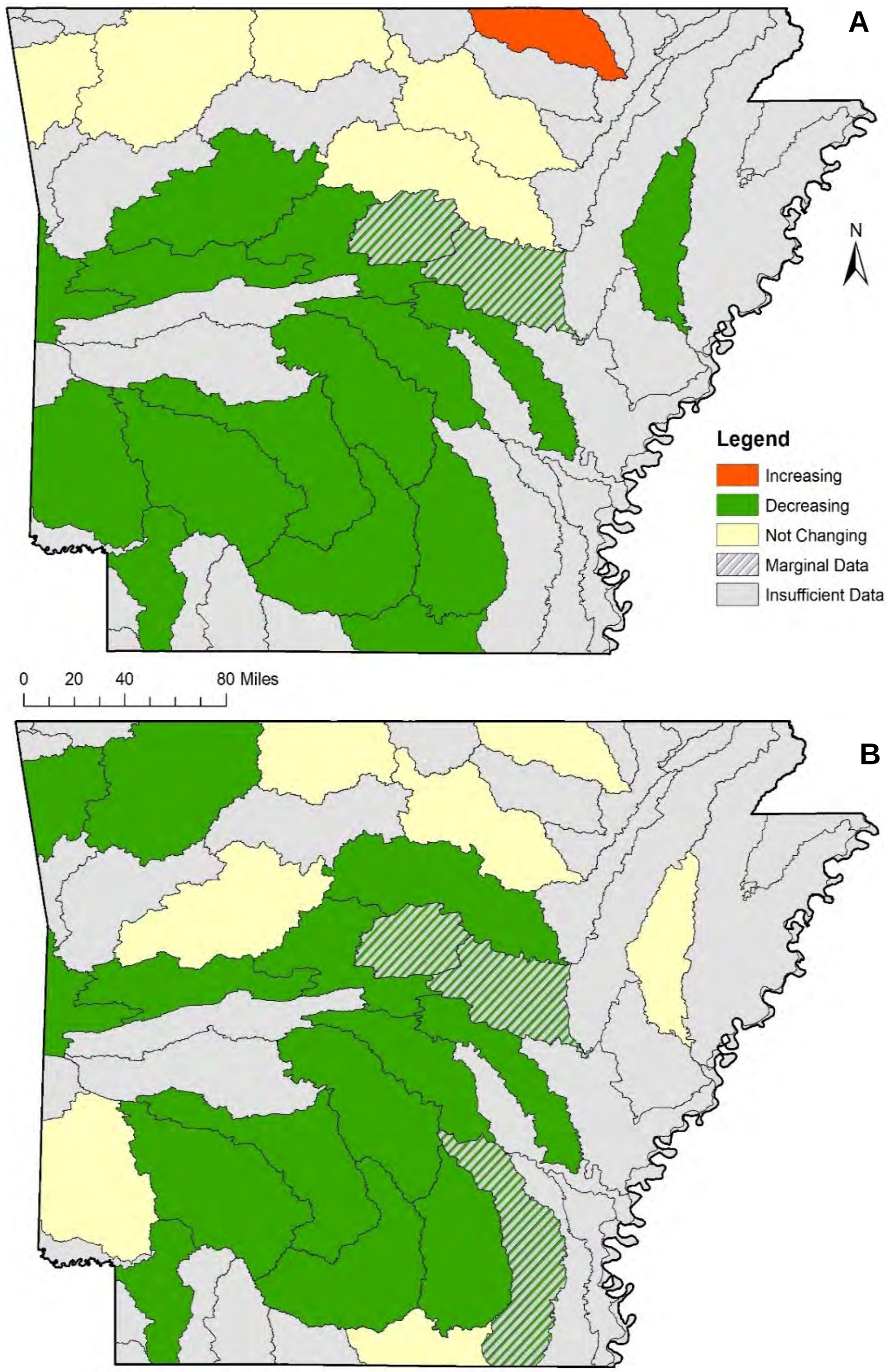


Figure 5. Results of HUC-8 level trend analysis on A) total nitrogen and B) total phosphorus 75th percentile of site median concentrations.

Two HUC-8s were flagged for marginal data availability to assess trend in TN (11110205 – Cadron and 08020301 – Lower White-Bayou Des Arc). These same HUC-8s were also flagged for TP, as well as 08040205 – Bayou Bartholomew, which did not meet data qualifications for trend analysis for TN. For HUC-8s flagged for insufficient data availability, limited number of long-term monitoring sites (n<3) drove data limitations. However, HUC-8s flagged for marginal data availability all had monitoring periods that were truncated or had data gaps.

Data analysis focus categorization

The prioritization framework identified seven HUC-8s for maximum focus status in Tier 1 with sufficient monitoring data to guide investment in nutrient reduction strategies (Figure 6):

- 08020205 – L'Anguille
- 08020402 – Bayou Meto
- 11010003 – Bull Shoals Lake
- 11010004 – Middle White
- 11110103 – Illinois
- 11110203 – Lake Conway-Point Remove
- 11110207 – Lower Arkansas-Maumelle

Nutrient levels in these watersheds represent the greatest potential for reduction. Though total nutrient magnitudes were the primary driver, Tier 1 also encompasses several HUC-8s where trend analysis suggested that conditions were not improving, namely 11110103 – Illinois for TN, 08020402 – L'Anguille for TP, and 11010004 – Middle White and 11010003 – Bull Shoals Lake for both TN and TP.

Twenty-three HUC-8s were assigned to Tier 2 focus status, with emphasis under the ANRS on future monitoring program investments due to demonstrated nutrient reduction needs, data limitations, or both. Of HUC-8s not assigned to Tier 1 or Tier 2 focus status, 23 were categorized as data-limited and assigned to Tier 3, while only five were categorized as data-sufficient and assigned to Tier 4. See Table 2 for Tier assignments for all Arkansas HUC-8s, including a weight of evidence summary of magnitude and trend results, partner priority status, and data availability.

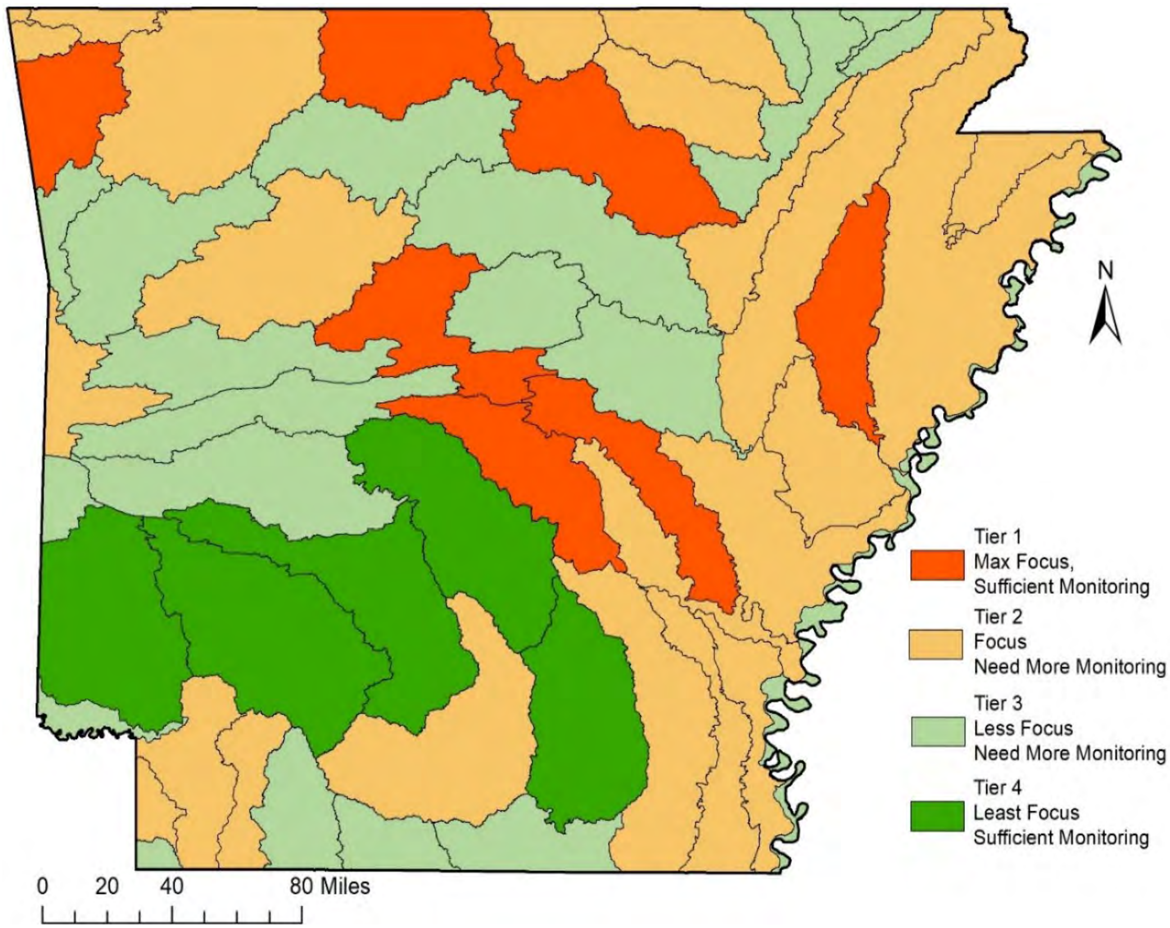


Figure 6. Categorization framework for HUC-8s under the ANRS update. Priority categories were 1) maximum focus for nutrient reduction activities, sufficient data; 2) Focus, but more data needed 3) less focus, but more data needed; and 4) least focus, with sufficient data.

Table 2. Priority tier assignments for all Arkansas HUC-8s, including summary of results for TN and TP magnitude assessment and trend analysis components of the data analysis, partner priority status, and data availability. Synthesis of these factors was the basis for priority tier assignments. Magnitude assessment scenarios (Sc) compared HUC8 screening levels to a range of screening thresholds, as follows: Sc 1 TN threshold = 1.0 mg/L for all ecoregions; Sc2 TN threshold for Mississippi Alluvial Plain (MAP) = 0.81 mg/L; Sc2 TN threshold for other ecoregions = 0.66 mg/L; Sc1 TP threshold for MAP = 0.14 mg/L; Sc1 TP threshold for other ecoregions = 0.10 mg/L; Sc2 thresholds for Boston Mountains (BOSM), Ouachita Mountains (OUAM), and Ozark Highlands (OZKH) = 0.07 mg/L. For MAP, Arkansas River Valley (ARV) and South Central Plains (SCP), only a Sc1 threshold was used in the TP screening.

				Factors determining priority tier			Data availability	
HUC8	Name	Ecoregion	Tier	TN Magnitude, Trend	TP Magnitude, Trend	Partner Priority	Magnitude	Trend
08010100	Lower Mississippi-Memphis	MAP	3	Not Assessed	Not assessed	-	Insufficient	Insufficient
08020100	Lower Mississippi-Helena	MAP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
08020203	Lower St. Francis	MAP	2	Above Sc 1 threshold	Above Sc 1 threshold	MRBI	Marginal	Insufficient
08020204	Little River Ditches	MAP	2	Below Sc 1 threshold	Above Sc 1 threshold	MRBI	Marginal	Insufficient
08020205	L'Anguille	MAP	1	Above Sc 1 threshold, decreasing	Above Sc 1 threshold, not changing	MRBI	Sufficient	Sufficient
08020301	Lower White-Bayou Des Arc	MAP	3	Below Sc 1 threshold, decreasing	Below Sc 1 threshold, decreasing	MRBI	Sufficient	Marginal
08020302	Cache	MAP	2	Below Sc 1 threshold	Above Sc 1 threshold	MRBI	Sufficient	Insufficient
08020303	Lower White	MAP	2	Not Assessed	Not assessed	MRBI	Insufficient	Insufficient
08020304	Big	MAP	2	Not Assessed	Not assessed	MRBI	Insufficient	Insufficient
08020401	Lower Arkansas	MAP	2	Not Assessed	Not assessed	MRBI	Insufficient	Insufficient
08020402	Bayou Meto	MAP	1	Above Sc 1 threshold, decreasing	Above Sc 1 threshold, decreasing	MRBI	Sufficient	Sufficient
08030100	Lower Mississippi-Greenville	MAP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
08040101	Ouachita Headwaters	OUAM	3	Below Sc 2 threshold	Below Sc 2 threshold	-	Sufficient	Insufficient
08040102	Upper Ouachita	OUAM	4	Below Sc 2 threshold, decreasing	Below Sc 2 threshold, decreasing	-	Sufficient	Sufficient

08040103	Little Missouri	SCP	4	Below Sc 2 threshold, decreasing	Below Sc 1 threshold, decreasing	-	Sufficient	Sufficient
08040201	Lower Ouachita-Smackover	SCP	2	Above Sc 1 threshold, decreasing	Below Sc 1 threshold, decreasing	-	Sufficient	Sufficient
08040202	Lower Ouachita-Bayou De Loutre	SCP	3	Above Sc 2 threshold, decreasing	Below Sc 1 threshold, not changing	-	Marginal	Sufficient
08040203	Upper Saline	OUAM	4	Below Sc 2 threshold, decreasing	Below Sc 2 threshold, decreasing	-	Sufficient	Sufficient
08040204	Lower Saline	SCP	4	Below Sc 1 threshold, decreasing	Below Sc 1 threshold, decreasing	-	Sufficient	Sufficient
08040205	Bayou Bartholomew	MAP	2	Above Sc 1 threshold	Above Sc 1 threshold, decreasing	MRBI	Sufficient	Marginal
08040206	Bayou D'Arbonne	SCP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
08050001	Boeuf	MAP	2	Not Assessed	Not Assessed	MRBI	Insufficient	Insufficient
08050002	Bayou Macon	MAP	2	Not Assessed	Not assessed	MRBI	Insufficient	Insufficient
11010001	Beaver Reservoir	OZKH	2	Above Sc 1 threshold, not changing	Below Sc 2 threshold, decreasing	NSA	Sufficient	Sufficient
11010003	Bull Shoals Lake	OZKH	1	Above Sc 1 threshold, not changing	Above Sc 1 threshold, not changing	-	Sufficient	Sufficient
11010004	Middle White	OZKH	1	Above Sc 2 threshold, not changing	Above Sc 1 threshold, not changing	-	Sufficient	Sufficient
11010005	Buffalo	BOSM	3	Below Sc 2 threshold	Below Sc 2 thresholds	-	Sufficient	Insufficient
11010006	North Fork White	OZKH	2	Below Sc 2 threshold	Above Sc 1 threshold	-	Sufficient	Insufficient
11010007	Upper Black	MAP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
11010008	Current	OZKH	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
11010009	Lower Black	MAP	3	Below Sc 1 threshold	Below Sc 1 threshold	-	Marginal	Insufficient
11010010	Spring	OZKH	2	Above Sc 2 threshold, increasing	Below Sc 2 threshold, not changing	-	Sufficient	Sufficient
11010011	Eleven Point	OZKH	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
11010012	Strawberry	OZKH	2	Below Sc 2 threshold	Above Sc 1 threshold	MRBI	Sufficient	Insufficient
11010013	Upper White-Village	MAP	2	Not Assessed	Not assessed	MRBI	Insufficient	Insufficient
11010014	Little Red	BOSM	3	Below Sc 2 threshold, not changing	Below Sc 2 threshold, decreasing	-	Marginal	Sufficient

11070206	Lake O' The Cherokees	OZKH	2	Not Assessed	Not assessed	NSA	Insufficient	Insufficient
11070208	Elk	OZKH	2	Above Sc 1 threshold	Above Sc 2 threshold	NSA	Sufficient	Insufficient
11070209	Lower Neosho	OZKH	2	Not Assessed	Not assessed	NSA	Insufficient	Insufficient
11110103	Illinois	OZKH	1	Above Sc 1 threshold, not changing	Above Sc 2 threshold, decreasing	NSA	Sufficient	Sufficient
11110104	Robert S. Kerr Reservoir	ARV	3	Above Sc 2 threshold	Below Sc 2 threshold	NSA	Marginal	Insufficient
11110105	Poteau	ARV	2	Above Sc 1 threshold, decreasing	Below Sc 2 threshold	NSA	Sufficient	Sufficient
11110201	Frog-Mulberry	BOSM	3	Below Sc 2 threshold	Below Sc 2 threshold	-	Sufficient	Insufficient
11110202	Dardanelle Reservoir	BOSM	2	Below Sc 2 threshold, decreasing	Above Sc 1 threshold, not changing	-	Marginal	Sufficient
11110203	Lake Conway-Point Remove	ARV	1	Above Sc 1 threshold	Above Sc 1 threshold	MRBI	Sufficient	Sufficient
11110204	Petit Jean	ARV	3	Below Sc 2 threshold, decreasing	Below Sc 2 threshold, decreasing	-	Marginal	Sufficient
11110205	Cadron	ARV	3	Below Sc 1 threshold	Below Sc 1 & 2 thresholds, decreasing	-	Sufficient	Marginal
11110206	Fourche La Fave	OUAM	3	Below Sc 2 threshold	Below Sc 2 threshold	-	Sufficient	Insufficient
11110207	Lower Arkansas-Maumelle	OUAM	1	Above Sc 2 threshold, decreasing	Above Sc 2 threshold, decreasing	-	Sufficient	Sufficient
11140105	Kiamichi	OUAM	3	Not Assessed	Not assessed	-	Insufficient	Insufficient
11140106	Pecan-Waterhole	SCP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
11140108	Mountain Fork	OUAM	3	Above Sc 2 threshold	Below Sc 2 threshold	NSA	Sufficient	Insufficient
11140109	Lower Little Arkansas, Oklahoma	SCP	4	Above Sc 2 threshold, decreasing	Below Sc 1 threshold, not changing	-	Sufficient	Sufficient
11140201	McKinney-Posten Bayous	SCP	2	Above Sc 2 threshold, decreasing	Above Sc 1 threshold, decreasing	-	Marginal	Sufficient
11140203	Loggy Bayou	SCP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient
11140205	Bodcau Bayou	SCP	2	Above Sc 1 threshold	Above Sc 1 threshold	-	Marginal	Insufficient
11140302	Lower Sulpher	SCP	2	Above Sc 1 threshold	Above Sc 1 threshold	-	Marginal	Marginal
11140304	Cross Bayou	SCP	3	Not Assessed	Not Assessed	-	Insufficient	Insufficient

Challenges to a statewide prioritization framework

Uneven coverage in the State's ambient water quality monitoring data sets was the primary challenge to a statewide HUC8-8 prioritization framework. Approximately one third of Arkansas HUC-8s did not qualify for either component of the analysis. In many cases, data-deficient HUC-8s may not represent the appropriate scale for ANRS prioritization. Some are data limited because only a small area is located in Arkansas, most notably 11140105 – Kiamichi. In some cases, Arkansas contains only a small downstream portion of the HUC-8, such as 11140106 – Pecan Waterhole, 11010007 – Upper Black, 11010011 – Eleven Point, and 11010008 – Current. Additionally, the scale of some HUC-8s may be too large for ANRS prioritization, such as three Mississippi River mainstem HUC-8s located on Arkansas's eastern border. For all these HUC-8s, Arkansas's ability to effect or demonstrate nutrient reduction with a single-state strategy is unlikely.

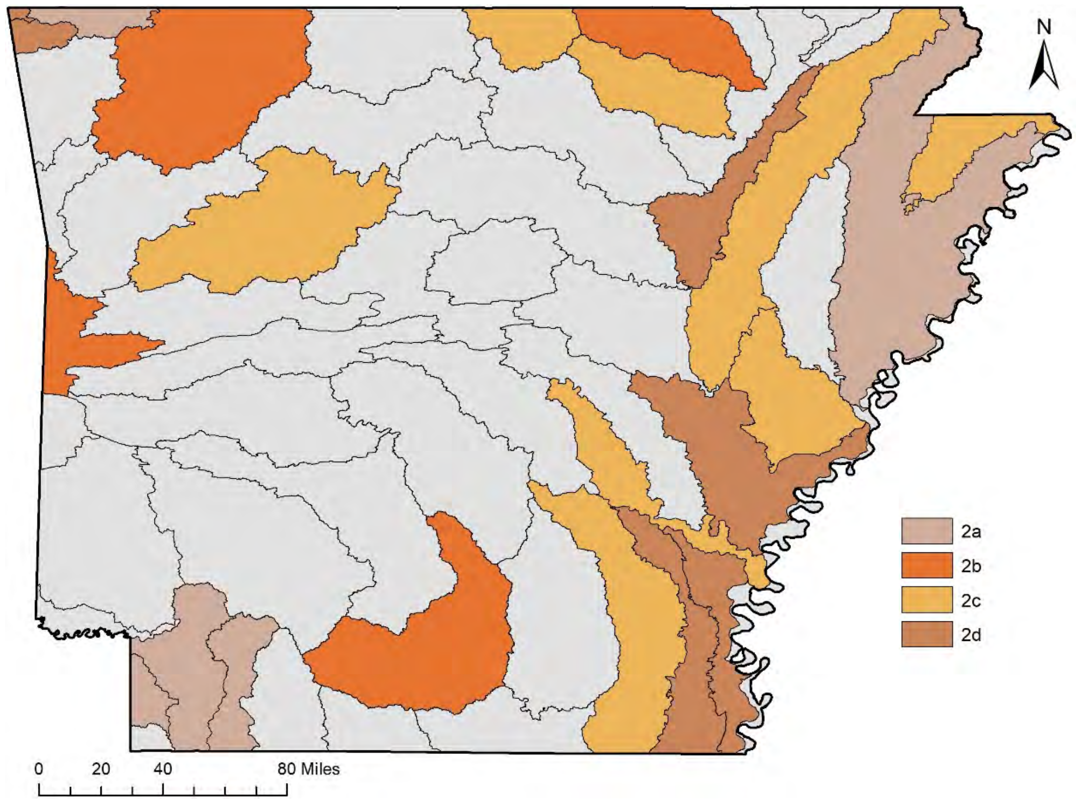
However, some data-deficient HUC-8s with limited area in Arkansas are known nutrient export hotspots, such as the Spavinaw Creek and Honey Creek sub-watersheds of 11070209 – Lower Neosho and 11070206 – Lake O' The Cherokees. Further, issues of scale largely do not apply for a cluster of category 5 HUC-8s located in the lower Mississippi River Alluvial Plain in Southeast Arkansas. The lack of a robust data record that includes multiple active monitoring locations and regular sample collection is an impediment to understanding how watersheds in these regions fit into a data-based prioritization framework for watershed prioritization under the ANRS.

Asecond challenge was related to the goal of maintaining a streamlined prioritization framework with a maximum of four tiers, with the first tier having a stated target number of only 5 – 8 HUC-8s. Gradients both in the weight of evidence for nutrient reduction need and data availability were observed across Arkansas HUC-8s, with a number of complex scenarios arising from synthesis of these factors that could not be accommodated uniquely with only four tiers. Thus, Tier 2 groups a broad range of scenarios, and sub-categories were needed that differentiate the HUC-8s with a common set of factors resulting in Tier 2 categorization, as well as the types of action and monitoring investments needed under the ANRS.

Subcategories describing these scenarios were: 2a) equivalent evidence for nutrient reduction need to Tier 1, but with insufficient data for quantitative assessment and goal setting; 2b) evidence of nutrient reduction need, but less than qualifying criteria for Tier 1, with sufficient data; 2c) evidence of nutrient reduction need, with limited data; and 2d) a partner priority (Mississippi River Basin Initiative or Nutrient Surplus Area) for nutrient reduction focus, but with insufficient data for assessment in any component of the data analysis (Figure 7).

Comparisons with current ANRS priority watersheds

The 2014 ANRS qualitatively identified 10 priority HUC-8s: 08040205 - Bayou Bartholomew, 08020302 - Cache River, 11110203 - Lake Conway-Point Remove, 08040201 - Lower Ouachita-Smackover, 11010012 - Strawberry, 11010001 - Beaver Reservoir, 11110103 - Illinois, 08020205 - L'Anguille, 11110105 - Poteau, and 08040203 - Upper Saline. Three, or 43%, of tier 1 HUC-8s identified in this study, overlap the 2014 priority HUC-8s (11110203 – Lake Conway-Point Remove, 11110103 – Illinois, and 08020205 – L'Anguille). Three 2014 priority HUC-8s (HUC-8s were 08040205 – Bayou Bartholomew, 08020302 – Cache River, and 11010012 – Strawberry) were identified in the data analysis for nutrient reduction need, but were not eligible for Tier 1 based on data limitations. These HUC-8s were assigned to Tier 2 as priorities for monitoring program investments for future ANRS updates. Three 2014 priority HUC-8s (08040201 – Lower Ouachita-Smackover, 11010001 – Beaver Reservoir, and 11110105 – Poteau) were fully assessed in the data analysis and were assigned Tier 2 focus status based on nutrient reduction need, but short of criteria qualifying for Tier 1. In contrast, 08040203 – Upper Saline was assigned to Tier 4, least focus status. Neither TN nor TP screening levels in the Upper Saline were greater than screening thresholds, while trend analysis suggested that the 75th percentiles of site median concentrations were decreasing for both nutrients.



2a – Max nutrient reduction need, enhanced data needed

- 08020203 – Lower St. Francis
- 08040205 – Bayou Bartholomew
- 11070208 – Elk
- 11140201 – McKinney-Posten Bayous
- 11140205 – Bodcau Bayou
- 11140302 – Lower Sulpher

2b – Nutrient reduction need, sufficient data

- 08040201- Lower Ouachita – Smackover
- 11010001 – Beaver Reservoir
- 11010010 - Spring
- 11110105 – Poteau

2c – Nutrient reduction need, enhanced data needed

- 08020204 – Little River Ditches
- 08020302 – Cache
- 11010006 – North Fork White
- 11010012 - Strawberry
- 11110202 – Dardanelle Reservoir

2d – Partner priority, baseline data needed

- 08020303 - Lower White
- 08020304 – Big
- 08020401 – Lower Arkansas
- 08050001 – Boeuf
- 08050002 – Bayou Macon
- 11010013 – Upper White-Village
- 11070206 – Lake O' The Cherokees
- 11070209 – Lower Neosho

Figure 7. Tier 2 HUC8s grouped by four subcategories that summarize the level of nutrient reduction need suggested by the data analysis, data availability, and partner priority status.

Trend analysis on sites in focus watersheds

Site-level TN and TP trend analysis results show that sites with increasing TN concentrations are clustered in a band across northern Arkansas, while increasing TP concentrations are more diversely spread across the state (Figure 8A-B; Table S6-7). Site-level results were largely in-line with HUC-level findings for trend in 75th percentiles of site median total nutrient concentrations (Table 3). Increasing nutrient concentrations, which were detected for only one nutrient-HUC combination in the HUC-level analysis, were also the least common result at the site-level, representing just 12 – 21% of 42 qualifying sites. Nutrient concentrations that were decreasing or not changing were far more commonly detected. For TN, decreasing trend was identified for 43% of sites; static concentrations for 31%. Trend results suggesting decreasing or static TP concentrations both comprised 43% of sites.

Table 3. Summary of trend analysis results, as percentage of sites with decreasing, increasing, or not changing TN and TP concentrations, for sites in HUC-8s that were flagged for a nutrient reduction focus for one or more component (trend or magnitude for TN or TP) of the overall categorization framework.

				Trend		
HUC-8	Name	Site count	Nutrient	Decreasing	Increasing	Not changing
08020205	L'Anguille	3	TN	67	0	33
			TP	0	33	67
08020402	Bayou Meto	4	TN	75	0	25
			TP	50	0	50
11010003	Bull Shoals Lake	7	TN	0	71	29
			TP	14	29	57
11010004	Middle White	4	TN	0	25	75
			TP	50	0	50
11110103	Illinois	9	TN	44	33	22
			TP	67	11	22
11110203	Lake Conway – Point Remove	9	TN	44	0	33
			TP	33	11	44
11110207	Lower Arkansas – Maumelle	7	TN	71	0	29
			TP	71	0	29

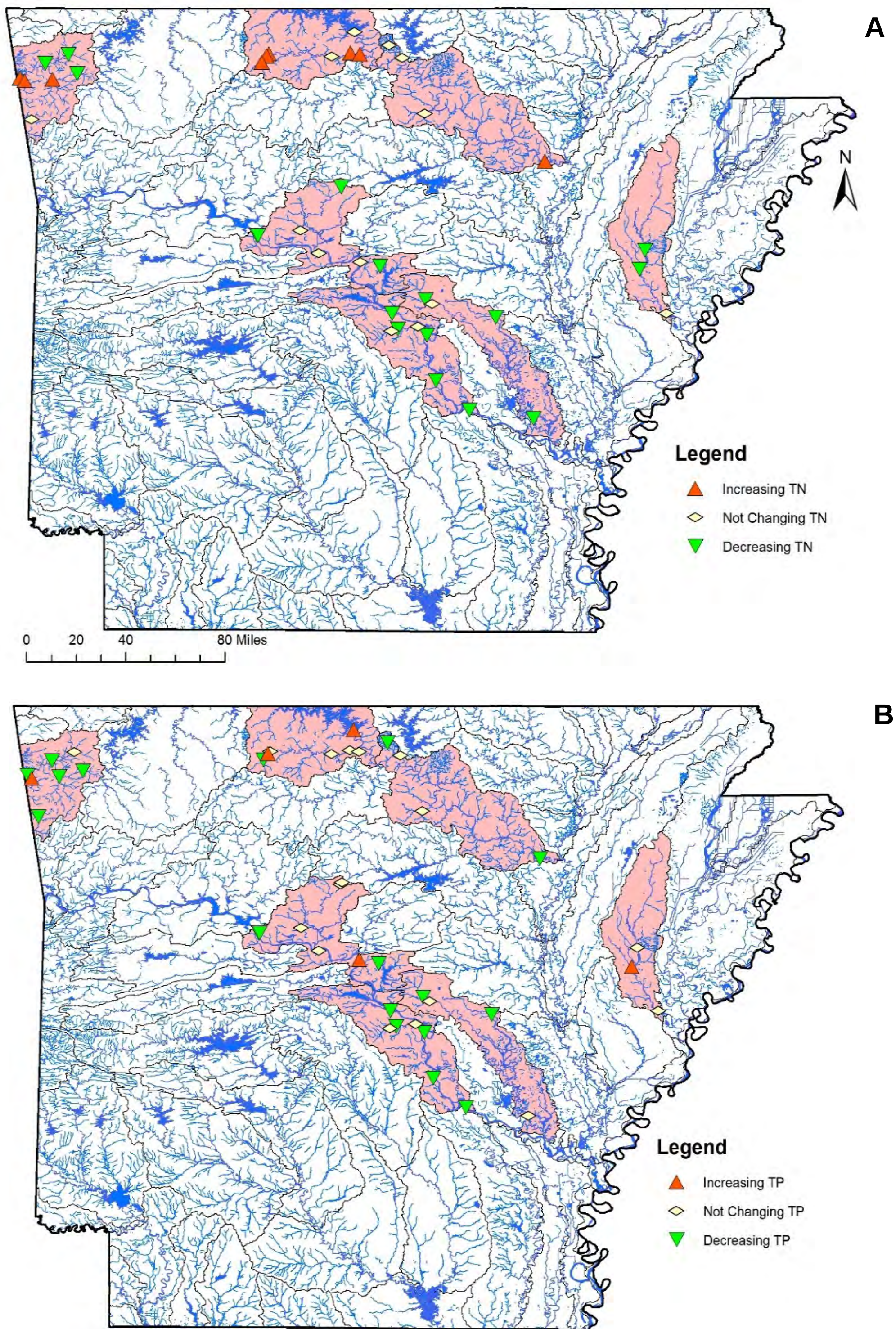


Figure 8. Site-level trend analysis results on A) TN and B) TP concentrations for qualifying sites located in HUC-8s flagged for a nutrient reduction focus for at least one component (trend or magnitude, TN or TP) of the overall prioritization framework.

Agreement between site- and HUC-level analysis was also typical for individual HUC-8s, with limited exceptions. Most notably, trend analysis suggested TN concentrations were increasing at 71% of sites within 11010003 - Bull Shoals Lake, in contrast to the HUC-level finding that TN concentrations were not changing. For TP, no change was detected for 44% of sites in 11110203 - Lake Conway-Point Remove, but HUC-8 level analysis suggested decreasing TP concentrations. Conversely, HUC-level trend analysis suggested no change in 11110103 – Illinois TN concentrations, but the most frequent site-specific result suggested decreasing trends (44 – 100%).

Conclusions

This project presents an approach to identify watersheds with the greatest nutrient reduction need at a statewide scale. Key findings of component assessments of the overall framework included regional gradients in HUC-8 75th percentiles of site median total nutrient concentrations, broadly decreasing nutrient trends and near statewide absence of increasing trends, clustering of increasing TN concentrations at sites in northern Arkansas, and spatial gaps in the State's ambient water quality monitoring program that prevented approximately one-third of HUC-8s from qualifying for any component of the data analysis.

The prioritization framework targeted HUC-8s with the greatest nutrient reduction need demonstrated in the data analysis for maximum focus in Tier 1 under the ANRS. These criteria identified seven HUC-8s:

- 08020205 – L'Anguille
- 08020402 – Bayou Meto
- 11010003 – Bull Shoals Lake
- 11010004 – Middle White
- 11110103 – Illinois
- 11110203 - Lake Conway-Point Remove
- 11110207 – Lower Arkansas-Maumelle

Most of these watersheds had other substantiating factors for prioritization, including nutrient levels that were not changing at the HUC-8 level (11010004 - Middle White, 11010004 - Bull Shoals Lake, and 11110103 -

Illinois), a majority of sites with increasing nutrients (11010004 - Bull Shoals Lake), MRBI priority watershed (08020205 - L'Anguille, 08020402 - Bayou Meto) or Nutrient Surplus Area (11010003 Bull Shoals Lake and 11110103 - Illinois) designation, or qualitative selection for prioritization under the 2014 ANRS (08020205 - L'Anguille, 11110103 – Illinois, 11110203 - Lake Conway-Point Remove).

The framework also honed in on HUC-8s with demonstrated nutrient reduction need based on less selective requirements, with data limitations, or both, for Tier 2. A total of 23 HUC-8s were assigned to Tier 2 focus status, with emphasis under the ANRS on future monitoring program investments to support assessment as part of future ANRS updates. Of HUC-8s not assigned to Tier 1 or Tier 2 focus status, 23 were categorized as data-limited and assigned to Tier 3, while only five were categorized as data-sufficient and assigned to Tier 4.

REFERENCES

AR Code § 15-20-1104. 2019.

Arkansas National Resources Commission. 2014. Arkansas Nutrient Reduction Strategy. Natural Resources Division, Little Rock, AR.

Diaz, R.J. and R. Rosenberg. 2008. Spreading dead zones and consequences for marine ecosystems. Science, 32: 926-929.

Dodds, W.K. 2006. Nutrients and the “Dead Zone”: the link between nutrient ratios and dissolved oxygen in the Northern Gulf of Mexico. FronTiers in Ecology and the Environment, 4: 211-217.

Fennel, K. and A. Laurent. 2017. N and P as ultimate and proximate limiting nutrients in the northern Gulf of Mexico: implications for hypoxia reduction strategies. Biogeosciences, 15:3121-3131.

Grolemund, G and H. Wickham (2011). Dates and Times Made Easy with lubridate. Journal of Statistical Software, 40(3), 1-25. URL http://www.jstatsoft.org/v40/i03.

Justić, D., N.N. Rabalais, and R.E. Turner. 1995. Stoichiometric nutrient balance and origin of coastal eutrophication

Marchetto, A. 2017. rkt: Mann Kendall Test, Seasonal and Regional Kendall Tests. R package version 1.5. https://CRAN.R-project.org/package=rkt

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. 2008. Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin. Washington, DC.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers, 77: 118-125.

Rabalais, N.N., R.E. Turner, Q. Dortch, D. Justic, V.J. Bierman, Jr., and W.J. Wiseman, Jr. 2002. Nutrient-enhanced productivity in the norther Gulf of Mexico, past, present, and future. Hydrobiologia, 475/476: 39-63.

Rabalais, N.N., R.E. Turner, B.K. Sen Gupta, and D.F. Boesch. 2007. Hypoxia in the northern Gulf of Mexico: does the science support the plan to reduce, mitigate, and control hypoxia? Estuaries and Coasts, 30: 753-772.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Turner R.E. and N.N. Rabalais. 1991. Changes in Mississippi River water quality this century: implications for coastal food webs. Bioscience, 41: 140-147.

Turner, R.E. and N.N. Rabalais. 2013. N and P phytoplankton growth limitation, northern Gulf of Mexico. Aquatic Microbial Ecology, 68: 159-169.

Wickham, et al. 2019. Welcome to the tidyverse. Journal of Open Source Software, https://doi.org/10.21105/joss.01686.

Appendix B. Stakeholder Comments and Natural Resources Division Response

Introduction

The Arkansas Nutrient Reduction Strategy (ANRS) was developed with the help of the coordination team and identified stakeholders. It was a long process that culminated with a presentation of a draft version of the ANRS to stakeholders. Hundreds of identified stakeholders were invited to the meeting. A total of 75 attended the online video conference meeting on March 2, 2022. Stakeholders were asked to review the draft ANRS and send comments by March 28, 2022. Eight stakeholders submitted written comments. Comments of similar categories were grouped together with broad categories of challenges to water quality analysis, specific geographic interest areas, regulations and enforcement, and recommendations. While some simple edits were found and commented on, they were simply incorporated into the final document. Please note some comments are verbatim, while other comments have been summarized to address effectively. This is a summary of general comments and actions to those stakeholder comments. All stakeholder comments are available on NRD's website.

Comments were submitted by:

University of Arkansas Division of Agriculture
US Department of Agriculture Natural Resources Conservation Service
Arkansas Ozark Waterkeeper and Buffalo River Watershed Alliance
Ozark Society
Kings River Watershed Partnership
Arkansas State University
Glenda Allison

Comments and Actions

Comments regarding challenges to water quality analysis and prioritization (Appendix A)

Several commenters identified limitations to the prioritization approach, specifically: 1) the nonuniform spatial and temporal availability of ambient water quality data across all watersheds; 2) prioritizing watersheds based only when data are available; 3) elevating watersheds with existing federal water quality initiative programs to Tier 1 even without the presence of sufficient data; 4) no consideration for other water quality parameters outside of nutrients (i.e. sediment/turbidity); 5) when water quality data are unavailable utilizing land use alteration patterns as a method to proactively address nutrient increases without water quality data; 6) clarification on data requirements needed for statistical evaluation and data requirements needed for Tier 1; and 7) use of median concentration to evaluate nutrient trends.

Response: NRD agrees that there were limitations to the Water Quality Analysis, specifically regarding data availability across all HUC 8 watersheds. The goal of the analysis was to identify HUC 8 watersheds in Arkansas where nutrient concentrations are the greatest using measured in-stream data, not models such as SWAT. It was originally assumed that (increasing) trend would be a primary component for watershed identification, but the process was adaptive once trend analyses were complete. Other processes, e.g. the nonpoint source risk matrix, is an already established process that accounts for multiple water quality threats like sediment and other pollutants.

The Natural Resources Division chose to limit the number of Tier 1 HUC 8s due to resource constraints of investing in nutrient reduction in more watersheds. Thus, the high standard of signals of concern for both TN and TP that were well-documented by data was applied to delineate Tier 1. Data considerations and needs to elevate or deprioritize are provided in Appendix 1.

The Natural Resources Division also chose to focus on measured concentrations, not estimated loads. It is difficult to demonstrate progress on loads due to the inter-annual to decadal variability in streamflow. The nutrient concentration component of loads is what the State's mitigation activities will directly affect, whereas the hydrologic component of loads is climate driven.

Comments on specific geographic areas

Several commenters identified the US Forest Service Robert's Gap Project and its potential to affect stream corridors and erosion.

One commenter specifically advocated for the addition of the Buffalo River Watershed as a Tier 1.
Two commenters identified the Kings River Watershed and specific issues with nutrient related issues of NPDES permitted facilities and nutrient management plans. Additional sediment issues of streambank erosion and stormwater runoff were also identified.

Response: Natural Resources Division appreciates commenter's interest in these specific geographic regions. Regarding the Buffalo River, the current Buffalo River Watershed Management Plan and the Regional Conservation Partnership Program through NRCS are working with local agricultural producers to implement voluntary conservation measures. Data considerations as to why it was not included as a Tier are addressed above. The US Forest Service Robert's Gap project is outside the scope of the ANRS and Natural Resources Division's statutory authority and any comments should be submitted to the US Forest Service.

Comments regarding regulations or enforcement

Several commenters identified Nutrient Surplus Area and nutrient management plans as effective tools for improving water quality. One commenter questioned the compliance and enforcement components of nutrient management in Arkansas. The commenter further expanded on expansion of litter application reporting outside of Nutrient Surplus Areas. A commenter suggested adding regulations to prevent loss of riparian corridors to the ANRS. A separate commentor suggested that the ANRS continue to be based primarily on voluntary efforts, existing regulations non withstanding, and not new regulations as we feel voluntary approaches is a superior approach to addressing non-point source pollution.

Response: Internally, the NRD Water Quality Section (Nonpoint Source Program and the ANRS) works closely with our Conservation Section that manages the Nutrient Management Program and is responsible for Nutrient Surplus Areas, development of nutrient management plans, and nutrient management applicator certification. It's widely agreed that nutrient management plans do prevent excessive application of nutrients. The use of nutrient management plans outside of the Nutrient Surplus Area are voluntary, and many poultry integrators do require growers to establish plans. We acknowledge the ANRS is primarily comprised of voluntary approaches, and NRD will continue to work with partners to implement voluntary conservation measures.

Comments or recommendations to improve or alter the ANRS

One commenter suggested utilizing land use and land cover data and changes in patterns to better inform watershed prioritization for the implementation of conservation measures regarding the expansion of poultry litter application. Further, this commenter included recommendations for the prioritization of voluntary conservation measures, including training and research needs in areas of expanding poultry farm growth. One commenter provided a recommendation of utilizing the Arkansas Conservation Partnership as a mechanism to help promote and implement the ANRS.

A commenter suggested increased funding towards research and development of a research subcommittee to foster development of additional needs in the ANRS. Specifically, the University of Arkansas Division of Agriculture was named as having staffing expertise and capacity to facilitate additional research in Tier 1 watersheds.

It was suggested that a weighted metric approach be utilized for establishing priority watersheds and identified the nonpoint source risk matrix as an example.

Response: Natural Resources Division fully recognizes data quantity limitations for many HUC 8 watersheds. Over the next two years we will work to increase water quality monitoring in Tier 2 watersheds to help inform decisions and actions on prioritization. Additionally, we will be working with the ANRS Coordination Team to review land use and land cover disturbance thresholds that may significantly alter nutrient concentrations. Other related nutrient disturbance metrics for will also be reviewed for watershed prioritization.