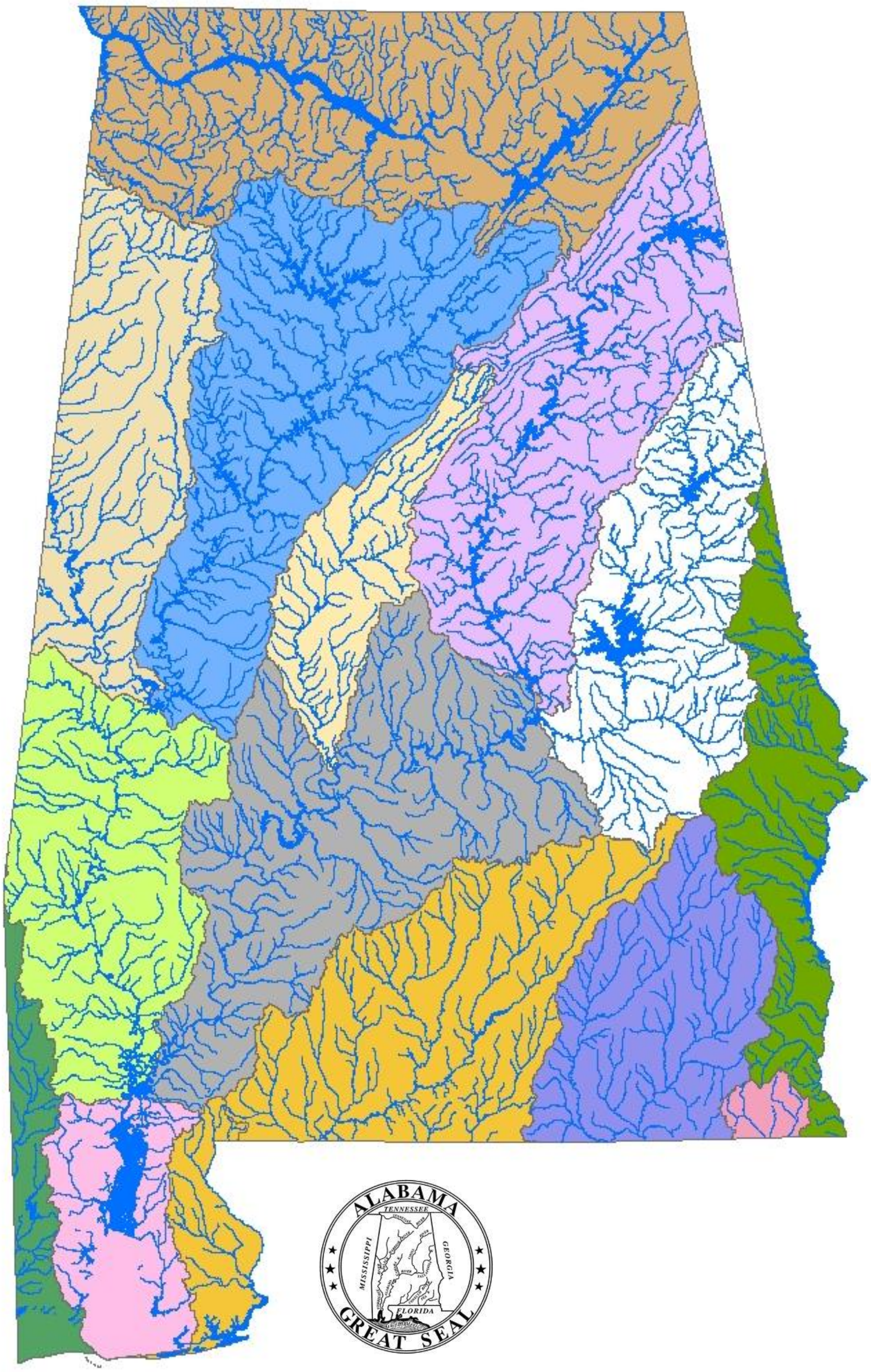
State of Alabama
Water Quality Monitoring Strategy



Alabama Department of Environmental Management
August 2025

State of Alabama

Water Quality Monitoring Strategy

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List of Acronyms

2B-TMB	2 Bank Transitional Macroinvertebrate Biological Survey
ABD	Assessment Database
ACNPCP	Alabama Coastal NonPoint Pollution Control Program
ADAI	Alabama Department of Agriculture and Industry
ADCNR	Alabama Department of Conservation and Natural Resources
ADECA	Alabama Department of Economic and Community Affairs
ADEM	Alabama Department of Environmental Management
ADPH	Alabama Department of Public Health
AEMA	Alabama Environmental Management Act
AFC	Alabama Forestry Commission
AFO	Animal Feeding Operation
AGPT	Algal Growth Potential Test
ALAMAP	Alabama Monitoring and Assessment Program
ALAWADR	Alabama Water Quality Assessment and Monitoring Data Repository
ALM	Alabama's Assessment and Listing Methodology
ASMC	Alabama Surface Mining Commission
ASSESS	ADEM Strategy for Sampling Environmental Indicators of Surface Water Quality Status
ATTAINS	Assessment and Total Maximum Daily Load Tracking and Implementation System
AU	Assessment Unit
AWIC	Alabama Water Improvement Commission
AWPCA	Alabama Water Pollution Control Act
BCG	Biological Condition Gradient
Bio-DEVAS	Biological Data Evaluation and Assessment
BioWADR	Biological Water Quality Assessment and Monitoring Data Repository
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CBI	Compliance Bioassay Inspection
CDC	Centers for Disease Control
CER	Critical Elements Review
COVID	Corona Virus Disease

LIST OF ACRONYMS (CONTINUED)

CSGWPP	Core Comprehensive State Ground Water Protection Program
CSI	Compliance Sampling Inspection
CWA	Clean Water Act
CWMP	Coastal Waters Monitoring Program
DEVAS	Data Evaluation and Assessment
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EABT	Even Annual Basin Target
EAST	Even Annual Statewide Target
EIS	Environmental Indicators Section
EPA	United States Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FDA	Food and Drug Administration
FHMU	Flowing Headwaters Monitoring Unit
FOD	Field Operations Division
FTE	Full-Time Equivalent
FTMP	Fish Tissue Monitoring Program
F&W	Fish & Wildlife water use classification
GAP	Groundwater Assessment Program
GIS	Geographic Information System
GSA	Geological Survey of Alabama
GWPAC	Ground Water Programs Advisory Committee
HGM	Hydrogeomorphic
HQ	EPA Headquarters
HUC	Hydrologic Unit Code
HWP	Healthy Watersheds Program
IBI	Index of Biotic Integrity
IS	Information Systems Branch
IWQMAR	Integrated Water Quality Monitoring and Assessment Report
LIMS	Laboratory Information Management System
LL Hg	Low-Level Mercury

List of Acronyms (continued)

LOQAM	Laboratory Operations and Quality Assurance Manual
LQAO	Laboratory Quality Assurance Officer
MDL	Minimum Detection Limit
MGY	Field Operations—Montgomery Branch
MU	Monitoring Unit
NCA	National Coastal Assessment
NEP	National Estuary Program
NLCD	National Land Cover Dataset
NPDES	National Pollution Discharge Elimination System
NPS	Non-Point Source
NRCS	National Resource Conservation Service
NW	Nonwadeable
NWB	Nonwadeable Boat sampling protocol
NWFMU	Nonwadeable, Flowing River Monitoring Unit
NWG-D	Nonwadeable Grab—Deep sampling protocol
NWG-S	Nonwadeable Grab—Shallow sampling protocol
NWI	National Wetland Inventory
NWQI	National Water Quality Initiative
NWQMC	National Water Quality Monitoring Council
OAW	Outstanding Alabama Water water use classification
OEO	Office of Education and Outreach
OEQ	Office of Environmental Quality
OWR	Office of Water Resources
PCB	Polychlorinated biphenyl
PHWA	Preliminary Healthy Watersheds Assessment
PortaWADR	Portable Alabama Water Quality Assessment and Monitoring Data Repository
PWS	Public Water Supply water use classification
QA	Quality Assurance
QC	Quality Control
QAM	Quality Assurance Manager

LIST OF ACRONYMS (CONTINUED)

QAPP	Quality Assurance Project Plan
QMP	Quality Management Plan
RAM	Rapid Assessment Methodology
RL	Reporting Limit
RPS	Recovery Potential Screening
RRMP	Rivers and Reservoirs Monitoring Program
RSMP	Rivers and Streams Monitoring Program
SHU	Strategic Habitat Unit
SID	State Indirect Discharge
SOP	Standard Operating Procedure
SPCC	Spill Prevention Control and Countermeasure
STORET	Storage and Retrieval Database
SWAP	State Wildlife Action Plan
SWQM	Surface Water Quality Monitoring
SWQMP	Surface Water Quality Monitoring Plan
TBD	To Be Determined
TMB	Transitional Macroinvertebrate Biological Survey
TMDL	Total Maximum Daily Load
TN	Tennessee
TSI	Trophic State Index
TVA	Tennessee Valley Authority
UIC	Underground Injection Control
USACOE	United States Army Corp of Engineers
USGS	United States Geological Survey
W-BIO	Wadeable—Biological sampling protocol
WCG	Watershed Condition Gradient
WD	Water Division
WDG	Watershed Disturbance Gradient
WFMU	Wadeable Flowing Monitoring Unit
WLA	Waste Load Allocation
WLMU	Wetland Monitoring Unit

LIST OF ACRONYMS (CONTINUED)

WMB	Wadeable Macroinvertebrate Biological Survey
WMP	Watershed Management Plan
WMP	Wetlands Monitoring Program
WQB	Water Quality Branch
WQS	Water Quality Standard
WQX	Water Quality Exchange
WRAP	Wetland Rapid Assessment Protocol
W-WQS	Wadeable Water Quality sampling protocol
XML	Extensible Markup Language

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INTRODUCTION

In 2003, the U.S. Environmental Protection Agency (EPA) released *Elements of a State Water Monitoring and Assessment Program* (EPA 2003). The purpose of this document was to outline basic recommended components for monitoring programs performed by states receiving Clean Water Act (CWA) §106 funds. States are required to develop a formal written monitoring strategy that addresses ten broad categories: Monitoring Strategy, Objectives, Design, Water Quality Indicators, Quality Assurance, Data Management, Data Analysis and Assessment, Reporting, Programmatic Evaluation, and Support Planning. Each state's monitoring strategy document should describe how the state is currently incorporating the "Ten Elements" recommendations in their monitoring programs, identify elements not sufficiently addressed, and outline a 10-year timeline for full implementation of these missing elements. The desired effect of the "Ten Elements" is the development and implementation of more comprehensive monitoring strategies by each state and enhanced comparability of data and assessments on a national scale.

In the following document, the Alabama Department of Environmental Management (ADEM) presents an overview of how its monitoring programs will address the "Ten Elements" recommendations, 2024-2030. These are presented in Sections I-X. Section XI provides a timeline of relevant past, current, and future monitoring activities and the date, or projected date, of incorporation into monitoring programs. Section XII provides a summary of the "Ten Elements" information for each of ADEM's individual monitoring programs.

The first ADEM monitoring strategy was developed in 1997. Originally entitled 'The ADEM Strategy for Sampling Environmental Indicators of Surface Water Quality Status' or '*ASSESS*', the strategy was implemented on a 5-year rotation cycle. An integral part of *ASSESS* was a thorough review of the Strategy at the end of each monitoring cycle. As part of the ADEM Monitoring Strategy review process, personnel from the Field Operations Division (FOD), Water Division (WD), and Office of Education and Outreach (OEO) met in 2004 to review results from the first 5-year monitoring cycle. The purpose of the 2004 meeting was to conduct a comprehensive review of the ADEM surface water quality monitoring programs, to include identification of data needs not met by *ASSESS,* and to discuss potential changes to the monitoring design that could address these needs. Based on the identified needs and recommendations, the Monitoring Strategy was revised, updated, and implemented in 2005. A second comprehensive review, revision, and update was completed in 2011-2012, having been delayed one year by extensive tasks required by the Deepwater Horizon oil spill to the Gulf of Mexico in 2010.

The 2015 Monitoring Strategy was the next step in an ongoing, iterative planning process. The Strategy set forth a 5-year plan to address the “Ten Elements” and was based on the in-depth review of the 2005-2014 dataset completed by ADEM, 2014-2015. This strategy document continued to build on existing monitoring capabilities and to progress towards addressing all state waters over time. ADEM viewed each 5-year Monitoring Strategy as an opportunity for long-term planning. Therefore, a discussion of future initiatives and a timeline were included to address incremental improvements necessary to incorporate requirements outlined in the “Ten Elements” document and to satisfy monitoring goals and requirements pursuant to the Alabama Water Pollution Control Act (AWPCA), the Alabama Environmental Management Act (AEMA), and the federal Clean Water Act (CWA).

A status review of ADEM water quality monitoring programs was conducted in 2019, but the Monitoring Strategy update was delayed by the 2020 COVID pandemic, the loss of experienced personnel, and other related complications. In 2023-2024, the status review was repeated and updated, culminating in this 2025 State of Alabama Water Quality Monitoring Strategy. This Strategy sets forth a 6-year plan to address the “Ten Elements” and will continue to build on existing monitoring capabilities and progress towards addressing all state waters over time. **This Strategy contains additional detail necessary to document changes in programs and procedures in recent years, so that this information will not be lost as personnel transition into retirement.**

I. MONITORING PROGRAM STRATEGY

ADEM has maintained a surface water quality monitoring program since 1974, but it did not develop a coordinated monitoring strategy until 1997 when the *ASSESS* document was published. This ASSESS document was developed in an effort to focus and document the Department's surface water quality monitoring mission. The strategy was updated in 2005 using the 2003 EPA *Elements of a State Water Monitoring and Assessment Program* as the basic framework. The 2005 Strategy outlined quality assurance plans, data management, data analysis, reporting, program review, and overall resource needs. The objectives and design of the Strategy were summarized in the Monitoring Objectives and Monitoring Design sections of the document.

ADEM's 2005 Monitoring Strategy was a coordinated monitoring approach designed to characterize water quality, to identify impacts from a variety of sources, and to provide a systematic and integrated framework for gathering necessary information to support the ADEM decision-making processes. The Strategy was comprised of four programs defined by wadeability and waterbody type:

- the Rivers and Streams Monitoring Program (RSMP)—wadeable rivers and streams
- the Rivers and Reservoirs Monitoring Program (RRMP)—nonwadeable rivers and reservoirs,
- the Coastal Waters Monitoring Program (CWMP)—coastal waters
- the Wetlands Monitoring Program (WMP)—wetlands

Each program incorporated specific protocols and methodologies to ensure that monitoring activities provided the highest quality information and made the most efficient use of available resources. To the extent possible, the protocols and methods used in each program corresponded with the minimum data requirements for each waterbody type in Alabama's Water Quality Assessment and Listing Methodology (ALM). The overall strategy was implemented on a 5-year rotation by basin and incorporated a combination of targeted, probabilistic, and long-term monitoring stations to meet state monitoring goals and objectives. Concentrating monitoring in one basin group enabled ADEM to identify opportunities to meet multiple monitoring objectives at a single site, increasing overall efficiency. It also created a comprehensive dataset to develop the criteria and indicators needed to meet other ADEM objectives. This approach was continued in the 2012 Monitoring Strategy, providing statewide data from two full monitoring cycles.

ADEM began development of the 2015 Monitoring Strategy in 2014, starting with a comprehensive review of the 2005 and 2012 Strategies. The review was conducted by personnel from the FOD, WD, the Nonpoint Source Unit (NPS), and the Office of Environmental Quality (OEQ) to ensure that the Strategy met overall monitoring objectives, as well as the objectives of the assessment/§303(d) listing, Total Maximum Daily Load (TMDL), and Non-Point Source (NPS) programs (Figure 1). This group effort also served to identify the Department's 2015-2019 monitoring priorities and to revise the Strategy as needed to meet these new priorities. Concurrently, the Assessment/§303(d), TMDL, and NPS groups were undergoing internal reviews to identify priorities for their programs. The ADEM used these individual reviews as an opportunity to improve coordination among these programs in order to better facilitate assessment and restoration efforts. Priorities identified by the Department during this process included monitoring impaired, unimpaired, and unassessed waters, evaluating the effectiveness of restoration efforts, and collaborating with partner agencies and stakeholders when possible.

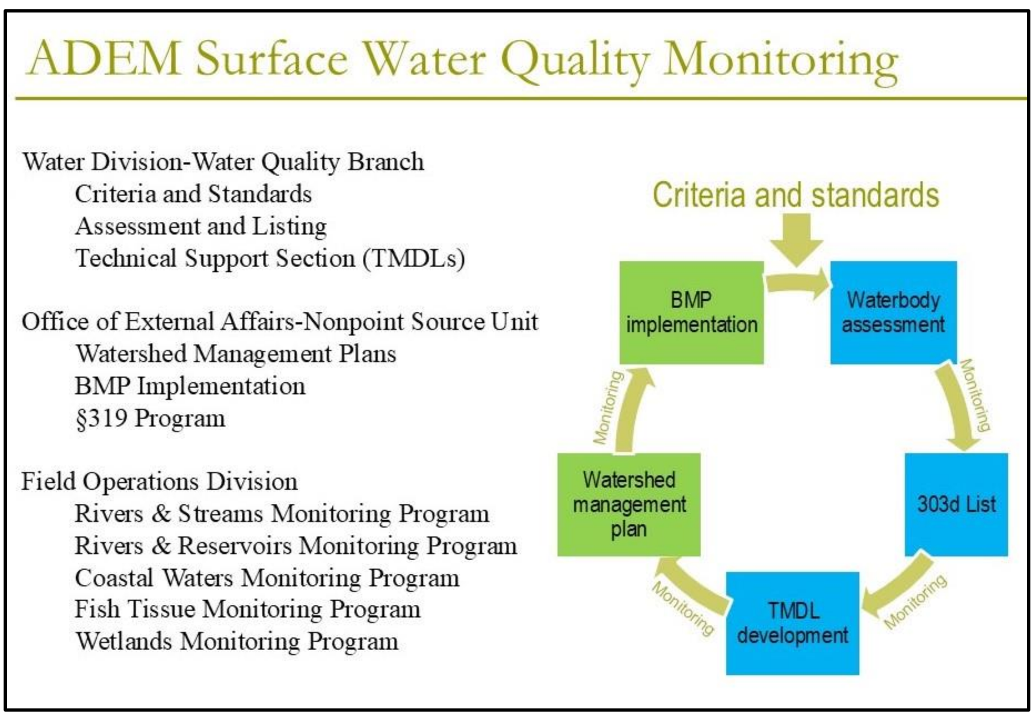

Figure 1. ADEM's water quality monitoring.

A status review of ADEM water quality monitoring programs was conducted again in 2019, but the Monitoring Strategy update was delayed by the 2020 COVID pandemic, the loss of experienced personnel, and other related complications. The review was conducted by personnel from the FOD, WD, NPS, and OEQ to ensure that the Strategy met overall monitoring objectives, as well as the objectives of the assessment/§303(d) listing, TMDL, NPS, and quality assurance programs. In 2023, the status review was repeated and updated, culminating in this 2025 State of Alabama Water Quality Monitoring Strategy. This Strategy sets forth a 6-year plan to address the "Ten Elements" and will continue to build on existing monitoring capabilities and progress towards addressing all state waters over time. ADEM views this Monitoring Strategy as an opportunity for long-term planning. Therefore, a discussion of future initiatives and a timeline were included to address incremental improvements necessary to incorporate requirements outlined in the "Ten Elements" document and to satisfy monitoring goals and requirements pursuant to the Alabama Water Pollution Control Act (AWPCA), the Alabama Environmental Management Act (AEMA), and the federal Clean Water Act (CWA). The ADEM 2024-2030 monitoring priorities are described more fully in Section II—Monitoring Objectives.

II. MONITORING OBJECTIVES

The objectives of ADEM's Monitoring Strategy are consistent with the federal Clean Water Act (CWA), as well as Alabama's statutory and regulatory monitoring requirements and data needs. They are applicable to all waters of the State, including wadeable rivers and streams, nonwadeable rivers, reservoirs/lakes, embayments, estuaries, coastal waters, wetlands, and groundwater. ADEM's Monitoring Strategy is designed to meet seven broad CWA objectives in all State waters over time:

1. Establish, review, and revise water quality standards
2. Determine water quality standards attainment
3. Identify high quality waters
4. Identify impaired waters
5. Estimate overall water quality
6. Identify causes and sources of impairment
7. Evaluate program effectiveness and trends in biological, chemical, and physical conditions

Over the last two decades, ADEM has concentrated on developing and implementing its CWMP, RRMP, RSMP, WMP, and FTMP to meet these objectives. These efforts have resulted in highly effective programs providing data of the highest quality in support of management decisions for various programs. A 2019 Critical Elements Review (CER) of the RSMP and RRMP categorized the programs to be of the highest level of technical rigor, able to detect incremental changes in biological, chemical, and physical conditions along a gradient of stress and to associate biological response to stressors and their sources (Yoder 2019). The programmatic levels reflect sequential stages in technical development of a monitoring program and are intended as a guide for assessing progress and targeting resources. For programs like the RSMP and RRMP at the highest level of technical rigor, the focus is on program maintenance and the incorporation of new advances in science and technology in order to continue to improve the program (USEPA 2013).

The CER had four primary recommendations for improving ADEM's monitoring programs over the next four 3-year cycles. Two additional recommendations were identified based on internal evaluation of ADEM's Monitoring Strategy. They are as follows:

1. *Continue to analyze existing datasets to relate biological response to stressors for development of biological indices and numeric criteria*. The RSMP has developed a long-term, comprehensive dataset of intensive biological, chemical, and physical data collected over a range of watershed conditions to develop indicators and criteria. Developing relationships between key chemical/physical and other common stressors and biological indices improves stressor identification and the causal analysis process. Biological response signatures for diatoms and macroinvertebrates to nutrients (total phosphorus and total nitrogen) have identified both diatom and macroinvertebrate community attributes that respond to nutrient enrichment (for development of nutrient-specific metrics), as well as the nutrient concentrations at which these attributes respond (for development of numeric nutrient criteria). Biological response signatures (macroinvertebrates, fish, diatoms) to other core parameters need to be completed to continue development of stressor-specific metrics and numeric criteria.
2. *Continue development, analysis, and implementation of supplemental indicators to monitor potential and known causes of impairment*. Supplemental indicators are developed to detect stresses that are not core indicators collected during routine monitoring and/or to measure stresses that are not detected through routine monitoring. An example of this would be siltation/habitat degradation that causes impairment to the biological community but does not increase turbidity or median total suspended solid concentrations in water quality samples collected monthly. Rain-event sampling to measure flow and turbidity and to collect total suspended solids during high flows can be used to document and measure the cause of impairment, to develop a restoration plan to address the issue, and to evaluate program effectiveness after the plan has been implemented.
3. *Develop monitoring methods and strategies for headwaters, nonwadeable streams, and large rivers*. Restricting the size of waterbodies monitored enabled the RSMP to develop into a monitoring program of the highest level of technical rigor within 10-15 years, despite limited resources. However, this approach has also limited the number of river miles assessed. In comparison to the RRMP and the CWMP, which have assessed 89% of Alabama's reservoirs/lakes and embayments and 83% of its estuaries, bays, and ocean waters, respectively, only 26% of Alabama's 59,000 perennial stream and river miles have been assessed, with 74% not assigned an assessment unit (ADEM 2024b). Incorporating

perennial, flowing headwaters, nonwadeable streams, and large rivers to collect core biological, chemical, and physical data are primary objectives of the RSMP and RRMP. These datasets will allow for the development of habitat and biological indices and ecoregional reference reach guidelines within the next 6-12 years.

These efforts will provide the data necessary to develop Biological Condition Gradient (BCG) indices to implement Alabama's narrative aquatic life use criteria. Development of BCG indices for Alabama's wadeable, flowing rivers and streams has provided indices that consistently define biological condition throughout the State, effectively communicate true biological condition and opportunities for protection and restoration, and support achievable goals and incremental progress towards those goals. The distinct BCG levels can be meaningfully applied to Alabama's water use classifications. This approach has the potential to provide a consistent definition of "balanced, indigenous population" of shellfish, fish, and wildlife for CWA 316(a) studies currently defined and conducted independently by power plants in order to ensure that these conditions are maintained below their heated water discharges.

4. *Conduct both macroinvertebrate and fish community surveys at all flowing waterbodies to fully assess biological, chemical, and physical conditions.* In wadeable streams and rivers, ADEM uses biological survey results to assess impacts of nutrients, siltation/habitat alteration, and multiple other parameters without established numerical criteria. Conducting both macroinvertebrate and fish surveys to assess each perennial, flowing stream and river station is strongly recommended because these communities are sensitive to different types of stressors, and the use of multiple communities to assess a waterbody provides greater confidence that the impact(s) from stressor(s) to aquatic communities will be detected (USEPA 2013). However, this is not an attainable goal for the ADEM Monitoring Strategy at this stage of its development. At current resource levels established in 2003, ADEM only completes both types of surveys at 7-11% of its wadeable monitoring sites annually.
5. *Develop biological indices for wadeable rivers and streams for multiple sampling periods.* The ADEM biological surveys received high marks for its well-defined sampling periods and site classifications and its integration and use in CWA programs, including permitting, assessment, trends analysis, etc. However, again, to make the most of limited resources,

ADEM has defined different sampling periods for different waterbody types. While this works very well for ADEM for this purpose, it makes it more difficult to fully integrate it into ADEM's CWA programs. To increase flexibility and program integration, the RSMP needs to conduct intensive monitoring in wadeable, flowing river and streams reference reaches, on a small scale, to develop and calibrate biological indices to other sampling periods.

6. *Monitor Category 1 waters on a consistent rotating basis.* There is no current policy guiding the monitoring and assessment of Category 1 waters. In the 2020 Integrated Water Quality Monitoring and Assessment Report (IWQMAR), 59 (21%) of the 283 Category 1 waters had not been sampled since 2011 (outside of the 2020 assessment dataset: 2013-2018); ninety-three (33%) of the Category 1 waters had not been monitored since 2014 (outside of the 2022 assessment dataset) (ADEM 2020a, Huff 2021). In the absence of more recent data, the existing category carries over to the next cycle. Since 2000, there has been a 21% increase in Alabama's statewide population (ADEM 2000, ADEM 2024b) and a 6.2% increase in urban land cover (Dewitz 2000, Dewitz 2021). As areas of high growth and development spread throughout the State, it becomes more vital to monitor Category 1 waters on a consistent and frequent basis.

Additionally, the EPA has acknowledged the need to increase protection of healthy watersheds in "*Coming Together for Clean Water: EPA's Strategy to Protect America's Waters*" (USEPA 2010). The Strategy identified increased focus on the protection of source waters and healthy watersheds as one of the five areas guiding the implementation efforts and actions to meet Strategy Plan objectives. To support protection of high-quality waters via the CWA programs, EPA's §303(d) and §319 programs have adopted policies encouraging states to protect unimpaired high-quality waters. A key element is using scientifically sound monitoring data to identify high-quality waters, like EPA does with its Healthy Watersheds Program. ADEM's biological surveys are especially important in identifying high-quality waters, classifying high-quality waters as *Outstanding Alabama Waters (OAW)*, and fully assessing *OAW* waters because these waterbodies must meet a more stringent aquatic life use criterion than all other use designations.

III. Monitoring Design

The ADEM Monitoring Strategy is a coordinated monitoring approach designed to characterize water quality, to identify impacts from a variety of sources, and to provide a systematic and integrated framework for gathering necessary information to support the ADEM decision-making process. The Strategy is comprised of four programs defined by waterbody type, tidal influence, wadeability, and flow. The monitoring designs used to develop and implement the ADEM CWMP, RRMP, RSMP, and WMP have resulted in very effective programs of the highest technical rigor, providing scientifically sound data in support of management decisions for various programs (Yoder 2019). In general, programs at this stage in their development primarily focus on program maintenance, analyzing existing data to fully develop and implement the most technically advanced objectives of the Strategy, and incorporating new advances in science and technology to continue to improve the program (USEPA 2013).

Since 2005, the ADEM Monitoring Strategy has been designed around six key elements:

1. A monitoring schedule based on a basin rotation
2. Consistent and predictable resource expenditures by each field office and laboratory
3. Watershed-based monitoring and a full inventory of monitoring needs
4. The use of ecoregions to reflect natural and expected conditions
5. A consistent measure of watershed condition
6. Consistent sampling frequency and parameters collected at every monitoring station

Monitoring Schedule

As part of the 2019 programmatic evaluation of the Monitoring Strategy, ADEM adopted a statewide 3-year basin rotation (Figure 2 and Table 1). The rotation concentrates monitoring in the target basins, enabling ADEM to develop a comprehensive dataset for indicator and criteria development basin-by-basin until a statewide dataset is complete. It provides consistent workloads each year for the ADEM field offices and labs, making the most of limited resources and increasing overall program efficiency. A 3-year basin rotation provides two full sets of data for the IWQMAR over the 6-year assessment period, as defined in the ALM.

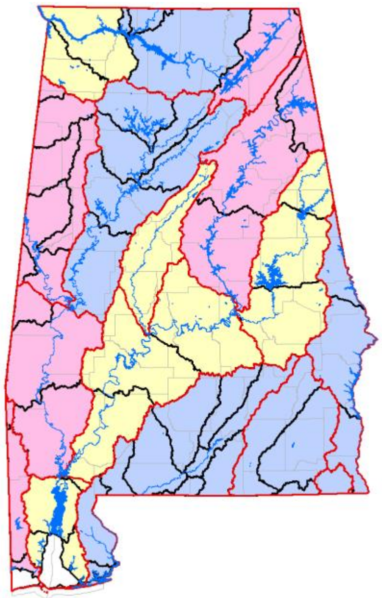

Figure 2. ADEM Monitoring Strategy 3-year basin rotation.

Table 1. ADEM Monitoring Strategy 3-year basin rotation schedule.

Map	Basins	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Yellow	West TN, Cahaba, Tallapoosa, Alabama, Mobile	2020	2023	2026	2029
Blue	Mid-TN, Black Warrior, Southeast AL	2021	2024	2027	2030
Violet	East TN, Coosa, Tombigbee, Escatawpa	2022	2025	2028	2031

Beginning in 2002, ADEM monitored the Tennessee River and reservoirs jointly with the Tennessee Valley Authority (TVA), with TVA monitoring the mainstem stations and ADEM monitoring tributary embayments. In 2020, the RRMP and RSMP adopted the 3-year rotation used by TVA to monitor Tennessee River reservoirs, sampling the east Tennessee basin (Guntersville), the middle Tennessee basin (Wheeler Reservoir), and the west Tennessee basin (Pickwick/Wilson Reservoirs) on a 3-year cycle. This allows for consistent resource expenditures for the Decatur Field Office and the Birmingham Lab throughout the 3-year rotation.

TVA now samples on a 2-year rotation to complete their Tennessee reservoir monitoring cycle. As a result, water quality data for mainstem and embayment stations on the Tennessee River are no longer regularly collected in the same sampling year. In order to ensure that we have accurate, defensible data with which to make assessment decisions on these waterbodies, the RRMP began to incorporate the TVA mainstem stations into the 3-year rotation in 2025. This will ensure that all data for each reservoir is collected concurrently using methods outlined in our standard operating procedures.

The Ambient Monitoring Network, which includes stations sampled as part of the RSMP, RRMP, and CWMP, is a group of statewide monitoring stations monitored regularly to provide data for long-term trend analysis, to develop water quality criteria, standards, and TMDLs, and to monitor water quality conditions at statelines as it enters and exits Alabama. First established in 1974, the trends network has evolved over time, undergoing reviews in 2005, 2015, and 2021.

During the 2021 review, annual monitoring (Jan-Dec) was maintained at thirty-one stations, primarily to monitor conditions of waters entering and leaving the State, to monitor conditions at TMDL and permit compliance locations, and to collect data more frequently in support of TMDL development (Huff 2021) (Table 2). While stateline monitoring is an important component of ADEM's Monitoring Strategy, monitoring sites located at the four corners of the State requires significant resources. Fifty additional stations are sampled once every three years on the basin rotation when sampling efforts are focused on their target basins. The stations are sampled monthly March-October or April-October, depending on their sampling protocol. A map of all current trend stations is available in Figure 3.

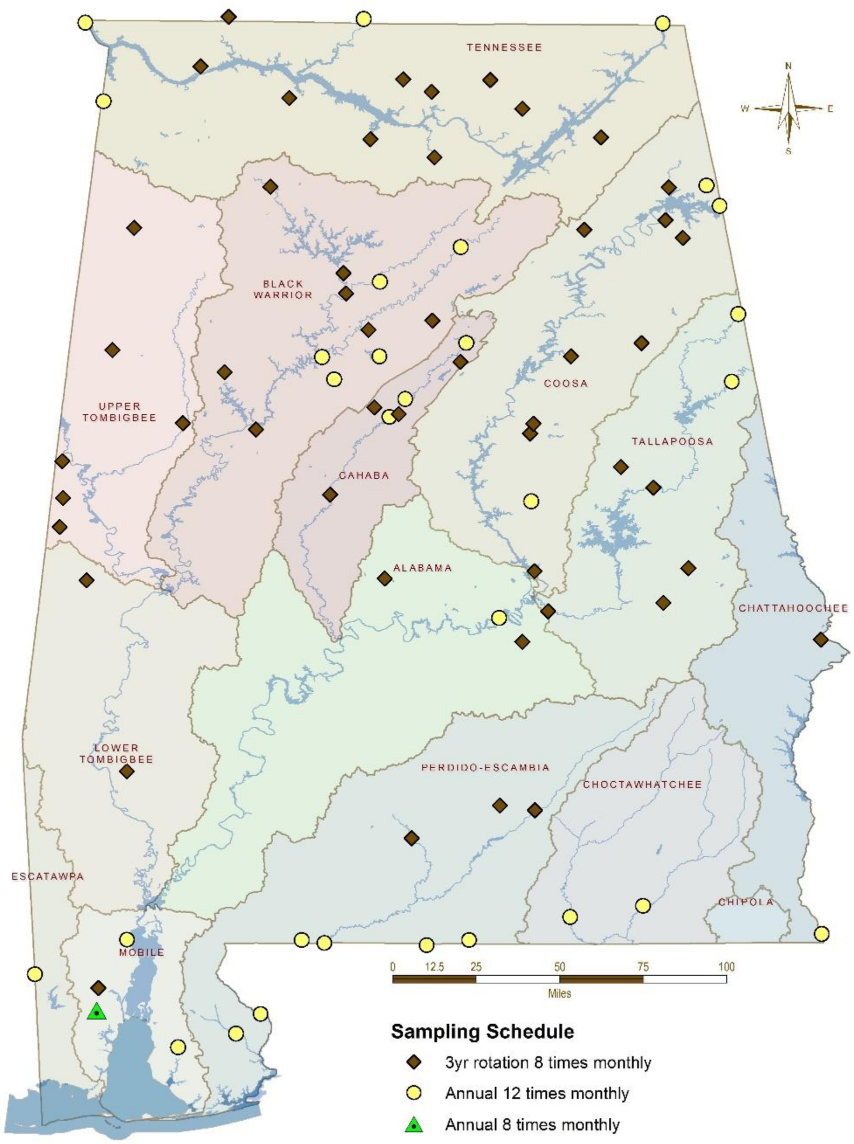

Figure 3. ADEM Ambient Monitoring Network sampling locations.

Table 2. Summary of annual trend monitoring locations.

Sampling Protocol	Monitoring Objective				TOTAL
	Stateline	Compliance Tracking	TMDL Model Development	Not Listed	
NWB	6	1	0	2	9
NWG-S/ W-WQS	7	1	0	3	11
W-BIO	3	5	2	1	11
TOTAL	**16**	**7**	**2**	**6**	**31**

Statewide Inventory of Monitoring Needs by Program

The goal of the Strategy is to implement a comprehensive monitoring program that serves all water quality needs of wadeable rivers and streams, nonwadeable rivers, reservoirs, and embayments, estuaries, coastal areas, wetlands, and groundwater. Since 2005, the ADEM has used 12-digit Hydrologic Unit Codes (HUC-12s) to plan, prioritize, and track monitoring activities. Using 12-digit HUCs has facilitated collaboration with multiple agencies and stakeholders also working to measure watershed conditions and to monitor and restore waterbodies at the HUC-12 scale.

Recent internal and external reviews of the RSMP and RRMP have indicated the need for additional biological monitoring and have identified gaps in monitoring coverage of perennial, flowing headwaters and nonwadeable rivers. An inventory of all waters monitored by the RSMP, RRMP, and CWMP has been an important aspect of the Strategy since 2005, but a more precise characterization of the flowing and non-flowing waterbodies needs to be adopted to fully understand the population of waters monitored by each program. Table 3 summarizes the categories of flowing waters along the longitudinal gradient from perennial headwaters to large rivers (Flotemersch et al. 2006) and relates these categories to the RSMP and RRMP and ADEM's sampling protocols. Table 4 summarizes seven categories of reservoirs found within Alabama. The categories are based on TVA's concept of main channel and tributary storage reservoirs. They have been proposed as an approach to developing fish community survey methods for nonwadeable rivers and reservoirs (O'Neil 2018).

More specific categories of waterbodies to be monitored by the RSMP and RRMP are important for three main reasons. First, they identify data gaps in monitoring coverage and relate these to the number of river miles assessed throughout the State. Second, they provide a method of estimating the number of waterbody types and the resources needed to monitor these waters. Third, in concert with other natural factors, the categories provide a method of defining how method development will be implemented.

Table 3. Classification and characteristics of perennial, flowing waters monitored by the RSMP and RRMP.

Monitoring Program	Category	Sampling Protocol	Drainage Area (sq mi)	Width (ft)	Mean Depth (ft)
RSMP	Headwaters (Perennial)	TBD	<5	Single Channel	<4
		TBD		Braided	<4
	Streams	W-BIO	5 to <90	Single Channel	<4
				Braided	>4
	Transitional (Large Streams/Small Rivers)	W-WQS/ NWG-S	>90 to <1,000	<100	<4
				>100	>4
RRMP	Rivers	NWB/ NWG-D	≥1,000 to <4,000	>100	fully NW
	Large Rivers		>4,000	>100	fully NW

Table 4. Proposed classification and characteristics of waterbodies for the development of nonwadeable biological survey methods (O'Neil 2018).

Category	Waterbodies
Unmodified rivers	Sipsey, Perdido, Choctawhatchee, Yellow, Lower Buttahatchee, Lower Locust Fork, Lower Mulberry Fork
Hydromodified rivers (Reaches downstream of dams)	Lower Alabama, Lower Tombigbee, Lower Tallapoosa, Lower Conecuh, Lower Pea, Coosa downstream of Jordan, Weiss by-pass, Lower Bear, mid-Tallapoosa, Sipsey Fork, Cahaba
Run-of-river reservoirs	
Large Storage	Guntersville, Wilson, Wheeler, Martin, Eufaula, Weiss, Pickwick
Small-moderate Storage	Alabama, Black Warrior, Tombigbee, Lay, Mitchell, Lower Chattahoochee, Harris
Very small Storage	Upper Pea, Point A, Gantt, Yates, Thurlow
Tributary Reservoirs	Smith, Lake Tuscaloosa, Bear Creek Lakes, Frank Jackson, Lake Converse, Inland and Highland Lakes

Reference reaches: Defining expected and natural conditions

Ecoregions are innate regional differences that exist in climate, landform, soil, natural vegetation, and hydrology that affect nutrient regime, substrate characteristics, and the composition of biological communities within aquatic ecosystems. By defining relatively homogeneous ecological areas, ecoregions provide a geographic framework for more efficient management of aquatic ecosystems and their components (Hughes et al. 1986, Hughes and Larsen

1988) and provide a scientifically defensible method of defining expected habitat, biotic, and chemical conditions within streams, rivers, reservoirs, and wetlands. Griffith et al. (2001) delineated six Level III ecoregions in Alabama: Piedmont, Southeastern Plains, Ridge and Valley, Southwestern Appalachians, Interior Plateau, and the Southern Coastal Plain. Within these, they delineated 29 Level IV ecoregions.

Since 1991, ADEM has used ecoregions as an *a priori* classification of streams to assist in the development of a dataset representative of wadeable, flowing streams statewide. However, as the RSMP, RRMP, and WMP develop biological survey methods for other waterbody types, it will be important to also identify "natural" or least-disturbed conditions for them using category and ecoregion, as well as other stable site characteristics, such as drainage area, gradient, width, depth, etc. It will be important to establish ecoregional reference reaches along the longitudinal gradient to provide the data needed to define site classes with distinct chemical, physical, and biological characteristics.

The RSMP has begun development of a monitoring strategy for perennial headwaters and transitional streams outside of the wadeable streams sampling period. By defining different sampling periods for each waterbody type, the program can sample more types of waterbodies throughout the year. However, it will be important to sample wadeable, flowing ecoregional reference reaches throughout the year, to more clearly define sampling periods for this waterbody type and to provide the flexibility to assess these waters year-round as biological monitoring is integrated into CWA program requirements. Similarly, documenting sampling precision would provide a method of estimating a true change in condition in other types of waterbodies to meet the needs of ADEM's CWA regulatory programs.

Site Selection

ADEM has established networks of long-term, fixed sites monitored annually or on the 3-year basin rotation as part of the CWMP, RRMP, RSMP, and WMP (see Monitoring Schedule section above).

Targeted sites are incorporated into the CWMP, RRMP, and RSMP in support of the 2015-2019 monitoring priorities. They are selected by the ADEM Water Quality Branch (WQB), NPS, Field Operations Division (FOD), other local, state, and federal agencies, and other stakeholders to provide data for use support and assessment, TMDL development, program evaluations, and use attainability analyses. These projects can be defined by the assessment categories and use classes that they target. The sites are monitored on a short-term basis, generally one- to five-years, for each project type.

Targeted monitoring has historically focused on fully assessing Category 2 and 3 waters, the monitoring of impaired (Category 5) waters to develop TMDLs (Category 4a), and the monitoring of the effectiveness of TMDLs and WMPs after implementation. As part of this Monitoring Strategy, Category 1 waters will be monitored at least once every 12 years (4 basin cycles) to ensure that instream conditions are maintained.

ADEM currently maintains two networks of monitoring units (MUs) to estimate overall water quality within its wadeable rivers and streams and coastal areas. In addition, the RSMP uses MUs to monitor watersheds along the full condition gradient to link increasing levels of stress to biological response. ADEM is piloting methods to delineate MUs for nonwadeable rivers and perennial headwaters and wetlands. However, different methods will be used to delineate MUs for these waterbody types and to select the subset to be monitored annually.

The CER recommended that the density of sampling sites within nonwadeable river reaches be increased to be able to isolate where changes in water quality occur and to define the causes of degraded conditions. As a pilot project, the subset of nonwadeable, flowing river monitoring units (NWFMUs) sampled each year will be concentrated downstream of wadeable, flowing RSMP stations also being sampled, as well as upstream of an embayment station, if possible. This enables ADEM to increase monitoring within this waterbody type and to evaluate the costs and benefits of increasing the number of sites monitored within a watershed.

The undisturbed network and density of headwaters and wetlands within a watershed is integral to natural reference conditions and the continued presence of high-quality waters downstream. They are an important ecological resource, supporting high levels of biological diversity and playing a vital role in the success of restoration efforts downstream. Disturbance to these waterbody types is also unique in that the gradient of conditions commonly includes their complete removal from the landscape. Monitoring of both perennial, flowing headwaters and wetlands will be concentrated within high-quality, wadeable, flowing rivers and streams reference reaches already being sampled. The natural variability in the density of headwater streams and the percent wetland land cover within high quality watersheds will be documented as a potential indicator of high-quality waters and as a potential cause of impairment to downstream waters. The WMP is currently focused on monitoring reference-quality headwater wetlands connected to blackwater streams and rivers. Monitoring these connected ecosystems supports a Departmental priority to define chemical/physical conditions characteristic of blackwater streams and rivers.

Measure of watershed condition

In 2004, the RSMP developed a method of calculating a watershed disturbance gradient (WDG) to classify each WFMU, as well as watersheds of all other wadeable, flowing stations, by its potential level of disturbance. These WDG scores were based on information from the National Land Cover Dataset (NLCD), population density, road crossings, and road density within the entire watershed upstream of a sampling site. The WDG scores were used to plan monitoring along a full watershed disturbance gradient in order to build a dataset encompassing the full stressor and biological condition gradients. This information is used in ADEM's probabilistic monitoring design to relate stressor and biological conditions at monitored sites to watersheds that were not monitored, providing an estimate of overall water quality. Data is also useful in identifying minimally disturbed and highly disturbed watersheds and in determining potential sources of impairment. The WDG worked well 2004-2014. While the WDG scores and categories are still a good estimate of watershed conditions and a good predictor of waterbody conditions, the tools used to calculate the measure are no longer supported by EPA.

EPA's Healthy Watersheds Program (HWP) has developed several tools, including the Preliminary Healthy Watersheds Assessment (PHWA) and the Recovery Potential Screening (RPS) tool to estimate watershed conditions at the catchment scale. These tools are easily accessible, readily available, and scalable from catchment to larger watersheds with relatively little effort. In addition, the PHWA and the RPS are more readily understood than the ADEM WDG because they rate watershed condition on a 0- to 100-point scale, with watershed health increasing with increasing score.

Indicators

EPA guidance calls for state monitoring programs to include "a core set of baseline indicators selected to represent each applicable designated use, plus supplementary indicators selected according to site-specific or project-specific decision criteria" (USEPA 2003). Core indicators are determined by waterbody type (tidal influence, wadeability, flow) and use classification. They are selected as the most appropriate for each resource type to include physical/habitat, chemical/toxicological, and biological endpoints to routinely assess attainment of applicable water quality standards. Supplemental indicators are used to verify impairment from a specific pollutant or to quantify concentrations and loadings (USEPA 2003). Core and supplemental indicators to assess coastal, nonwadeable rivers and reservoirs, and wadeable rivers and streams are summarized at the end of each program description in Section XII.

There are two important questions about indicators that must be tackled as ADEM develops and implements the next phase of its Monitoring Strategy. First, biological survey results currently serve as the only means of applying Alabama's narrative aquatic life use criteria. They are also used to assess impacts from nutrients, siltation/habitat alteration, and multiple other parameters without established criteria. Despite these important functions, biological monitoring was removed as a core indicator to assess wadeable, flowing streams and rivers in 2016, at least in part due to ADEM's inability to conduct a biological survey at each wadeable flowing river or stream monitoring station. Second, the RSMP dataset needs to be analyzed to determine the most effective and efficient baseline monitoring routine. In 2005, the program implemented intensive sampling of conventional water quality parameters to provide an independent assessment of water quality for indicator and criteria development. While the 2000-2014 ALM required collection of only three conventional samples if a macroinvertebrate survey had also been conducted, the RSMP implemented the collection of eight conventional samples. Since 2016, the ALM has not included a biological survey as a core indicator, requiring eight conventional parameters regardless of whether a biological survey has been conducted (ADEM 2024a).

The need to develop supplemental indicators as a part of the RSMP, RRMP, and CWMP continues to increase in order to verify impairment from specific pollutants and to quantify concentrations and loadings. Supplemental indicators developed to more accurately enumerate pollutant concentrations and loadings for TMDL development and to track restoration progress are resource intensive and conducted over a longer timeframe. For example, an intensive geomean survey must be completed to develop each pathogen TMDL in order to address pathogen impairment at multiple waterbodies listed since 2016. Statewide, the number of these surveys requested increased from 13 in 2022, 28 in 2023, and 42 in 2024, an increase of over 300% in two years. These surveys are resource intensive, particularly in terms of staffing.

In addition to the geomean survey, each of these pathogen-impaired stations must be re-sampled monthly March-October to provide the data for TMDL development. Reviewing monthly *E. coli* data more quickly in order to detect these impairments and to request a geomean survey during the next basin cycle would prevent the need for two sets of monthly water quality data.

Communication

An important aspect of the ADEM Monitoring Strategy is communication. The ADEM Monitoring Strategy established a process of internal programmatic review and communication across Divisions and field offices as an integral part of each monitoring cycle (Figure 4). This process includes a Monitoring Coordinator, as well as a small group of water quality managers in the ADEM FOD, WD, and NPS. Basin Teams were developed to improve communication among project managers, field staff, and ADEM management within FOD, WD, and NPS. Surface Water Quality Facilitators were also appointed to ensure consistency among the teams. The roles and responsibilities of each entity are described below.

Surface Water Monitoring Coordinator: A Departmental Surface Water Quality Monitoring Coordinator was appointed in 2005 to improve communication within ADEM, as well as with other agencies, and to ensure consistency in monitoring activities. The coordinator provides oversight of procedures, methods, and resolution of issues as they arise in the monitoring programs. The coordinator also maintains overall responsibility for the Strategy and all updates. A primary contact was also established for the Central and Branch Field Offices to assist with coordination and communication throughout ADEM.

Water Quality Managers: Water Quality Managers within FOD, WD, and NPS are responsible for setting water quality goals and objectives in terms of assessment and listing, TMDL development, restoration, criteria development, and monitoring. They review Monitoring Strategy results from the previous 5-year monitoring cycle, identify data needs that were not met by the previous 5-year monitoring strategy, discuss and prioritize the goals of the next 5-year monitoring strategy, and determine how best to meet these goals.

Surface Water Quality Facilitators: Surface Water Quality Facilitators are senior-level staff or management responsible for implementing the Monitoring Strategy, developing tools to assist the Basin Teams with the development of the Annual Surface Water Quality Monitoring Plan (SWQMP), and answering questions and addressing issues as needed.

Basin Teams: Basin Teams are comprised of the Basin Coordinators and project managers within FOD, WQB, and NPS and field staff from each field office conducting monitoring within that basin. Responsibilities of the Basin Team include development of the annual basin plan for their respective basin group, tracking and documenting SWQMP decisions and revisions, basin team status summaries, data requests and reviews, and review of final reports. They review the SWQMP results, identify any data needs that were not met, discuss and prioritize the goals for the following year, and other factors that need to be considered during the development of each annual SWQMP, which summarizes the sampling locations, sampling frequencies, and sampling parameters to be monitored in the coming year. Participation in Basin Teams provides opportunities for team members to become familiar with the data needs and issues within their basin and supports the ADEM goal of providing a high-performing work environment for staff. It also provides extensive opportunities for staff training and experience.

State Agency Water Quality Meeting: Field Operations Division continues to support the Department's Strategic Operations goals of building credible relations with external stakeholders. Every two years, ADEM hosts the State Agency Water Quality meeting to improve communication and coordination among all agencies in Alabama that are involved in water resource and water quality activities. In addition, a primary goal of ADEM surface water programs is to support common program goals as effectively and efficiently as possible by coordinating monitoring efforts among partner agencies and stakeholders throughout Alabama and by the monitoring of priority waters identified by these entities.

Reporting on the 3-year basin rotation

The RSMP, RRMP, and CWMP complete reports summarizing monitoring conducted each year. In general, the goal is to complete these reports within two years of data collection. Completing these reports by August of the second year will enable the Basin Teams to review the reports, discuss results during the Basin Team Meeting, and incorporate follow-up sampling as needed.

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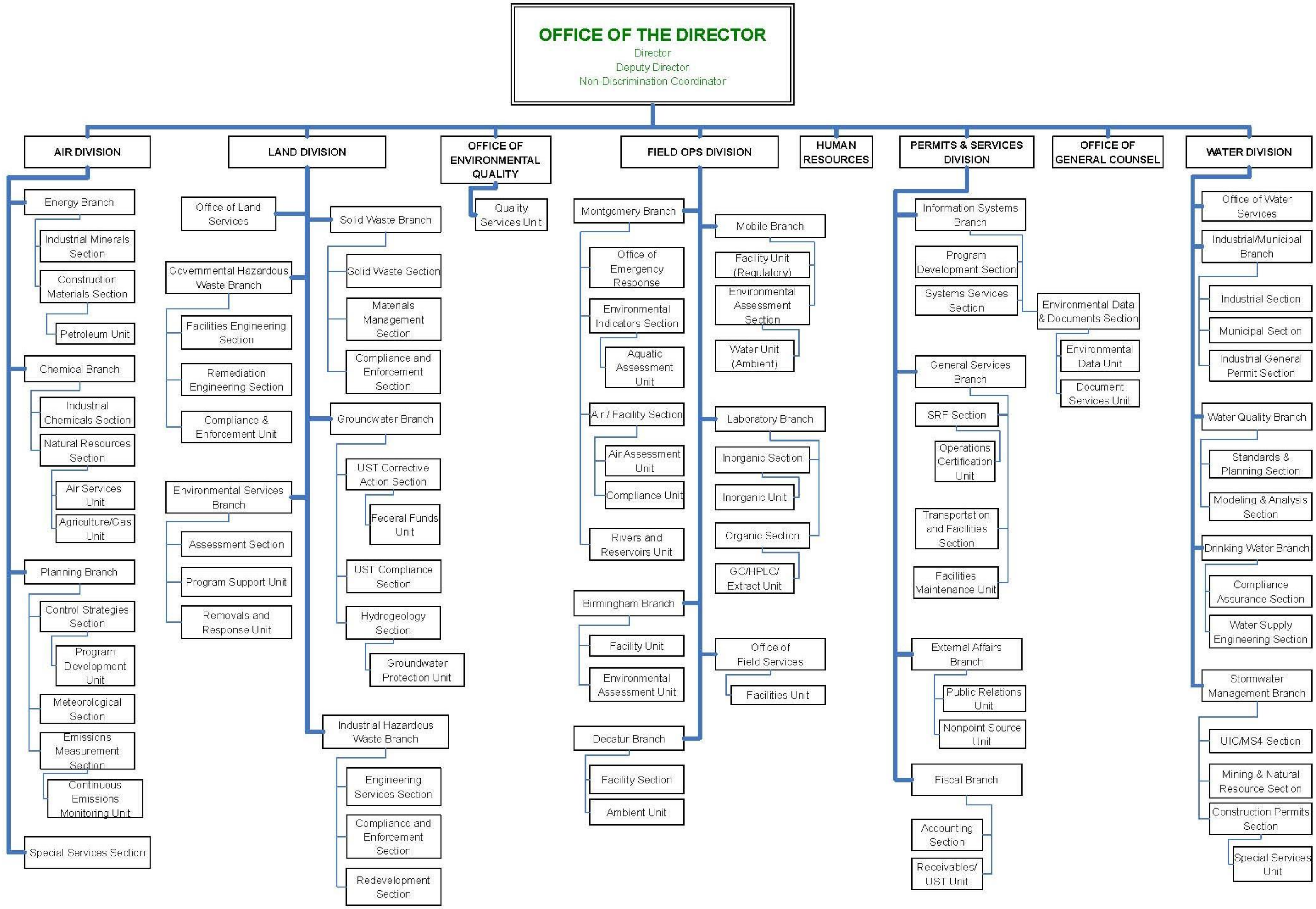

Figure 4. ADEM organizational chart.

IV. CORE AND SUPPLEMENTAL WATER QUALITY INDICATORS

EPA guidance calls for state monitoring programs to include "a core set of baseline indicators selected to represent each applicable designated use, plus supplementary indicators selected according to site-specific or project-specific decision criteria" (USEPA 2003). Core indicators are determined by waterbody type (tidal influence, wadeability, flow) and use classification. They are selected as the most appropriate for each resource type to include physical/habitat, chemical/toxicological, and biological endpoints to routinely assess attainment of applicable water quality standards. Supplemental indicators are used to verify impairment from a specific pollutant or to quantify concentrations and loadings (USEPA 2003). Core and supplemental indicators to assess coastal, nonwadeable rivers and reservoirs, and wadeable rivers and streams are summarized at the end of each program description in Section XII.

Core Indicators

As a monitoring program builds a comprehensive dataset, core indicators are first able to document general conditions and trends. Over time, and with continued collection and analysis of data, the accuracy and discriminatory power of criteria and indices can be refined, and the ability of these tools to detect small, incremental changes in water quality improves. Comprehensive datasets can associate biological response to specific stressors (USEPA 2013). For well-developed monitoring programs, such as the RSMP, the RRMP, and the CWMP, focus is on program maintenance and the incorporation of new advances in science and technology in order to continue to improve the program (USEPA 2013).

In addition to adding new core indicators as new data needs arise (e.g., the complete suite of total metals were added to the RSMP in 2019 to meet permitting requirements) and as improved technology for new or existing indicators are developed (e.g., lower MDLs to detect exceedances of hardness-based metals criteria; use of a more readily available measure of watershed condition), ADEM's existing datasets need to be analyzed to continue to relate biological response to specific stressors for development of biological indicators and numeric criteria. Completion of biological signatures based on ADEM's biological, physical/habitat, and chemical/toxicological data would also improve the Department's ability to associate a cause(s) of biological impairment using routine monitoring data.

Biological survey results are an important part of the assessment process. Alabama has not established numeric biological criteria and therefore uses biological survey results as a means of applying the narrative criteria contained in ADEM Administrative Code r. 335-6-10 (ADEM 2021a). Biological survey data are used in combination with other surface water quality data and information to arrive at an overall use support determination and to support the stressor identification process, particularly in assessing impacts from nutrients, siltation/habitat degradation and multiple other stressors without established numeric criteria. Biological survey results, in combination with other surface water quality data, also play an important role in establishing and documenting natural conditions in waterbodies that would otherwise be listed as impaired.

The question of whether a biological survey can be included as a core indicator to assess perennial, flowing rivers and streams is an important one. Biological monitoring was removed as a core indicator to assess wadeable flowing rivers and streams in 2016, at least in part due to ADEM's inability to conduct a biological survey at each wadeable, flowing river or stream monitoring location, and/or to provide results of the biological surveys in a timely manner for use during the assessment process. Multiple factors contribute to these issues. They are as follows:

1. *Intensive sampling of water quality parameters*. Intensive sampling of wadeable flowing rivers and streams was implemented in 2005 as an important component of the RSMP Monitoring Strategy. While the 2000-2014 ALM required collection of only three monthly (Mar-Oct) conventional samples if a macroinvertebrate survey was conducted, the RSMP Monitoring Strategy implemented the collection of eight monthly (Mar-Oct) conventional samples in 2005. Intensive sampling provided the data needed to develop statewide biological condition gradient (BCG) indices for both macroinvertebrates and fish by 2015, as well as the data to document biological responses to specific stressors to support the causal identification process. However, intensive monthly water quality sampling has continued for a decade past the completion of BCG indices.
2. *An increased number of biological surveys without an increase in biological taxonomists*. The number of taxonomists has not increased substantially in 30 years. In 1994, three taxonomists completed all macroinvertebrate surveys, sample processing, and genus-level identifications. In 2024, while the number of staff collecting macroinvertebrates has doubled, and all Environmental Indicator Section (EIS) staff are now involved in

processing samples, there are currently still only three macroinvertebrate taxonomists completing genus-level identifications.

3. *Increased number of primary responsibilities*. In addition, up until 2004, the primary tasks and responsibilities of taxonomists were limited to the collection, processing and identification of macroinvertebrate samples. Since 2005, the tasks and duties of biological taxonomists have greatly expanded to include intensive monthly water quality sampling, completion of multiple types of supplemental surveys, completion of the annual SWQMP, and facilitating basin team meetings and station recons. Taxonomists also maintain, troubleshoot, and develop the main ALAWADR modules, DEVAS and BioDEVAS, and database user queries and reports.

Recent review of the RSMP and RRMP suggest that the high level of technical rigor associated with these two programs has in part been achieved by concentrating efforts within a limited number of targeted waterbody types. The review indicated the need to expand these two programs into perennial, flowing headwaters and nonwadeable rivers, respectively (Yoder 2019). This recommendation is supported by the 2024 IWQMAR, which shows only 26% of perennial, flowing streams and rivers to have been assessed (ADEM 2024b).

Monitoring perennial, flowing headwaters over the next two 3-year monitoring cycles should focus on the collection of core biological, chemical, and physical data from high-quality reference watersheds. This will provide comprehensive datasets to document reference conditions, to classify waterbodies, to develop biological indices, and to calculate ecoregional reference guidelines.

Supplemental Indicators

The need to develop supplemental indicators as a part of the RSMP, RRMP, and CWMP continues to increase in order to verify impairment from specific pollutants and to quantify concentrations and loadings. Supplemental indicators can be developed as stressor-specific surveys to support a weight-of-evidence assessment approach. These are screening-level surveys conducted quickly at a subset of sites where recent monitoring shows a high potential for impairment from a specific pollutant. Examples include rapid periphyton surveys, diurnal dissolved oxygen (DO) studies, and siltation surveys to further document impairment from nutrient enrichment and siltation. Supplemental indicators are also developed to more accurately enumerate pollutant concentrations and loadings for TMDL development and to track restoration progress. These types of indicators are resource intensive and are conducted over a longer timeframe.

V. Quality Assurance/Quality Control Program

Quality Management Plan

All monitoring efforts and related activities are performed under the ADEM Quality Management Plan (QMP). The QMP is revised by the Department and approved by EPA Region 4 on a 5-year cycle following procedures outlined in SOP #8303 *Preparation, Review, Approval, Distribution, and Archival of the Departmental Quality Management Plan (QMP)* with the current version approved by EPA on October 25, 2024 (ADEM 2024c). The ADEM Quality Assurance Manager (QAM), who is also the Chief of the Office of Environmental Quality (OEQ), has the overall responsibility for the development, implementation, and continued operation of the Department's quality system.

Quality Assurance Program/Project Plans

One of the primary tools for quality assurance (QA) and quality control (QC) management is the QA Program/Project Plan (QAPP). The monitoring program is responsible for producing, reviewing, and updating these documents for approval by the QAM. The QAPPs are developed in accordance with ADEM SOP #8302 *Preparation, Review, Approval, Distribution, and Archival of Quality Assurance Program/Project Plans (QAPPs)*.

The *Quality Assurance Program Plan (QAPP) for Surface Water Quality Monitoring (SWQM) in Alabama* (ADEM 2023b) describes the standard activities and supporting documents to conduct this program. Routine and certain special studies that include program monitoring activities are implemented under the SWQM QAPP and additional specific annual study plan documents. Unique special studies have a QAPP specific to each particular study. Special studies involving an immediate public health threat or criminal investigation most often will be carried out under the SWQM QAPP due to the limited time frame for response and obtaining samples. In addition to fulfilling the federal grant requirements, the QAPPs are intended to serve as a historic record of the activities and assessment methods used to ensure the quality, accuracy, precision, and completeness of the data collected and analyzed for each project and describes the data quality objectives for the final use of the data.

Standard Operating Procedures

Field Operations Division is responsible for developing, reviewing, and revising standard operating procedure (SOP) documents following procedures outlined in SOP #8301 *Preparation, Review, Approval, Distribution, and Archival of Standard Operating Procedure (SOP) Documents*, as well as implementing the SOPs for all activities related to water quality data generation (field and laboratory). Field-related SOPs document the various procedures for sample collection/processing, field instrument calibration and measurement, and sample chain-of-custody. Laboratory–related SOPs document the procedures for analytical laboratory sample prep/extraction, sample analysis, general housekeeping and data management, and biological community sample processing/identification/analysis. The OEQ maintains document control through standard procedures for document numbering, formatting, review and revision documentation/tracking, approval, and archival/retirement.

Quality Document Accessibility and Archival

Current copies of the QMP, Laboratory Operations and QA Manual (LOQAM), QAPPs/study plans, and field and laboratory SOPs are maintained on the ADEM intranet by the OEQ to allow Department-wide access to all approved quality documents. Only the versions accessed on the intranet are controlled copies. Printed and downloaded versions are not controlled copies.

Additional documents available on the intranet include: sample chain-of-custody forms, required sample preservation/holding times/containers/sample volumes, approved field and laboratory forms/data sheets, and database user manuals. Monthly Department-wide email notifications are sent by the QAM listing all updates to the intranet Quality Assurance website. The QMP and all QAPPs, study plans, LOQAM chapters, and SOPs are archived in Laserfiche by the OEQ.

QA/QC Field Procedures

Physical/Chemical

Field procedures to determine the quality of the physical/chemical data collected are documented in SOP #9021 *Field Quality Control: Measurements and Samples*. These procedures include replicate water samples collected at five percent and field parameters collected at ten percent of sampling events. Replicate data are used as a relative measure of sample collection and processing or measurement precision.

Blank samples are also collected at the same frequency as replicate samples by filling sample containers with deionized water at the site and processing deionized water through any collection and/or filtration equipment in the same manner as regular samples. This allows staff to monitor the on-site sampling environment, sampling equipment decontamination, sample container cleaning, the suitability of sample preservatives and analyte-free water, and sample transport and storage conditions.

Biological Community Surveys

Comparability of habitat and biological surveys conducted by different collectors is measured using different measures, depending on the type of survey and waterbody. The purpose of replicate samples is to ensure that results obtained are accurate, repeatable, and representative of the sampling location and to establish measurement precision of ADEM standard operating procedures.

Survey methods are under development for both macroinvertebrates and fish in headwater streams, wetlands, and rivers; replicate surveys are not conducted.

Macroinvertebrates:

Replicate macroinvertebrate surveys are conducted annually at five percent of sampling locations.

Wadeable, flowing rivers and streams: Replicate surveys may be conducted by collecting other unsampled habitat areas within the same reach as the original survey or by sampling the reach just upstream of the original sampling reach. Replicate surveys may be conducted by the same team immediately following the initial survey. However, at least one replicate survey each sampling year must be conducted by a different team at the same time as the initial survey in order to ensure consistency across sampling teams.

Nonwadeable, flowing streams and rivers: One replicate is conducted annually if 20 or fewer sites are assessed. The replicate survey may be conducted by sampling other habitats within the same reach or by sampling the reach just upstream of the original sampling reach.

Fish:

Wadeable, flowing rivers and streams: Replicate fish surveys are conducted annually at five percent of sampling locations. The purpose of replicate fish surveys is to ensure consistency of the fish team across sampling events. Replicate surveys are conducted by the same team during separate site visits because having two teams sampling the same reach simultaneously is personnel-intensive and may cause excessive habitat disturbance in the reaches being sampled leading to unreliable results.

Non-wadeable, flowing streams and rivers: Survey methods are under development; replicate surveys are not conducted.

Diatoms:

Wadeable, flowing rivers and streams: Replicate diatom surveys are conducted annually at five percent of sampling locations. Replicate surveys may be conducted by sampling other habitat areas within the same reach or sampling the reach just upstream of the original sampling location.

QA/QC Laboratory Procedures/Methods

Biological Laboratory: Sample Processing:

Macroinvertebrates:

Biological laboratory quality assurance procedures are an integral part of all biological programs. The completeness of processing of all macroinvertebrate samples is ensured by QA'ing each sub-sample as it is completed. The efficiency of each sample processor is tracked to ensure they are meeting minimum requirements and to improve their abilities over time.

Biological Laboratory: Identifications:

Macroinvertebrates: Two macroinvertebrate taxonomists have been certified by the Society of Freshwater Sciences to ensure the accuracy of identifications. Five percent of each taxonomist's identifications are re-identified by a certified taxonomist to document accuracy. This includes both genus- and family-level identifications. Status as a full taxonomist is maintained by identification and QA of at least five samples annually.

Fish: Field identifications are completed by two taxonomists. Photo or specimen vouchers of each species are collected to verify identifications. Representative specimens that cannot be identified in the field are collected for laboratory identification.

Diatom, plant, and amphibian identifications are completed by contractors with expertise in these areas.

Biological Laboratory: Reference Collections:

Macroinvertebrates and Fish: At least one specimen of each macroinvertebrate and fish taxon collected in ADEM samples is maintained in an in-house reference collection.

Biological Laboratory: Taxonomic Certifications:

Macroinvertebrates: A minimum of one macroinvertebrate taxonomist is certified to complete EPT and Chironomidae genus-level identifications for training and QA/QC purposes.

Fish: A goal of the ADEM Monitoring Strategy is to assist in the development of a fish taxonomic certification program for Alabama administered by an independent federal or state entity.

Analytical Laboratory Procedures

Laboratory Support:

Laboratory analytical support for the Department is provided by the ADEM Laboratory System with locations in Montgomery, Birmingham, Mobile, and Decatur. The laboratory is responsible for organic, inorganic, and radiochemical analyses for the Department's water quality monitoring programs. Analyses are performed using protocols approved in 40CFR136 and documented in SOPs available on the ADEM intranet. In addition, the Central Laboratory in Montgomery is fully certified by EPA Region 4 for the analysis of all regulated inorganic and organic chemical drinking water contaminants.

It is the mission of the laboratory to provide quality data to support Departmental monitoring programs. This is achieved by maintaining a fully equipped environmental laboratory and a technically skilled, properly trained, and dedicated staff that produces physical and chemical data of a known and defensible quality. All ADEM laboratories maintain documentation tracking laboratory staff training activities and analytical competency qualifications.

It is the intent of the laboratory that all data generated by the laboratory is of the quality that meets or exceeds the data quality objectives of the associated project. Managers and analysts of the laboratories share the responsibility of ensuring that analytical methods, instruments, and parameter detection/quantification are such that the data produced are scientifically sound and defensible. It is of utmost importance that the quality of all data produced by the laboratory be defined and communicated to the end user(s) of the data. This is implemented by:

- having in place and following a complete and systematic process of quality control activities to assist in defining data quality.
- ensuring that data quality is documented and communicated to all users of the data by assigning appropriate qualifier codes according to prescribed procedures.
- implementing a review process to verify that data are generated in accordance with sound and appropriate technical procedures and to ensure that all activities associated with the analyses, calculations, and data reduction are complete and accurate.

The ADEM Laboratory System maintains a separate *Laboratory Operations and Quality Assurance Manual (LOQAM)* that deals specifically with the laboratory quality system through a coordinated effort between the laboratory managers and the OEQ. The document is reviewed annually and approved by the laboratory location managers, the Laboratory Quality Assurance Officer (LQAO), the Quality Assurance Manager (QAM), and the FOD Chief (ADEM 2023a).

QA Program Oversight

The ADEM quality system oversight is conducted by the OEQ. The OEQ is charged with the ongoing development and enhancement of the Department-wide quality system through continued dialogue with all Divisions regarding issues related to quality processes, quality documentation, data quality/management, and laboratory needs. Additionally, the OEQ works to enhance compliance with QA/QC procedures via quality assistance, quality assurance, quality document review, and internal quality assessments.

The OEQ conducts internal quality assessments of field data collection and documentation activities and field staff entry accuracy into the ALAWADR database. Results of these assessments are communicated through the chain-of-command to the Branch Chief and the Monitoring Coordinator.

The OEQ also conducts internal quality assessments of laboratory methods, standard processes, and documentation. Results of these assessments are communicated through the chain-of-command to the Laboratory Managers.

In addition to the OEQ staff, each FOD Branch Chief serves as the point-of-contact for OEQ staff to disseminate new information and/or procedures and as a focal point for quality-related questions and suggestions. FOD supervisors and senior staff members assigned by management may provide assistance to OEQ auditors as technical experts during quality assessments of field data collection activities.

Current and Future Initiatives

ADEM will continue to enhance the quality system during the life cycle of this document. This process will use the *Guidance for Developing Quality Systems for Environmental Programs* (USEPA 2002) as its primary resource. OEQ staff will continue to provide assistance with implementation and coordination of additional quality control activities, as needed.

VI. DATA MANAGEMENT/STORAGE

ADEM's development of ALAWADR, its centralized Oracle database, has arguably been the most critical process in fully implementing ADEM's 2005 Monitoring Strategy. At that time, monitoring data was housed in two Mainframes, over two dozen Microsoft Access databases, multiple Excel spreadsheets, loose-leaf binders, and hard copy reports. Assessment data and information was maintained by a single person in multiple Excel spreadsheets and GIS layers. While well-managed and fully QC'ed, maintaining these data sources separately was time-consuming and almost completely prevented data analysis and reporting.

ADEM's approach to database development has been integral to its success. The most important components of this approach include a modular design to continue development toward the ADEM overall data management system and development of an ALAWADR workgroup composed of database users, administrators, and information systems experts. The workgroup conducts a thorough requirements analysis and a detailed mock-up for each new module in-house. This process greatly assists in the communication necessary to design programming and build, test, and implement the module. In addition to documenting database requirements and design, the workgroup uses this process to improve communication and planning throughout its surface water programs. Another important aspect of ADEM's approach has included working with other state and federal agencies managing the same types of data to assist in database development and implementation.

Modules and Functionality: Completed

The following is provided to highlight what has been accomplished so far but to also provide a general sense of the length of time required to complete each module. While ADEM has been very successful in finding grants to fund each module completed by an outside contractor, the importance of the full involvement of database administrators, users, and information systems experts cannot be overstated. The time commitment required by all members of the database workgroup for the entire length of the project is extensive. In practice, members of the workgroup also become heavily involved in data migration, maintaining ALAWADR, trouble-shooting issues, and designing and developing queries and reports needed to continue to improve the functionality of the database.

Development of ALAWADR's main module illustrates the importance of working with a qualified contractor. Completion of the database table structure, modeled after the EPA's Storage and Retrieval Database (STORET), took a decade to complete. Development of the remaining modules was completed by EPA Region 4 contractors or contractors carefully evaluated and selected by the database workgroup using a standardized process. Significant functionality was completed by in-house programmers to complement work completed by outside contractors. Development of ALAWADR as a web-based data management system began in 2007 by an EPA contractor. The main modules of ALAWADR used to enter chemical/physical and observational data were completed in 2008. Functionality added to the main modules of ALAWADR included import of LIMS laboratory results and data sonde measurements and completion of the first phase of PortaWADR, the ALAWADR module used to complete on-site data entry of simple forms for upload to the database. Modules were then completed to enter taxonomic information (macroinvertebrates, fish, diatoms, plants, amphibians) and attributes, and macroinvertebrate and fish sample collection, processing, and identification.

The BioWADR module allows users to create and calculate metrics and indices for habitat, watershed, macroinvertebrate, and fish data without the need for programming. Functionality was added to calculate screening-level macroinvertebrate metrics and indices, nonwadeable macroinvertebrate metrics and indices, and macroinvertebrate and fish BCG indices. The user can calculate indices for a single station visit or calculate one index for all station visits within a specific date range.

The Data EValuation and ASsessment (DEVAS) module was designed to manage and track assessment data and information. It contains multiple modules that function together and uses the data in ALAWADR to manage and track assessment units, to conduct station-level assessments, and to manage and track final assessments and causes and sources of impairment. It then translates the assessment data and information and generates an XML file, which is then submitted to ATTAINS.

Functionality was also added to the database to randomly select a percentage of each crew leader's station visits to audit data entry. Multiple downloads, queries, and reports have been created to analyze and report monitoring data.

Modules and Functionality: In development

In 2018, the WQB, EIS, and Information Systems Branch (IS) worked together to enter all IWQMAR and 303(d) information from the 1996-2016 cycles into DEVAS. The purpose of this process was so that the entire data history of each waterbody and assessment unit would be available to users from ALAWADR in one central location. As each assessment unit is assessed, data and information must be revised and corrected to prevent issues with the XML data translation and submission to ATTAINS. Intensive review of DEVAS data to understand and identify common data issues and the quick correction of these issues would improve future submission to ATTAINS. In addition, the tables submitted to ATTAINS every other year are standardized. The reports that automatically generate these tables should be completed.

The use of biological data and information is critical to management decisions. ADEM conducts extensive QA/QC on data entry, the accuracy of taxonomic identifications, and the comparability of results from screening-level surveys versus intensive genus-level identifications. Functionality needs to be added to BioDEVAS to allow entry of these QC data and generation of comparison reports.

Modules and Functionality: Future initiatives

While tremendous strides have been made in ALAWADR's functionality, several future initiatives listed in the 2005, 2012, and 2015 Strategies have not been completed and are listed below. The tremendous time commitment required by the database workgroup in addition to their normal, routine responsibilities and tasks contributes to the slow progress in developing some ALAWADR modules. The tasks associated with maintaining, troubleshooting, and developing portions of ALAWADR will require significant time commitments from all workgroup members. Data management and database development are on-going, iterative processes that must keep up with new data needs, new methods, etc. High turnover rates in each of the CWA programs have impacted ADEM's ability to fully train a subset of users to serve as workgroup participants. Multiple staff in each program need to participate in the training so that capacity is not lost if a work group member leaves. Future initiatives for ALAWADR include the following:

- **BIODEVAS**
  - Add functionality to enter and calculate periphyton metrics, including diatom community indices
  - Add functionality to calculate QA/QC identification results

    - Add functionality to enter and calculate wetland RAM, amphibian and floristic attributes, metrics, and indices

- **DEVAS**
    - Continue to develop and de-bug data submissions to ATTAINS
    - Develop and implement the Water Quality Criteria Tracking Module
    - Add functionality to compile internal and external data for assessment and other analyses
    - Add functionality to screen monitoring data against water quality standards
    - Develop and implement Assessment Unit (AU)-level DEVAS module
    - Complete module to automate submission of IWQMAR reports
    - Complete module to manage and track assessment unit "actions" (AU assessment, causes, sources, TMDL development, NPS projects, etc.)

- **Other enhancements:**
    - Update functionality within the main modules of ALAWADR (e.g. add stations to a project via GIS, add photos at the station visit level, scan and Laserfische forms at the station visit level)
    - Complete user interface/upload of station-watershed attributes
    - Complete GIS/Data Analysis Tools module
    - Incorporate corrective action table into QA/QC module
    - Develop portable module for on-site data entry of forms (e.g. grid/transect data)
    - Begin the process of uploading macroinvertebrate and fish survey data to WQX
    - Develop functionality in ALAWADR to import Departmental-owned professional data and non-owned professional data collected by ADEM partners

VII. Data Analysis/Assessment

ADEM's Monitoring Strategy is a coordinated monitoring approach designed to characterize water quality, identify impacts from a variety of sources, and provide a systematic and integrated framework for gathering necessary information to support the ADEM decision-making process. The monitoring strategy is currently comprised of four programs defined by tidal influence, flow, waterbody type, and wadeability—the RSMP (wadeable rivers and streams), the RRMP (nonwadeable rivers and reservoirs), the CWMP (coastal waters), and the WMP (wetlands).

Using its Monitoring Strategy over the last 20 years, ADEM has developed its CWMP, RRMP, and RSMP into monitoring programs recognized to be of the highest quality and technical rigor (Yoder 2019). Through this process, it has also identified areas that need to be addressed to improve: 1) monitoring coverage, 2) identification of causes and sources of impairment, and 3) detection of incremental changes in water quality conditions, both to accurately evaluate program effectiveness and to react to degradation in biological, chemical, and physical conditions more quickly (Yoder 2019).

ADEM has identified eight issues that can be evaluated and analyzed using existing datasets and information in order to improve its monitoring strategy and to address the five primary recommendations of the 2019 Critical Elements Review (CER) of its monitoring programs. They are as follows:

1. *Develop biological response signatures*. Developing relationships between key chemical/physical and other common stressors and biological indices improves stressor identification and causal analysis process. Biological response signatures for diatoms and macroinvertebrates to nutrients (total phosphorus and total nitrogen) have identified both diatom and macroinvertebrate community attributes that respond to nutrient enrichment (for development of nutrient-specific metrics), as well as the nutrient concentrations at which these attributes respond (for development of numeric nutrient criteria). Biological response signatures (macroinvertebrates, fish, diatoms) to other core parameters need to be completed to continue development of stressor-specific metrics and numeric criteria.
2. *Calibrate the diatom index*. Diatom community indices have been shown to be the most effective, accurate, and sensitive indicators of nutrient enrichment and response to changes in nutrient conditions in wadeable, flowing rivers and streams (Stevenson 2003, USEPA 2014, Charles et al. 2019). In 2019, EPA developed a diatom index for riffle-run streams

of the southeastern United States using data collected by Tennessee, Georgia, Alabama, and Kentucky. The index has been calculated for Alabama diatom data collected 2004-2017. Calibrating this index would enable ADEM to accurately measure nutrient concentrations and conditions within Alabama's riffle-run streams.

3. *Calibrate index of overall estimate of water quality*. Through a 2016 grant awarded by EPA Region 4 and EPA Headquarters (HQ), the ADEM and EPA developed a model to estimate overall water quality of wadeable, flowing rivers and streams based on ADEM biological survey results and catchment watershed information available from StreamCat. The model only needs to be calibrated to ADEM's macroinvertebrate BCG indices to provide an overall estimate of water quality of Alabama's wadeable, flowing rivers and streams.
4. *Conduct Biological Condition Gradient (BCG) Workshops*. Between 2014 and 2015, with the assistance of EPA R4 and EPA HQ, the RSMP convened two BCG workshops to develop BCG indices for macroinvertebrates and fish in wadeable rivers and streams throughout the State. Macroinvertebrate taxonomists and ichthyologists with extensive experience working in wadeable rivers and streams throughout Alabama worked together to review fish and macroinvertebrate data collected by the Geological Survey of Alabama and ADEM, respectively, to assign BCG attributes and to develop BCG indices. Reconvening BCG workgroups to review and revise the fish and macroinvertebrate BCG attributes and indices used since 2014 can help improve these tools, introduce them to a new generation of scientists, and continue to spread the use of these tools to assess wadeable rivers and streams statewide.

The remaining five data analysis questions relate to ADEM's need to increase spatial coverage of its RSMP and RRMP to include perennial, flowing headwaters, nonwadeable flowing streams and rivers, and flowing rivers and to conduct at least one biological survey at each of these three waterbody types, as well as all wadeable, flowing rivers and streams.

5. *Analyze existing data to ensure that 304(a)(1) criteria are applicable and appropriate to Alabama's waterbodies.* As an example, ADEM adopted EPA's *E. coli* criteria in 2013. In 2014, the summer criterion for *Fish and Wildlife* (*F&W)* and *Public Water Supply* (*PWS)* streams was decreased, and in 2017, the more stringent summer criteria were extended to May and October (ADEM 2014). Between 2014 and 2018, 138 waterbodies were listed as impaired; 128 (93%) of the impaired waterbodies were listed only for *E. coli*, including

some of Alabama's ecoregional reference reaches and highest quality streams and rivers, suggesting that the EPA criteria may be too stringent for many stream types in Alabama. Using an ecoregional reference reach approach, the data from these high-quality waters would be used to calibrate the pathogen criteria to different regions of the State.

6. *Evaluate the efficiency of the RSMP baseline sampling*. Between 2005 and 2015, intensive sampling of conventional water quality parameters in wadeable, flowing rivers and streams provided the data needed to develop statewide biological condition gradient (BCG) indices for both macroinvertebrates and fish by 2015. It also provided the data to document biological responses to specific stressors to support the causal identification process. However, now that the ADEM has developed statewide BCG indices using its 20-year comprehensive dataset, the efficiency of continuing this sampling regime must be weighed against the importance of expanding the monitoring coverage of the RSMP and RRMP, the need for biological survey results to apply narrative aquatic life use criteria and to assess impacts from nutrients, siltation/habitat degradation, and multiple other stressors without established numeric criteria, and the potential for supplemental indicators to verify impairment from a specific pollutant or to quantify concentrations and loadings.
7. *Document QA/QC characteristics of biological, chemical, and physical data results*. The ADEM monitoring programs have reached the highest levels of technical rigor. To do so, monitoring efforts have focused on a limited number of waterbody types. Documenting sampling precision would provide a method of estimating a true change in condition in other types of waterbodies to meet the needs of ADEM's CWA regulatory programs.
8. *Evaluate the accuracy and discriminatory power of screening-level survey methods*. The use of screening-level biological survey methods to evaluate conditions for the IWQMAR and 303(d) listing and to identify impaired and high-quality waters needs to be evaluated. The use of these types of surveys could improve the timeliness of reporting biological results and allow taxonomists to concentrate their efforts where more intensive methods are required.

VIII. Reporting

Background

Historically, data collected by the ADEM monitoring programs are provided to the requesting Division or compiled into reports that are designed to meet requirements of the Clean Water Act (CWA), to fulfill EPA grant requirements, and/or to inform stakeholders. Improvements to the ADEM data management system have enabled the Department to meet many of the reporting needs identified in the 2005, 2012, and 2015 Monitoring Strategies, including improved content and applicability of reports and increased number of report writers. Data can now be downloaded directly from ALAWADR by the requesting Division. All ADEM water quality and observational data is also available for download from the National Water Quality Monitoring Council (NWQMC) Water Quality Data Portal and EPA's How's My Waterway.

In the past, it has been difficult to compile the data collected by ADEM monitoring programs for reports to be completed for the Water Quality Standards (WQS), Assessment/§303(d) Listing, TMDL, and NPS programs. With improvements to ALAWADR, data can be downloaded for completion of required reports. Over the past several years, the ADEM has put emphasis on increasing the availability of water quality information on its website. The following information can be found on the ADEM website:

- Water quality regulations and standards
- Biennial Integrated Water Quality Monitoring and Assessment Reports (IWQMAR); the associated ALM document is included with each IWQMAR
- §303(d) Lists and Fact Sheets
- TMDLs
- FTMP, CWMP, RRMP, and RSMP Monitoring Summary Reports

Information on the ADEM Nonpoint Source Pollution Program is available on their page of the ADEM website.

Bacteria levels monitored at public recreational beaches along the Gulf Coast for the Coastal Alabama Beach Monitoring Program are posted on the Coastal Programs page of the ADEM website and are routinely updated as new data is available. Advisories are publicized through press releases and posted on signs at each of the 26 sampling locations.

Current and Future Initiatives

- Develop a probabilistic report for wadeable streams that provides a statistical assessment of 100% of wadeable streams;
- Develop methods to document and report incremental changes in water quality;
- Develop a method of documenting changes in watershed conditions over time;
- Incorporate Basin Team Report reviews as part of the reporting process;
- Automate submission of IWQMAR reports to improve accuracy and efficiency of reporting;
- Complete module to manage and track assessment unit (AU) "actions" (AU assessment, causes, sources, TMDL development, etc.) to improve communication and transparency within ADEM surface water programs, as well as with EPA and stakeholders; and,
- Complete GIS/Data Analysis Tools module to create more "user-friendly" reports and increase accuracy of management decisions.

IX. Programmatic Evaluation

Since 1997, programmatic evaluation of the ADEM Monitoring Programs and Strategy has been an integral part of the ADEM Monitoring Strategy. Originally conducted every five years, evaluations now take place every six years. The ADEM Water Quality Monitoring Coordinator is responsible for the Monitoring Strategy development, review, and revisions. In addition, annual coordination meetings are conducted to discuss and develop the annual Surface Water Quality Monitoring Plan (SWQMP).

A status review of ADEM water quality monitoring programs was conducted in 2019, but the Monitoring Strategy update was delayed by the 2020 COVID pandemic, the loss of experienced personnel, and other related complications. The review was conducted by personnel from the FOD, WD, NPS, and OEQ to ensure that the Strategy met overall monitoring objectives, as well as the objectives of the assessment/§303(d) listing, TMDL, NPS, and quality assurance programs. Other goals included identifying the Department's 2024-2030 monitoring priorities and revising the Strategy as needed to meet these new priorities. In 2023, the status review was repeated and updated, culminating in this 2025 State of Alabama Water Quality Monitoring Strategy. This Strategy sets forth a 6-year plan to address the "Ten Elements" put forth by EPA and will continue to build on existing monitoring capabilities and progress towards addressing all state waters over time. ADEM views this Monitoring Strategy as an opportunity for long-term planning. Therefore, a discussion of future initiatives and a timeline are included to address incremental improvements necessary to incorporate requirements outlined in the "Ten Elements" document and to satisfy monitoring goals and requirements pursuant to the Alabama Water Pollution Control Act (AWPCA), the Alabama Environmental Management Act (AEMA), and the federal Clean Water Act (CWA). The ADEM 2024-2030 monitoring priorities are described more fully in Section II. Monitoring Objectives.

In the past, the annual coordination meetings were conducted in the fall by managers of surface water quality programs in ADEM FOD, WD, and the OEO. This process was successfully implemented in 2004-2014.

As part of the 2015 Monitoring Strategy, annual Surface Water Quality Monitoring Plans (SWQMPs) are now developed by Basin Teams. This provides opportunities for team members to become familiar with the data needs and issues in their basin and brings awareness to issues and needs of the other individual programs within ADEM, increasing their level of knowledge and experience. Consequently, it increases opportunities for staff training and experience throughout the monitoring, assessment/303d listing, TMDL, and NPS programs. From 2014-2018, individual Basin Team meetings were conducted for the five major basins/basin groups in the state in order to develop individual Surface Water Quality Monitoring Plans (SWQMPs) for each basin. Now that the RRMP, RSMP, and CWMP all monitor on a 3-year rotation, Basin Team meetings are conducted only for the target basins that will be sampled in the upcoming cycle. The meetings are conducted in the fall of each year and include representatives from the WQB, NPS, and FOD. The Basin Team meetings are an opportunity for project managers to review and discuss their projects with the Basin Team to ensure that selected stations and requested parameters meet the needs for successful project completion. Any other topics and issues relevant to the basin may also be discussed during the meeting.

An overarching goal of the ADEM 2015 Monitoring Strategy was to support common program goals as effectively and efficiently as possible by coordinating monitoring efforts among partner agencies and stakeholders throughout Alabama and conducting monitoring of priority waters identified by these entities. Basin Teams work with state and federal agencies, as well as other stakeholders across the State to plan and coordinate monitoring efforts within priority watersheds.

Initiated in 2011, the State Agency Water Quality meeting is conducted every other year. The meeting, organized by the ADEM Water Quality Monitoring Coordinator, is attended by ADEM WD, FOD, and NPS staff, as well as staff from the Alabama Department of Conservation and Natural Resources (ADCNR), Geological Survey of Alabama (GSA), Alabama Department of Public Health (ADPH), the Alabama Department of Economic and Community Affairs (ADECA) Office of Water Resources (OWR), and the Alabama Forestry Commission (AFC). Additional state agencies with water interests are included over time whenever possible. The primary purpose of this meeting is to discuss issues related to water monitoring that are important to the agencies, to provide status reports on monitoring and activities, and to coordinate future monitoring activities.

Annual Section 106 Workplans are developed with EPA Region 4 and contain monitoring program commitments for the coming fiscal year. In addition, the Department also assists EPA in end-of-year reviews of progress toward implementation of these Workplan commitments.

Current and Future Initiatives

The 2019 and 2023 Programmatic Evaluation was conducted by managers of the ADEM surface water quality programs. The Basin Teams should be prepared to fully participate in the programmatic evaluation of future Monitoring Strategies.

X. General Support and Infrastructure Planning

Demands for water quality monitoring programs and staff continue to increase each year while staff levels remain static. To continue at its current level of effort and success, it is critically important that support and infrastructure for ADEM surface water quality programs increase (Table 5).

The current initiatives identified throughout this document support priorities of ADEM monitoring programs and are as follows:

1. Develop numeric nutrient criteria, concentrating on tributary embayments, estuaries, and coastal waters.
2. Develop tools to assess siltation impacts, develop siltation TMDLs, and track restoration efforts.
3. Continue to develop chemical, physical, and biological metrics and indicators for wadeable and nonwadeable streams, rivers, and estuaries.
4. Continue to collect data to define natural or background conditions.
5. Establish reference reaches in protected areas.
6. Monitor waters in all five categories.
7. Monitor the effectiveness of implemented watershed management plans and TMDLs.

Given the accelerated pace of water quality monitoring program needs and the incorporation of new techniques, the following table of current support and infrastructure resources is considered to be only an estimate of the resources needed to meet the annual monitoring target established as part of the 2025 Monitoring Strategy. Continued ability of monitoring programs to successfully manage increasing tasks over time will be contingent upon available resources, qualified staff, and core program changes and additions.

Table 5. Current support and infrastructure resources.

Program Status	**Annual FTEs**
RRMP, RSMP, CWMP, WMP • Data collection, processing, and identification, data entry, data analysis, and reporting	34
QA/QC and Database Support	3
Laboratory	20

XI. Monitoring Program Timeline

The following timeline spans the development of past, current, and future monitoring program activities. Historical information is provided as a reference to current program development and the projected future course. All programs and projects listed are included because of the commitment of staff and resources to all of these efforts and the related effect on schedules and timelines. Water quality monitoring demands continue to increase to enable ADEM to address very complicated and resource-intensive water quality issues, such as nutrient enrichment, siltation, and emerging contaminants. The future course and schedule of program development will depend heavily on availability of resources, core program changes/additions, future priorities, and emerging issues.

- Studies of Pollution in Streams of Alabama: **1949**
- Initiation of fish tissue contaminant sampling and analyses: **1970**
- Initiation of National Pollution Discharge Elimination System (NPDES) Compliance Sampling Inspections (CSIs): **1973**
- Initiation of Ambient Monitoring Program: **1974**
- Initiation of Wasteload Allocation (WLA) and Time-of-Travel Studies: **1983**
- Initiation of Use Attainability Analyses Studies: **1984**
- Initial EPA/ADEM statewide reservoir water quality monitoring survey: **1985**
- Initiation of Water Quality Demonstration Studies: **1985**
- Initiation of NPS Intensive Surveys: **1988**
- Initiation of state groundwater monitoring: **1989**
- ADEM/Auburn University statewide reservoir water quality monitoring survey: **1989**
- ADEM Reservoir Monitoring Program initiated: **1990**
- EPA/ADEM/Auburn University Clean Lakes Program Phase I Intensive Reservoir Surveys: **1990-1998**
- Fish Tissue Monitoring Program (FTMP) initiated: **1991**

- Ecoregional Reference Reach Monitoring Program initiated: **1991**
- Initiation of Coastal Watershed Surveys: **1993**
- Coastal Alabama Monitoring and Assessment Program (ALAMAP) probabilistic water quality assessments: **1993-1999**
- Initiation of Intensive Fecal Surveys: **1996**
- Development of Basin-wide Screening Assessment methods for streams and wadeable rivers: **1996**
- Development of Upland Alabama Monitoring and Assessment Program (ALAMAP) with EPA-Corvallis: **1996**
- Development of initial monitoring strategy, ASSESS: **1997**
- Implementation of watershed approach/basin rotation in monitoring programs: **1997**
- Implementation of Basin-wide Screening Assessments of streams and wadeable rivers: **1997-2004**
- Implementation of Upland Alabama Monitoring and Assessment Program (ALAMAP) probabilistic stream water quality assessments: **1997-2004**
- Completion of monitoring and assessment targeted at §303d-listed waterbodies to meet consent decree: **1999-2004**
- Initiation of Coastal Alabama Recreational Waters Monitoring Program: **1999**
- ADEM statewide probabilistic groundwater assessment: **2000-2002**
- National Coastal Assessment monitoring: **2000**
- Initiation of EPA-Required nutrient criteria development: **2000**
- Development and implementation of nutrient criteria for Alabama lakes: **2001-2025**
- Initiation of compliance monitoring for lakes nutrient criteria: **2001-2025**
- Development and implementation of periphyton assessment techniques: **2002-2019**
- ADEM and TVA Reservoir Water Quality Monitoring Coordination Meeting: **2002**

- Initiation of annual Surface Water Quality Monitoring Coordination Meetings: **2003**
- River segment monitoring incorporated into Reservoir Monitoring Program: **2004**
- Programmatic Evaluation of ASSESS: **2004**
- Environmental Quality Unit established: **2004**
- Cahaba River/Hatchet Creek Intensive Survey for Nutrient Target Development: **2004-2006**
- Initiation of the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) Marina Water Quality Study: **2004**
- Mobile Bay Water Quality Study conducted: **2004**
- New ADEM Central Laboratory construction: **2005-2006**
- Initiation of Assessment Database (ADB): **2005**
- Initiation of database module development for STORET upload: **2005**
- Designation of Water Quality Monitoring Coordinator: **2005**
- Initiation of Water Quality Assessment and Listing Methodology Documents: **2005**
- Implementation of revised Water Quality Monitoring Strategy: **2005**
- Expansion of Ambient Monitoring Network: **2005**
- Rivers and Streams Monitoring Program initiated: **2005**
- Rivers and Reservoirs Monitoring Program initiated: **2005**
- Initiation of Mobile Bay NEP Sub-estuary study: **2005**
- National Coastal Condition Assessment: **2005**
- Initiation of Elk River Watershed TMDL Development study: **2005**
- 316(b) Regulations and Required Biological Assessments: **2005**
- Development and Implementation of Clean Sampling/Trace Metals Collection/Analysis Techniques: **2005-2011**

- Nonwadeable/Large River Macroinvertebrate Bioassessment Method Development and Implementation: **2005-present**
- Coastal Waters Monitoring Program Development and Initiation: **2005-2011**
- Surface Water Quality and Biological Database Development, Implementation, and Historical Data Migration Completion: **2005-2011**
- Stream Fish Index of Biotic Integrity (IBI) Development: **2005-2012**
- Annual ADEM Water Quality Monitoring Coordination meetings: **2006-2014**
- ADPH adopts mercury action level of 0.33 µg/L in fish: **2006**
- Initiation of National Lakes Assessment monitoring: **2007**
- Development of nutrient criteria for Estuarine and Coastal Waters: **2007-present**
- Office of Environmental Quality established: **2008**
- Development of ADEM Macroinvertebrate Indices: **2008**
- *E. coli* criteria development and implementation: **2008-2009**
- Auburn University Algal Toxin Program participation: **2009-2014**
- Southeast Wetlands Monitoring Intensification Project: **2009-2013**
- National Coastal Condition Assessment: **2010**
- Weeks Bay Nutrient Sources Fate, Transport, and Effects Study: **2010-2012**
- Tallapoosa River Basin-Nutrient Criteria Development for Wadeable Streams Project: **2010-2012**
- Assessment of Water Quality Near Surface Coal Mining Facilities in the Black Warrior River Basin: **2010-2012**
- National Wetlands Condition Assessment: **2010-2012**
- ADEM's emergency response to Deepwater Horizon oil spill: **2010-2014**
- Programmatic Evaluation of the 2005 Water Quality Monitoring Strategy: **2011-2012**

- Biennial State Agency Water Quality Meeting Initiation: **2011**
- Completion of the first ADEM 5-year Wetlands Program Development Plan: **2011**
- Alabama and Mobile Bay Integrated Assessment of Watershed Health: **2012-2014**
- Development and implementation of Alabama's Wetland Workgroup: **2012-2015**
- Initiation, development, and implementation of Siltation Surveys: **2012-2024**
- Implementation of the 2012 Monitoring Strategy: **2012-2014**
- Nonwadeable/Large River Fish Community Bioassessment Method Development and Implementation: **2012-2019**
- Development of updated ADEM Macroinvertebrate Indices: **2013**
- Programmatic Evaluation of 2005 and 2012 Monitoring Strategies: **2014-2015**
- Calibration of Biological Condition Gradients for macroinvertebrate and fish communities in North Alabama streams and wadeable rivers: **2014**
- Initiation of Rain Event Sampling: **2014**
- FTMP discontinues dioxin monitoring in fish tissue: **2014**
- Forested Wetland Classification Surveys: **2014-2017**
- Implementation of 2015 Water Quality Monitoring Strategy: **2015-2019**
- National Coastal Condition Assessment: **2015**
- FTMP initiates monitoring on 3-year basin rotation: **2015**
- Expansion of Ambient Monitoring Network: **2015-2016**
- Implementation of Basin Teams: **2015-2019**
- Implementation of Even, Annual Sampling (EAST and EABT): **2015-2019**
- Calibration of Biological Condition Gradients for macroinvertebrate and fish communities in Alabama's Coastal Plain streams and wadeable rivers: **2015**
- Completion of Macroinvertebrate Data Entry Module: **2015**

- Development and Implementation of Wetland Nutrient Criteria Workgroup: **2015**
- Five-year update ecoregional reference reach guidelines: **2015**
- Annual review and update ecoregional reference reach status: **2015-2019**
- Implementation of RRMP and CWMP on 3-year monitoring cycle: **2015-2019**
- Completion of Fish Community Data Entry Module: **2016**
- Intensive Survey of Cahaba River/Hatchet Creek: Post-TMDL implementation assessment: **2016**
- Delineation of Coastal Waters along 10 Foot Contour Line: **2016**
- Revision of CWMP: **2016**
- Revision of Ambient Monitoring Network: **2016**
- FTMP initiates monitoring on 5-year basin rotation: **2017**
- Propose nutrient criteria for rivers and streams: **2017-present**
- Initiation of Programmatic Review of the 2015 Water Quality Monitoring Strategy: **2019**
- Rivers and Reservoirs Unit established: **2019**
- FTMP begins biopsy plug collection for mercury analysis in fish tissue: **2019**
- COVID Pandemic: **2020-2023**
- National Coastal Condition Assessment: **2020**
- Implementation of RSMP on 3-year basin rotation: **2020**
- FTMP collects only mercury samples (biopsy plugs) due to COVID pandemic: **2020-2021**
- Revision of Ambient Monitoring Network: **2021**
- Initiation of Public Water Supply (PWS) reservoir monitoring: **2021**
- Completion of Programmatic Review of 2015 Monitoring Strategy: **2023-2024**

- Implementation of 2025 Water Quality Monitoring Strategy: **2025-2030**
- National Coastal Condition Assessment: **2025**
- AGPT sample collection and analysis discontinued for RRMP and CWMP: **2025**

XII. SUMMARY OF ADEM WATER QUALITY PROGRAMS

A summary of each of the ADEM monitoring programs follows. These summaries are arranged by major monitoring program: Coastal Waters Monitoring Program, Rivers and Reservoirs Monitoring Program, Rivers and Streams Monitoring Program, Wetlands Monitoring Program, Fish Tissue Monitoring Program, Permit Compliance Monitoring Program, and the Groundwater Monitoring Program. Different types of monitoring that have historically occurred are conducted under these major programs using procedures that are consistent for the types of waterbodies in which they occur.

COASTAL WATERS MONITORING PROGRAM (CWMP)

Background

ADEM began monitoring water quality of coastal and near-coastal waters in the 1970s as part of the ADEM Ambient Monitoring Network. In 1993, Coastal Sub-watersheds Monitoring was implemented to assess the conditions of small sub-basins within Baldwin and Mobile Counties (ADEM 1993). During that same year, ADEM also implemented Coastal ALAMAP, a probabilistic monitoring program designed to statistically assess 100% of the larger, estuarine receiving waterbodies within Alabama's coastal area (ADEM 1993). In 1998, the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) was implemented to document water quality conditions within Mobile and Baldwin Counties and to evaluate the effectiveness of restoration efforts. In 1999, in cooperation with the Alabama Department of Public Health (ADPH), ADEM implemented the Coastal Alabama Recreational Waters Program to routinely monitor bacteria levels at five public recreation beaches along the Gulf Coast.

In 2011, ADEM initiated the Coastal Waters Monitoring Program (CWMP) and documented a plan for a more comprehensive program in the 2012 Monitoring Strategy. The 2012 CWMP focused on monitoring wadeable and nonwadeable waters in the coastal area. It added routine assessments and water quality data collection at: 1) historical trend sites; 2) permanent fixed sites located in 12 coastal watersheds where additional long-term monitoring data are needed; 3) targeted sites selected to verify and document current conditions at 303(d)/TMDL stream segments; and 4) targeted sites within watersheds selected as priorities by the ADEM NPS Management Program. Sampling was conducted 3 to 12 times per year, as needed and/or as resources allowed.

The 2012 CWMP was designed to complement the monitoring activities listed below:

1. **Coastal Alabama Beach Monitoring Program:** This monitoring involves the collection of water samples from twenty-five public recreational sites in Alabama's coastal waters. Samples are analyzed for the indicator bacteria, *Enterococci*. The objective of this program is to increase public awareness and to provide valuable water quality information to help the public make more informed decisions concerning their recreational use of Alabama's natural coastal waters. A summary and data from this program are available for public access on the ADEM website.

2. **Alabama Coastal Non-Point Pollution Control Program (ACNPCP):** This program implements Coastal Alabama Targeted Water Quality Studies that are designed to locate sites and to identify and document baseline water quality conditions that exist within the two coastal counties of the State. These studies are designed to correlate BMPs as they relate to landuses and potential nonpoint source (NPS) impacts in close proximity to waterbodies within the Mobile and Baldwin County sub-watershed areas. Completed reports are available for public access on the ADEM website.

3. **National Coastal Condition Assessment (NCCA)**: This is a nation-wide EPA probabilistic monitoring survey conducted every five years. The purpose of the assessment is to determine the condition of estuarine waters and coastal resources both on a state and national scale. NCCA reports are available on the Coastal page of the ADEM website.

Objectives

The objectives of the CWMP are to:

1. Establish, review, and revise water quality standards.
2. Determine water quality standards attainment.
3. Identify high-quality waters.
4. Identify causes and sources of water quality impairments.
5. Evaluate program effectiveness.
6. Estimate water quality trends.
7. Estimate overall water quality.

Design

For regulatory purposes, coastal waters were redefined in 2015 as waters delineated within the 10' contour line. A 3-year rotation of these waters was established for the CWMP, with the coastal area divided into the Western, Eastern, and Mobile Bay areas. The rotation corresponds well with the 6-year data assessment period required for the IWQMAR. A map of the 3-year basin cycle is provided in Figure 5.

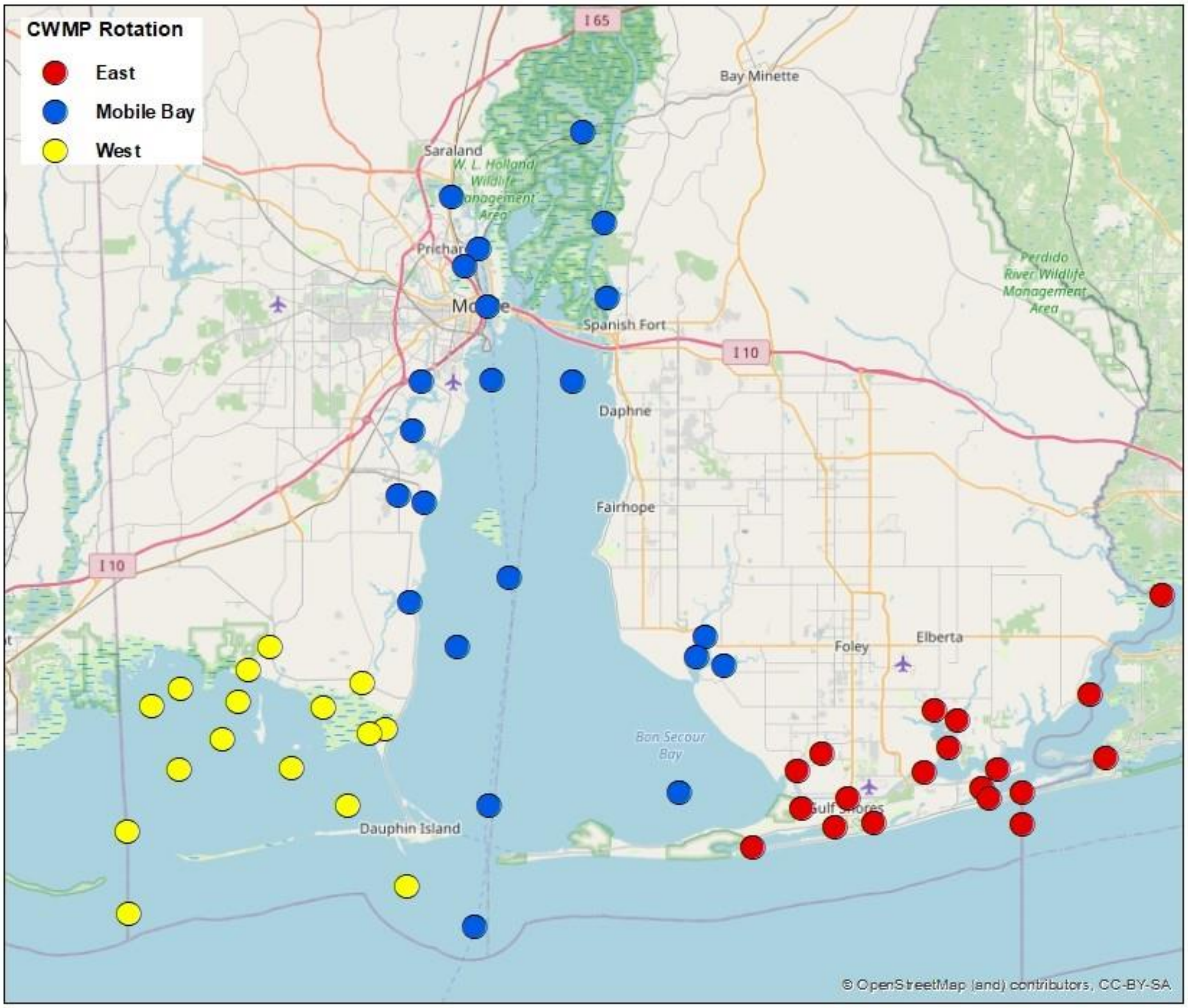

Figure 5. Locations of ADEM CWMP stations on 3-year rotation.

The 2015 CWMP incorporated a combination of long-term fixed network and targeted sites. ADEM maintains a network of long-term, fixed ambient monitoring stations as part of the RSMP, RRMP, and CWMP called the Ambient Monitoring Network. These are permanent monitoring locations established to identify long-term trends in water quality and to develop TMDLs and water quality standards.

Collection of data to establish nutrient criteria for estuaries was identified as a priority of the 2015 Monitoring Strategy and remains a goal of the 2025 Strategy. As part of this effort, intensive monitoring is conducted at each coastal station monthly, March-October, on a 3-year rotating basin schedule. This data will provide a comprehensive determination of water quality throughout the algal growing season and can be used to develop nutrient criteria and TMDLs.

In addition, targeted monitoring is conducted in watersheds to document water quality conditions before and after best management practices are implemented. These studies are conducted in conjunction with the ACNPCP and the Mobile Bay NEP, both of which focus restoration efforts within the 12-digit HUC sub-watersheds of the Escatawpa, Mobile-Tensaw, and Perdido River basins located within Baldwin and Mobile Counties. Pre- and post- restoration monitoring is also conducted for the ADEM statewide §319 and TMDL programs and the National Water Quality Initiative (NWQI) of the National Resource Conservation Service (NRCS).

Core and Supplemental Water Quality Indicators

Core Indicators: Secchi transparency, photic depth, total depth, water temperature, turbidity, total dissolved solids, total suspended solids, specific conductance, alkalinity, dissolved oxygen, pH, salinity, ammonia, nitrate+nitrite-nitrogen, total Kjeldahl nitrogen, dissolved reactive phosphorus, total phosphorus, chlorophyll *a*, 5-day carbonaceous biochemical oxygen demand, and field observations (recent/current weather, air temperature, and flow conditions).

Supplemental Indicators: *E. coli*, *Enterococcus,* hardness, ultimate carbonaceous biochemical oxygen demand, total/dissolved metals, low-level mercury, 72-hour diurnal dissolved oxygen, and other in situ parameters as needed.

RIVERS AND RESERVOIRS MONITORING PROGRAM (RRMP)

Background

ADEM began monitoring lake water quality statewide in 1985, followed by a second statewide survey in 1989. In 1990, the Reservoir Water Quality Monitoring Program was initiated by ADEM. In 2005, the program was changed to the Rivers and Reservoirs Monitoring Program (RRMP) with the addition of free-flowing, nonwadeable rivers. The RRMP assesses the water quality and trophic status of nonwadeable rivers and publicly-owned lakes/reservoirs across the state. ADEM has defined publicly-owned lakes/reservoirs as those that are of a multiple-use nature, publicly-accessible, and exhibit physical/chemical characteristics typical of impounded waters. Lakes designated strictly for water supply, privately owned lakes, or lakes managed by the ADCNR strictly for fish production were not initially included in this definition. Currently, forty-one lakes/reservoirs meet this definition of being publicly-owned. In addition, ADEM began monitoring Public Water Supply (PWS) reservoirs in 2021, adding fourteen drinking water lakes to the RRMP basin rotation, bringing the total number of lakes/reservoirs monitored regularly by the RRMP to fifty-five.

Beginning with the 2012 Monitoring Strategy, monitoring of lakes/reservoirs and nonwadeable rivers occurred at two levels of effort under the RRMP:

1. Intensive monitoring of river, main-stem reservoir, and tributary embayment stations conducted monthly, April-October, on a 5-year basin rotation
2. Compliance monitoring of reservoirs with established nutrient criteria conducted monthly, April-October, at least once every three years

Since 1985, monitoring conducted within these waterbodies has provided an extensive dataset that the Department uses to develop appropriate criteria and standards for each of the State's forty-one publicly-owned lakes/reservoirs. Progress made as a result of the 2005 and 2012 Monitoring Strategies enabled ADEM to implement revisions to the design of the RRMP in order to better meet the needs of Alabama's assessment/listing program and 2014 Nutrient Criteria Implementation Plan.

Objectives

The objectives of the RRMP are:

1. To develop and maintain a water quality database for all rivers, publicly-accessible lakes, and *PWS* reservoirs in the state sufficient to conduct comprehensive assessments of water quality, to categorize waters for the IWQMAR, to develop criteria, and to determine criteria compliance.
2. To establish trends in river and lake trophic status that are only established through long-term, consistent monitoring efforts.
3. To conduct assessments of water quality for all publicly-accessible lakes as required by Section 314 of the Clean Water Act.

The 2015 Monitoring Strategy prioritized the development and implementation of numeric nutrient criteria for tributary embayments and PWS lakes. While criteria development for embayments are still under development by ADEM's Water Quality Branch (WQB), the RRMP has made progress in the development of PWS reservoir nutrient criteria by completing one 3-year cycle (2021-2023) of PWS reservoir monitoring in fourteen drinking water lakes across the state.

Design

In 2015, the RSMP went from a 5-year basin rotation to annual statewide monitoring as a result of an intensive program review conducted in 2014. However, monitoring all reservoirs in a river system during the same year was determined to be an important data need for programs that rely on RRMP data. With an intensified sampling effort, all RRMP stations shifted from a 5-year basin rotation to a 3-year basin rotation, eliminating the need for a separate compliance monitoring rotation for reservoirs.

A 3-year basin rotation corresponds well with the 6-year data assessment period required for the IWQMAR. Maintaining a consistent and achievable level of effort year-to-year was an important factor in establishing the rotation. In 2020, the basin rotation schedule was slightly modified when the RSMP changed from annual statewide monitoring to a 3-year basin rotation so that both programs could sample the same target basins each year. This enabled the two programs to work together to sample a basin from the headwaters to the larger river and reservoirs each year.

A map of the current 3-year basin cycle is provided in Figure 6.

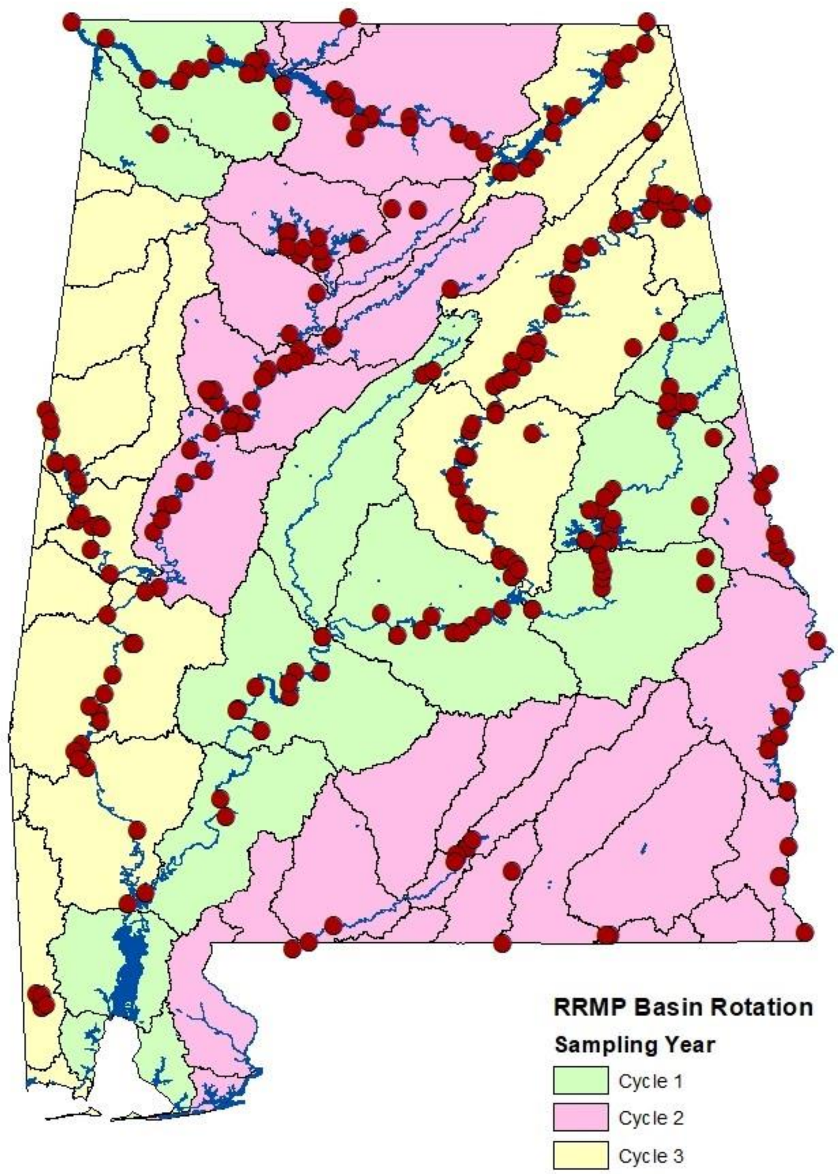

Figure 6. Locations of ADEM RRMP stations on 3-year rotation.

Reservoirs and lakes monitored for the program range in size from 54 to 45,200 acres. Smaller lakes have a minimum of one station, typically in the dam forebay. In larger reservoirs, additional stations are added in the mid-reservoir, upper reservoir (transition area), and tailrace as needed. Tributary embayment stations are established in larger embayments and/or those with larger inflows, with selection of embayments distributed throughout the range of human disturbance. River stations are located along the length of the flowing reach to the extent that resources allow, with stations partitioned according to tributaries and point/nonpoint sources.

Intensive monitoring

Intensive monitoring of river, main-stem reservoir, and tributary embayment stations is conducted monthly, April-October, on a 3-year rotating schedule to provide a comprehensive determination of water quality throughout the algal growing season and to provide data that can be used to develop nutrient criteria and TMDLs. Data are analyzed at the end of the sampling season to determine use support.

Current Initiatives

The ADEM monitors reservoir tributary embayments to provide data to develop criteria for these embayments as outlined in Alabama's Nutrient Criteria Implementation Plan (ADEM 2021b). In addition, monitoring tributary embayments also serves as an indicator of water quality in upstream tributaries and provides a basis for establishing nutrient criteria protective of upstream uses.

ADEM is also conducting 72-hour diurnal dissolved oxygen surveys within reservoir embayments. The surveys are conducted in accordance with the RRMP 3-year basin cycle.

Collection and analysis of samples for low-level mercury (LL Hg) was identified as a data need in the 2005 and 2012 Monitoring Strategies and the 2014 Programmatic review. Forty LL Hg sites were established around the state to assist with the development of statewide TMDLs for mercury in fish and for NPDES permit development. Some sites are also located near coal-fired power plants to evaluate trends in mercury concentrations after the elimination of coal from the production of electricity. With current resources, the RRMP samples twenty of these sites each year so that a complete rotation is conducted every two years. The fourth rotation of LL Hg sampling was completed in 2025.

Core and Supplemental Water Quality Indicators

Core Indicators: Secchi transparency, photic depth, total depth, water temperature, turbidity, total dissolved solids, total suspended solids, specific conductance, alkalinity, dissolved oxygen, pH, ammonia, nitrate+nitrite-nitrogen, total Kjeldahl nitrogen, dissolved reactive phosphorus, total phosphorus, chlorophyll *a*, 5-day carbonaceous biochemical oxygen demand, chloride, and field observations (recent/current weather, air temperature, and flow conditions).

Supplemental Indicators: *E. coli*, hardness, ultimate carbonaceous biochemical oxygen demand, total/dissolved metals, hardness, dissolved organic carbon, color, low level mercury, 72-hour diurnal dissolved oxygen, and other in situ parameters as needed.

Reporting

Rivers and Reservoirs Monitoring Program summary reports can be found on the ADEM website.

RIVERS AND STREAMS MONITORING PROGRAM (RSMP)

Background

The ADEM Rivers and Streams Monitoring Program (RSMP) is a watershed-based monitoring program designed to provide data that links watershed condition and assessment results. Implemented on a 3-year basin rotation, the RSMP uses watershed condition to plan monitoring activities along a full disturbance gradient to produce a dataset representing both the full stressor gradient and the full biological condition gradient. A primary goal of this monitoring design was to provide stressor-response data that can be used to develop criteria and indicators. Using this Strategy, the RSMP built a comprehensive dataset that was used to develop and implement Biological Condition Gradient (BCG) indices for macroinvertebrates and fish in wadeable rivers and streams throughout the State within ten years.

Objectives

The RSMP Monitoring Strategy is designed to meet seven broad CWA objectives in all non-navigable, flowing waters over time. Those objectives are:

1. To establish, review, and revise water quality standards.
2. To determine water quality standards attainment.
3. To identify high quality waters.
4. To identify impaired waters.
5. To estimate overall water quality.
6. To identify causes and sources of impairment.
7. To evaluate program effectiveness and trends in biological, chemical, and physical conditions.

A 2019 Critical Elements Review (CER) classified the RSMP as a program of the highest technical rigor, providing scientifically defensible data in support of management decisions, able to detect incremental changes in biological, chemical, and physical conditions along a gradient of stress and to associate biological response to stressors and their sources (Yoder 2019). Monitoring programs at this level of technical development generally focus on program maintenance, analyzing the existing datasets to fully develop and implement the most technically advanced objectives of the Strategy, and incorporating new advances in science and technology to continue to improve the program (USEPA 2013).

Data Analysis:

The RSMP will continue to analyze its existing dataset to 1) relate biological response to stressors for development of biological indices and numeric criteria and to improve stressor identification and the causal analysis process; 2) calibrate its index of overall estimate of water quality; 3) calibrate its diatom index; 4) document its performance-based characteristics (accuracy and precision); 5) evaluate the effectiveness of screening-level macroinvertebrate methods; and 6) reconvene its Biological Condition Gradient (BCG) Workgroups to review and revise the fish and macroinvertebrate BCG attributes and indices based on the use of these tools since their development in 2014. These tasks can be completed within three years (See the Objectives and Data Analyses Sections).

Programmatic Evaluation

The next steps in the RSMP Monitoring Strategy hinge on analysis of the existing 20-year dataset. Recent programmatic reviews have indicated the need for additional biological monitoring in flowing rivers and streams and the need to extend the RSMP to monitor perennial, flowing headwaters. The RSMP has operated at capacity since implementing its 2005 Monitoring Strategy. However, it is not feasible to address these monitoring gaps while continuing the baseline monitoring routine adopted in 2005, when the RSMP began monitoring conventional water quality parameters to the degree necessary to provide data to assist in development of Biological Condition Gradient (BCG) indices. Between 2005 and 2015, the RSMP collected eight conventional samples at every station when only three were required for assessment when a macroinvertebrate survey had been conducted, as specified in the 2000-2014 ALM. Now that the BCG indices are complete, the need to continue this level of sampling should be evaluated. If the RSMP can reduce conventional samples without decreasing accuracy of monitoring and assessment results, it will allow resources to be used to increase biological sampling and to potentially increase the number of stations monitored annually.

Monitoring Design

The RSMP is conducted on a 3-year basin rotation, linking the RSMP to the monitoring conducted in coastal waters and nonwadeable rivers and reservoirs (See the Monitoring Design Section).

ADEM uses 12-digit Hydrologic Unit Codes (HUC-12) to plan, prioritize, and track monitoring activities. Using 12-digit HUCs has facilitated collaboration with multiple agencies and stakeholders also working to measure watershed conditions and to monitor and restore waterbodies at the HUC-12 scale. ADEM used HUCs as the basis for delineating wadeable, flowing monitoring units (WFMUs) to provide a broad inventory of RSMP monitoring needs and coverage (Figure 7). In 2018, each of the 1,486 12-digit HUCs was assigned to one primary monitoring program based on specific criteria. One thousand RSMP HUC-12s were identified. These RSMP HUC-12s:

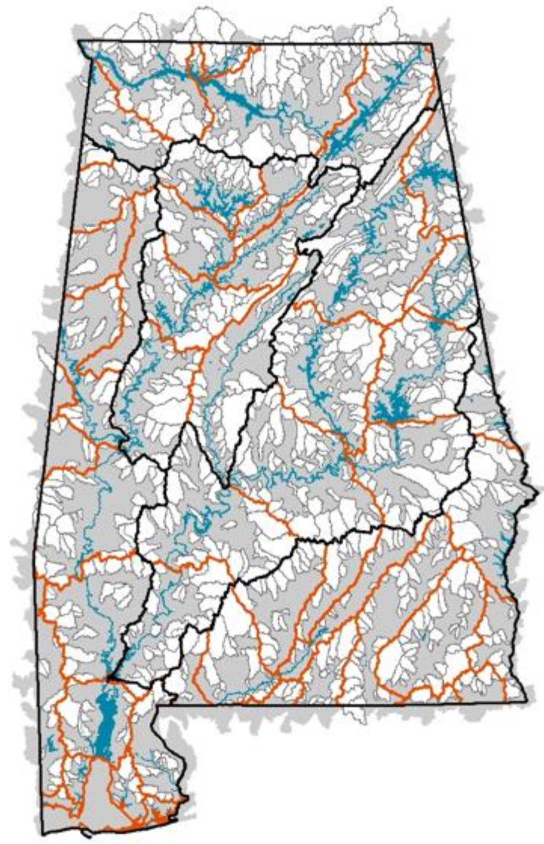

Figure 7. Delineated wadeable, flowing monitoring units.

- do not contain tidally influenced waters.
- have land cover consisting of <15% wetland.
- are not located within ecoregion 65p, are not a reservoir/lake or embayment, and do not contain a nonwadeable boat (NWB) station.

Wadeable, flowing monitoring units are defined as the downstream-most, fully wadeable accessible monitoring location. ADEM concentrated development of its WFMUs within these HUC-12s, with 1,069 delineated. This network represents all wadeable, flowing rivers and streams throughout the State. In conjunction with a measure of watershed condition, it is used to plan monitoring along the full condition gradient. Data from WFMUs are used to provide an overall estimate of water quality and to develop criteria and biological indicators.

The RSMP has categorized the perennial, flowing rivers and streams it monitors by drainage area, width, depth, and primary sampling protocol to determine methods to inventory perennial, flowing headwaters to meet Monitoring Strategy objectives. This provides a tool for identifying monitoring gaps and waterbody types (Table 6).

Table 1. Category and characteristics of waterbodies monitored as part of the RSMP. Each category is monitored using different methods. The RSMP assigns different sampling periods to different waterbody types to make the most of limited resources.

Monitoring Program	Category	Sampling Protocol	Drainagae Area (sq mi)	Width (ft)	Mean Depth (ft)	Reach Length (ft)	Survey Conducted	Biological Sampling Period
RSMP	Headwaters (Perennial)	TBD	<5	Single channel	<4	200		Mar-Apr
		TBD		Braided		300	WMB	
	Streams	W-BIO	5 to <90	Single channel	<4	300	WMB	mid-Apr - late May
				Braided		600	WMB	
	Transitional (Large Streams/Small Rivers)	W-WQS/ NWG-S	>90 to <1,000	<100	<4	600	TMB	Sep-Nov
					>4	900	TMB	
				>100	<4	600	2B-TMB	
					>4	900	2B-TMB	

By definition, ADEM monitoring programs recognize the longitudinal link between coastal waters, upstream to nonwadeable rivers, wadeable rivers and streams, and headwaters. Headwaters also represent a branching network of small streams that greatly contribute to the biological diversity downstream as they converge together and become larger streams and rivers (Finn et al. 2011). Higher density of headwaters within a watershed contributes to high quality waters with high biodiversity downstream and has also been shown to be highly predictive of the success of downstream restoration efforts, serving as the source of macroinvertebrates to recolonize these areas (Dodds and Oakes 2008, AFS 2018, Miltner and McLaughlin 2019) The filling, pumping, ditching, and removal of headwater streams impacts downstream biodiversity (Jackson 2019).

Site Selection

By defining relatively homogeneous ecological areas, ecoregions provide a geographic framework for more efficient management of aquatic ecosystems and their components (Hughes et al. 1986, and Hughes and Larsen 1988) and provide a scientifically defensible method of defining expected habitat, biotic, and chemical conditions within wadeable streams and rivers in the Piedmont, Southeastern Plains, Ridge and Valley, Southwestern Appalachians, Interior Plateau, and the Southern Coastal Plain Ecoregions. The RSMP also categorizes waters by other stable site characteristics, such as drainage area, gradient, width, depth, etc. It will be important to establish ecoregional reference reaches along the longitudinal gradient to provide the data needed to define site classes with distinct chemical, physical, and biological characteristics.

The RSMP defined different sampling periods for wadeable streams, perennial headwaters, and transitional streams and rivers (Table 6). While this strategy enables ADEM to sample more types of waterbodies throughout the year, it makes it more difficult to fully integrate it into ADEM's Assessment & Listing and TMDL programs. To increase flexibility and program integration, the RSMP needs to conduct intensive monitoring in wadeable, flowing rivers and streams-on a small scale-to develop and calibrate biological indices to other sampling periods.

Delineating WFMUs and FHMUs provides the RSMP the full inventory of each waterbody type throughout the State. Describing each reference reach and MU by ecoregion, drainage area, gradient, stream width and water depth provides natural characteristics that define site classes among ecoregions and along the natural transitions from headwaters to nonwadeable rivers.

A subset of WFMUs are monitored annually. They are randomly selected to ensure that the full gradient of watershed conditions is monitored to provide data for indicator and criteria development and to provide an estimate of overall water quality conditions.

If resources allow, monitoring of FHMUs will be concentrated within high-quality wadeable, flowing rivers and stream reference reaches also being sampled. The natural variability in the density of headwater streams within high-quality watersheds will be documented as a potential indicator of high-quality waters or as a potential cause of impairment to downstream waters.

Measure of watershed condition

The RSMP is a watershed-based monitoring program that uses a measure of watershed condition to plan monitoring activities along a full disturbance gradient to produce a dataset representing both the full stressor gradient and the full biological condition gradient. The ADEM plans to adopt the EPA Preliminary Healthy Watersheds Assessment (PHWA) and the Recovery Potential Screening (RPS) tool. These tools are easily accessible, readily available, and scalable from catchment to larger watersheds with relatively little effort.

Indicators

A primary goal of the RSMP Strategy is to conduct at least one biological survey at all perennial, flowing river and stream stations. ADEM will continue to conduct macroinvertebrate and fish community surveys at different locations to maximize the number of sites surveyed annually.

The RSMP continues to develop stressor-specific surveys to support a weight-of-evidence assessment approach. These are screening-level surveys conducted quickly at a subset of sites where recent monitoring shows a high potential for impairment from a specific pollutant. Examples include rapid periphyton surveys, diurnal DO studies, and siltation surveys to further document impairment from nutrient enrichment and siltation.

<u>Core Indicators</u>

In situ measures: Flow (where appropriate), Total stream depth, Sampling depth, Water temperature, Dissolved oxygen, pH, Specific conductance, Turbidity

Habitat Survey: Wadeable Riffle-run, Wadeable Glide-pool, Nonwadeable

Biological Surveys: Macroinvertebrates or Fish IBI

Physical parameters: Total suspended solids, Total dissolved solids, Hardness, Alkalinity

Chemical parameters: Ammonia-nitrogen, Nitrate+nitrite-nitrogen, Total Kjeldahl nitrogen, Total phosphorus, Dissolved reactive phosphorus, Chlorophyll *a*, Total organic carbon, Five-day carbonaceous biochemical oxygen demand, Chlorides, Sulfate

Metals: Total and Dissolved Aluminum, Total and Dissolved Iron, Total and Dissolved Manganese, Total and Dissolved Antimony, Total and Dissolved Arsenic+3, Total and Dissolved Cadmium, Total and Dissolved Chromium+3, Total and Dissolved Copper, Total and Dissolved Lead, Total and Dissolved Nickel, Total and Dissolved Selenium, Total and Dissolved Silver, Total and Dissolved Thallium, Total and Dissolved Zinc

<u>Supplemental Indicators: Screening-level</u>

Potential nutrient impairments: Periphyton Survey, Diurnal dissolved oxygen surveys

Potential siltation impairments: Habitat survey, Siltation survey

Potential organics impacts: Pesticides, semi-volatiles, Atrazine, Glyphosate

<u>Supplemental Indicators: TMDL development and program effectiveness</u>

E. coli impairments: Intensive Geomean Surveys

Nutrient impairments: Periphyton surveys, Diurnal dissolved oxygen surveys

Siltation impairments: Rain-event sampling

WETLANDS MONITORING PROGRAM (WMP)

Background

The National Wetland Inventory (NWI) estimates freshwater and tidal wetlands to comprise 3,600,000 and 27,000 acres of Alabama, respectively. Together they account for approximately 10% of the State. Wetlands in Alabama are incredibly varied, ranging in size from small, isolated areas of less than one acre to “America’s Amazon,” Alabama’s largest wetland, the 100,000 acre, tidally influenced Mobile-Tensaw Delta. Located north of Mobile Bay, it ranges from five to ten miles wide and 40 miles long (USFWS n.d.).

Wetlands are transitional between terrestrial and aquatic habitats. They are found where water covers the soil or where the water table is at or near the surface all year, or at varying times of the year including the growing season, greatly affecting soil development. These conditions result in unique communities of terrestrial and aquatic plants and animals. They are an important ecological resource, functioning in many ways important to the landscape, including flood control, erosion control and bank stability, improved water quality, and nutrient retention. They support high levels of biological diversity and serve as nesting, breeding, nursing and feeding grounds vital to many species.

However, these wetlands are less than half of the estimated 7,500,000 acres of wetland that have disappeared over the last 200 years—drained, filled, and converted to cropland and pine plantations or developed into residential, urban, or industrial areas. Alabama’s State Wildlife Action Plan (SWAP 2015) included several wetland types in its list of fifteen priority wildlife habitats, with 27 “greatest conservation need” species dependent on these wetland habitats.

Objectives

The initial goals of the WMP were to monitor and assess all wetland types throughout the State and to develop a comprehensive, long-term dataset to meet all Monitoring Strategy objectives. The program focused on identifying reference wetlands, which involves defining site classes of wetlands closely associated with high-quality wadeable, flowing river and stream reference watersheds. These wetlands are integral to natural reference conditions and the continued presence of high-quality waters downstream. The natural variability in the percent wetland land cover within high-quality watersheds were documented as a potential indicator of high-quality waters, and as a potential cause of impairment to downstream waters.

The WMP focused on monitoring reference-quality headwater wetlands connected to blackwater streams and rivers. Monitoring these connected ecosystems supports a Departmental priority to define chemical/physical conditions characteristic of blackwater streams and rivers. Future efforts may focus on high-quality wetlands identified by the SWAP and common within important Strategic Habitat Units (SHUs).

Monitoring Design

Like ADEM's other monitoring programs, the WMP was conducted on the 3-year basin rotation, but it was also focused on wetlands located within the Southeastern Plains ecoregion that are closely associated with high-quality, wadeable rivers and streams watersheds.

Statewide Inventory of Wetlands

A complete, accurate statewide inventory of wetlands is widely recognized as a priority (SWAP 2015). Multiple methods of wetland classification have been developed and are used by different state and federal agencies, as well as academia, to meet varied and important objectives:

EPA's Preliminary Healthy Watersheds Assessment (PHWA) and Recovery Potential Screening (RPS): These are tools that include the National Land Cover Dataset (NLCD) wetlands categories at the catchment scale (See Monitoring Design Section).

National Wetlands Inventory (NWI): This program produces maps of wetlands from aerial imagery, labeling map classes using the classification of wetland and deepwater habitats (Cowardin et al.1979). It includes three levels (System, Subsystem, Class) for marine, estuarine, riverine, lacustrine, and palustrine habitats systems. Wetlands with rooted or floating vegetation are classified as palustrine or lacustrine (FGDC 2013). It is used by the EPA National Wetlands Condition Assessment.

Hydrogeomorphic (HGM) Classification: This approach supports functional condition assessment (Smith et. al. 1995) of a specific wetland referenced to data collected from wetlands across a range of physical conditions. It uses geomorphic position and hydrologic characteristics to group wetlands into seven different wetland classes as defined by Brinson (1993). The seven classes are: depressional, riverine, mineral flats, organic flats, tidal fringe, lacustrine fringe, and sloping. It is used to delineate wetlands by the US Army Corps of Engineers (USACOE).

NatureServe Terrestrial Ecological Systems: This classification of terrestrial environments integrates vegetation communities with landscape setting, soils, hydrology, and other natural dynamics. This classification system can be cross-walked to the other classification systems. This will be an important component of a statewide inventory, as ADEM works with multiple entities using each of these systems.

Site Selection

The WMP focused on monitoring reference-quality headwater wetlands connected to blackwater streams and rivers. Monitoring these connected ecosystems supports a Departmental priority to define chemical/physical conditions characteristic of blackwater streams and rivers. Blackwater stream systems are characterized by their tea-colored, highly tannic water with high concentrations of dissolved particulate organic matter and iron. These streams are often naturally acidic, characterized by a pH lower than Alabama's criterion of 6.5 su for *F&W* streams. They are formed as groundwater seeps slowly through highly organic soils up to the surface, creating extensive headwater wetlands. Although often spatially close, alluvial streams are located within heavy clay basins, producing turbid brown water, while the flow in spring-run streams is very clear due to their artesian openings and direct contact with groundwater aquifers. Future efforts may focus on high quality wetlands identified by SWAP and common within important Strategic Habitat Units (SHUs).

Indicators and method development

In 2016, ADEM began analyzing dissolved organic carbon (DOC) content and water color in samples collected at all stations located in the Southeastern Plains (65) and Southern Coastal Plains (75) ecoregions to determine if waters visually identified as tannic are naturally characterized by pH >6.5, to determine if DOC and color could be used to classify waterbodies as "*blackwater*," and to establish pH criterion appropriate to these waterbodies.

The EPA is in the process of developing guidance to help states and tribes monitor and assess blackwater stream and river systems (Flotemersch personal communication). As part of this effort, EPA is analyzing the ADEM dataset because Alabama was one of the few states to report DOC as a core indicator of its monitoring programs. EPA is in the process of analyzing this data, along with catchment scale metrics from StreamCat to identify a set of indicators that best predict blackwater conditions. These analyses should be completed within the next three years.

ADEM conducted Wetland Rapid Assessment Protocols (WRAPs) and plant and amphibian surveys of wetlands associated with wadeable ecoregional reference blackwater river and stream reaches monitored as part of the RSMP. The wetland surveys were conducted to fully develop these methods, to train staff, and to begin including wetland monitoring as integral to defining baseline reference conditions used to monitor and assess the health of blackwater streams. Standard operating procedures to conduct plant and amphibian surveys were completed in 2023.

These efforts were expanded in 2024 to characterize three types of ecoregional reference streams and their associated wetlands—blackwater streams, alluvial streams, and clear-run streams, all located within the Southeastern Plains (Armbruster et al. 2025). The study includes the collection of quarterly water quality samples collected from both the wetland and its receiving stream, as well as multiple biological surveys.

In 2015, ADEM convened a wetland workgroup to discuss state wetland monitoring objectives, the need for a complete and accurate wetland inventory and classification system, and collection and survey methods. A wetland workgroup needs to be convened again to revisit these topics and to standardize sample and survey methods for the purposes of program collaboration and data consistency.

<u>Core Indicators</u>

In situ measures: Flow (where appropriate), Total stream depth, Sampling depth, Water temperature, Dissolved oxygen, pH, Specific conductance, Turbidity

Physical parameters: Total suspended solids, Total dissolved solids, Hardness, Alkalinity

Chemical parameters: Ammonia-nitrogen, Nitrate+nitrite-nitrogen, Total Kjeldahl nitrogen, Total phosphorus, Dissolved reactive phosphorus, Chlorophyll a, Total organic carbon, Five-day carbonaceous biochemical oxygen demand, Chlorides, Sulfate

Metals: Total and Dissolved Aluminum, Total and Dissolved Iron, Total and Dissolved Manganese, Total and Dissolved Antimony, Total and Dissolved Arsenic+3, Total and Dissolved Cadmium, Total and Dissolved Chromium+3, Total and Dissolved Copper, Total and Dissolved Lead, Total and Dissolved Nickel, Total and Dissolved Selenium, Total and Dissolved Silver, Total and Dissolved Thallium, Total and Dissolved Zinc

Field Assessment Forms

Wetlands: WRAPs (Troy University)

Streams: Habitat Surveys (Wadeable Riffle-run, Wadeable Glide-pool)

Biological Surveys

Streams and Wetlands: Macroinvertebrates and Fish surveys conducted using different methods; results should be compared

Wetlands only: plant community, amphibians, turtles, and birds

FISH TISSUE MONITORING PROGRAM (FTMP)

Background

ADEM and its predecessor, the Alabama Water Improvement Commission (AWIC), have collected fish for analysis of contaminant levels since 1970. For the 20 years that followed, fish collections focused on areas of known or suspected contamination. In 1991, ADEM instituted the Fish Tissue Monitoring Program (FTMP) to provide statewide screening of bioaccumulative contaminants in fish tissue and to provide the ADPH with data needed for determination of potential risk to those who consume fish from Alabama waters. The program historically exists as a cooperative effort between ADEM, ADPH, ADCNR, and TVA.

Following expansion of the program to statewide screening, fish from all of Alabama's major reservoirs, rivers, streams, and state-managed public fishing lakes were collected over a 5-year period. Data from these locations were provided to the ADPH for issuance, modification, or removal of fish consumption advisories.

In 1997, the FTMP was incorporated into the ADEM Watershed Management Approach. Pursuant to this approach, water quality of each major drainage basin in the state was assessed by ADEM on a 5-year rotating basis. In addition to the basin locations sampled each year, ADEM continued to sample areas of concern outside the focus basin as needed or requested by cooperating agencies and as resources allowed.

Because of the variability in contaminant concentrations observed in fish collected from locations over several years and the need for additional monitoring at a number of locations, the approach to annual monitoring was refined in 2002. Annual fish tissue monitoring became multi-faceted and site selection was determined through the following process:

1. Sampling locations throughout the focus basin (Tier I basin screening);
2. Repetitive sampling of sites where ADPH determined that EPA/FDA action levels had been exceeded (Tier II known impact);
3. Sampling remaining areas across Alabama where fish had not been collected for the program (Tier I screening).

Repetitive sampling of sites where EPA/FDA action levels had been exceeded was conducted as follows:

1. Sites that exceed EPA/FDA action levels for the first time were sampled for a minimum of two concurrent years to provide verification of contaminant concentrations, as requested by ADPH;
2. Sites where ADPH consumption advisories currently existed were sampled at a minimum of every three years to provide data for analysis of trends in contaminant concentrations.

The frequency of sampling for these sites was dependent on available resources. The FTMP also monitored sites outside the focus basin as needed or when requested by cooperating agencies.

In June 2006, ADPH adopted the EPA guidance level for mercury in fish of 0.33 µg/g for issuance of public consumption advisories, replacing the FDA guidance level of 1.0 µg/g previously used. With the reduction in the guidance level for mercury, many more sites received ADPH consumption advisories as they were sampled in the years to follow. In March 2014, the FTMP discontinued dioxin monitoring below paper mills. Dioxin monitoring was discontinued because levels in fish had been below method detection levels since 2004 and below levels requiring consumption advisories since the early 1990s.

The program was further modified in 2015 to not only provide the data needed by ADPH for consumption advisories, but to also meet the data needs of the ADEM' ALM. In order to meet these needs, fish tissue samples were collected within each major river basin in the state on a 3-year rotating basis, providing two repetitions of sampling within the 6-year period required for monitoring data in the ALM. The initial regional rotation was as follows:

- Alabama, Cahaba, Tallapoosa, and Tennessee Rivers (2015);
- Coosa and Tombigbee Rivers (2016);
- Black Warrior, Perdido-Escambia, Choctawhatchee, Pea, and Chattahoochee Rivers (2017).

In addition to the major river basin schedule, coastal sample locations (locations south of the I-65 Mobile River bridge) were divided into three geographic regions—eastern, central, and western—and sampled on a 3-year rotation as well.

Within the river basins and coastal zone, site selection included the following station types:

1. Repetitive sampling of sites where ADPH determined that EPA/FDA limits had been exceeded;
2. Repetitive sampling of sites within each major Alabama reservoir in support of Alabama's ALM;
3. Sampling remaining areas in Alabama where fish had not been collected for the FTMP or other areas of concern as they arise.

The combination of the increase in advisory locations for mercury in fish along with the 3-year basin rotation instituted in 2015 caused an increase in the number of yearly sample locations to a point that it became unsustainable for the program. In order to maximize available laboratory resources and streamline data reporting, the program was further modified to its current form in 2017, returning to its former schedule of a 5-year basin rotation with the following site selection priorities:

1. Sampling locations throughout the focus basin;
2. Repetitive sampling of sites within the focus basin where ADPH has determined that EPA/FDA action limits have been exceeded;
3. Repetitive sampling of sites within the focus basin in support of Alabama's Assessment and Listing Methodology;
4. Sampling remaining areas in Alabama where fish have not been collected for the FTMP or other areas of concern as they arise.

The 2020 through 2022 basin rotation schedules were modified due to the need to minimize close contact of staff during the COVID response. The Tombigbee and Mobile Basins were sampled in 2020, while the Black Warrior and Cahaba basins were sampled in 2021. Since mercury is the main compound of concern within those basins, all 2020 and 2021 samples were collected using the non-lethal field biopsy plug method and analyzed for individual mercury only. No in-lab fish processing occurred during 2020 or 2021. The Alabama, Coosa, and Tallapoosa Basins include PCB advisories which require lab processing for entire fish filets. Those basins were deferred to 2022. The current basin rotation is as follows:

- Tennessee River (2023)
- Perdido-Escambia, Choctawhatchee, Pea, and Chattahoochee Rivers (2024)
- Mobile and Tombigbee Rivers (2025)

- Black Warrior and Cahaba Rivers (2026)
- Alabama, Coosa, and Tallapoosa Rivers (2027)

In addition to the major river basin schedule, coastal sample locations (locations south of the I-65 Mobile River Bridge) are divided roughly into five geographic regions and sampled on a 5-year rotation as well.

The extent to which the above goals are accomplished each year is dependent upon available resources. To date, several thousand fish from more than 350 locations have been collected, processed, and analyzed for the FTMP. Locations sampled during the 2019-2023 5-year basin rotation are shown in Figure 8.

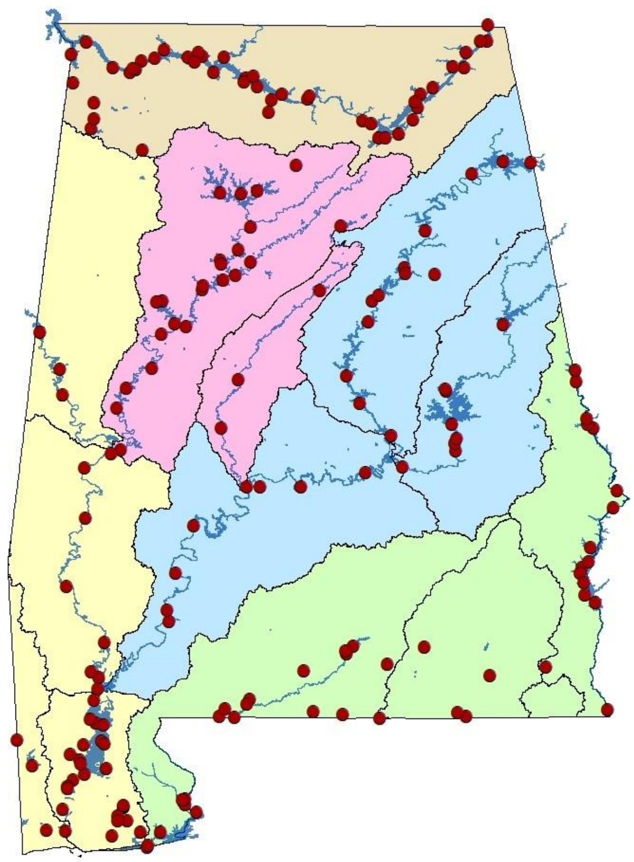

Figure 8. FTMP stations sampled 2019-2023.

Objectives

The objectives of the FTMP are:

1. To provide ADPH with the data needed for determination of potential risk to those who consume fish from Alabama waters.

2. To provide the ADEM WQB data required to meet the needs of Alabama's ALM.
3. To provide a statewide screening of bioaccumulative contaminants in fish tissue.
4. To monitor trends in contaminant concentrations in fish tissues.

Design

Routine organic analyses of PCBs and pesticides are more expensive and labor-intensive for the laboratory to process and analyze than mercury. To maximize available lab resources, routine organic analyses were reduced where no previous exceedances have occurred. Sample sites are divided into two groups for analysis—Screening sites and Targeted sites. Screening sites are locations where no data exists, or chemical contaminants in fish have not been found to exceed levels of concern for human health. Targeted sites are locations where screening samples have identified concentrations of chemicals that exceed levels of concern for human health.

Beginning in 2018, analysis requested for the FTMP is determined by the following schedule:

- Routine Screening Locations (Tier I)
    - "Individual Mercury Analysis" each 5-year sample rotation;
    - "Composite All Other Parameters" once within a 15-year period.
- Targeted Locations (Tier II)
    - "Individual Mercury Analysis" and "Individual Analysis" for the contaminant of concern each 5-year sample rotation;
    - "Composite All Other Parameters" once within a 15-year period.

The number of sampling locations each year typically varies from 35 to 45 stations. The number of fish collected each year typically ranges from 300-550. Stations sampled and numbers of fish collected vary according to the size of the basin, number of Targeted sites, and resources available in a given year.

Sampling is typically conducted in the fall of the year October-December. These months are preferred in fish tissue monitoring programs for the following reasons:

1. Organic pollutants, primarily stored in fatty (lipid) tissue, should be at the greatest concentration as fat content of fish is highest at this time of year;

2. Target species are more easily collected while water levels are low and as water temperatures cool;
3. Fall collections do not interfere with spawning seasons of target species.

Collection methods may include electrofishing and/or gillnets as needed. At each location, six individuals of the same species are collected from each of two primary feeding groups—predators and bottom-feeders. The primary targeted predator species are largemouth bass or spotted bass, while the primary bottom feeder species are channel catfish or blue catfish. Where mercury contamination is the primary concern, only predator species may be collected if resources are limited. To better understand contaminant concentrations across trophic levels and populations, additional species, such as crappie, bream, and striped bass, may also be collected. Collected fish are within a size range identified in SOP #2300, with the additional requirement that catfish weigh a minimum of one pound as requested by ADPH. Following completion of analyses, all data are compiled and provided to ADPH for modification of Alabama's Fish Consumption Advisories and are distributed to cooperating agencies.

Fish sampling and tissue preparation procedures for the FTMP are as described in the following ADEM documents: *Fish Tissue Monitoring Program Sample Collection Procedures* (SOP #2300), *Fish Tissue Monitoring Program Sample Processing and Data Reporting Procedures* (SOP #2301), and *Fish Tissue Monitoring Program Non-Lethal Biopsy Plug Sample Collection and Processing Procedures* (SOP #2302).

Core and Supplemental Water Quality Indicators

Core Indicators:

Table 7 provides a list of core indicators currently reported by the FTMP.

Supplemental Indicators: As needed for Targeted assessments.

The physical condition of important sport and/or commercial fish species collected for tissue monitoring is evaluated using relative weight. Relative weight is a condition indicator used by fishery biologists to compare individual fish or a group of fish with a standardized norm. Using this system a fish that scores 80 to 100 would be considered in good-to-excellent condition while a fish that scores 79 or below would be considered fair-to-poor. These same fish are also examined for any external anomalies such as lesions (sores), tumors, parasites, and deformities. This relative weight condition indicator is used to evaluate the trends in the health of a fish community.

Table 7. List of core indicators reported for fish tissue samples collected for the FTMP.

Parameter	Method	RL	MDL	FDA Guidance Level	EPA Guidance Level
Arsenic, Total	EPA200.8	5.0 ug/g	0.059 ug/g		
Cadmium	EPA200.8	5.0 ug/g	0.081 ug/g		
Mercury, Total	EPA7473	0.1 ug/g	0.056 ug/g		0.33 ug/g
Selenium, Total	EPA200.8	5.0 ug/g	0.165 ug/g		
Chlordane, Total	SW8081A	0.125 ug/g		0.3 ug/g	
4,4-DDD	SW8081A	0.002 ug/g		Total DDT 5.0 ug/g	
4,4-DDE	SW8081A	0.002 ug/g			
4,4-DDT	SW8081A	0.002 ug/g			
2,4-DDD	SW8081A	0.002 ug/g			
2,4-DDE	SW8081A	0.002 ug/g			
2,4-DDT	SW8081A	0.002 ug/g			
Chlorpyrifos	SW8081A	0.002 ug/g			
Dieldrin	SW8081A	0.002 ug/g		0.3 ug/g	
Endosulfan I	SW8081A	0.002 ug/g			
Endosulfan II	SW8081A	0.002 ug/g			
Endrin	SW8081A	0.002 ug/g			
gamma-BHC (Lindane)	SW8081A	0.002 ug/g			
Heptachlor	SW8081A	0.002 ug/g		0.3 ug/g	
Heptachlor Epoxide	SW8081A	0.002 ug/g		0.3 ug/g	
Hexachlorobenzene	SW8081A	0.002 ug/g			
Mirex	SW8081A	0.002 ug/g		0.1 ug/g	
Arochlor 1016	SW8082	0.125 ug/g			
Arochlor 1221	SW8082	0.125 ug/g			
Arochlor 1232	SW8082	0.125 ug/g			
Arochlor 1242	SW8082	0.125 ug/g			
Arochlor 1248	SW8082	0.125 ug/g			
Arochlor 1254	SW8082	0.125 ug/g			
Arochlor 1260	SW8082	0.125 ug/g			
Total PCBs	SW8082	0.125 ug/g		2.0 ug/g	
Toxaphene	SW8081A	0.125 ug/g		5.0 ug/g	
Percent lipids	SW3640A	0.10%			

Reporting

FTMP summary reports can be found on the ADEM website.

Information on current fish consumption advisories that were developed from FTMP data are available on the ADPH website. Nutritional information and safe practices for selecting and preparing fish are also available at that site.

Permit Compliance Monitoring Program

Background

Congress passed the Federal Water Pollution Control Act (1965) requiring state development of water quality standards for all interstate waters. Thereafter, the law was amended to include revisions outlined in the Clean Water Act (1972) which further delineated water quality standards on an intrastate level and required discharging facilities to comply with set-forth permits in order to achieve these water quality standards. The Act was further amended by the Water Quality Act of 1987 which, in part, brought about the regulation of industrial and municipal stormwater.

ADEM has developed a comprehensive monitoring strategy that includes, as a component, the compliance monitoring of National Pollution Discharge Elimination System (NPDES), State Indirect Discharge (SID), and Underground Injection Control (UIC) permits issued by the Department.

Objectives

The objective of the Permit Compliance Monitoring Program is to determine a facility's compliance with the Departmental issued NPDES, SID or UIC permit(s).

Design

ADEM uses various compliance sampling techniques to assure the implementation of state and federal laws and the protection of overall environmental quality. One of the compliance monitoring programs conducted by ADEM consists of Compliance Sampling Inspections (CSIs) of permitted facilities. During the CSI, an extensive review of the permitted facility's records and reports is conducted. Facilities are required to maintain all records and reports for a minimum of three years. Reviewed records include Departmental issued permits, discharge monitoring reports, chain of custody forms, laboratory analytical data, laboratory standard operating procedures, calibration records, Best Management Practice (BMP) and Spill Prevention Control and Countermeasure (SPCC) plans, along with any associated inspections.

Compliance inspectors also conduct a facility walk-through to gauge the effectiveness and operation of the treatment or pretreatment processes utilized by the permitted facility. Along with the records review and treatment plant inspection, representative samples required for monitoring parameters listed in the facility's permit are obtained. ADEM also conducts Compliance Bioassay

Inspections (CBIs), which include collection of effluent samples to evaluate the biological effect of a permittee's effluent on test organisms (i.e., bioassays).

The Department has agreed with EPA to conduct inspections at varying frequencies for permitted entities. Generally, a commitment list is developed at the beginning of each inspection year based upon factors, such as the classification of the discharger (e.g. major or minor source), the status of the receiving waterbody (e.g., TMDL or impaired water), time since the last inspection, citizen complaints, federal requests, and proximity of locations.

A compliance sampling inspection may include (but is not limited to) collection of samples by grab or composite (flow or timed) sampling techniques. Composite samples consist of equal volume aliquots being collected at equal time or flow intervals throughout the duration of discharge, not to exceed twenty-four hours. Samples are collected from permitted outfalls at influent, effluent, receiving waterbody, or overland flow sampling locations. Samples of the receiving waterbody may be collected both upstream and downstream of the permitted outfall/discharge point. Samples may be collected for field measurements, chemical laboratory analysis, microbiological analysis, and/or bioassay. The sample results are then used to interpret the degree of potential impact to the receiving water and to assess permit compliance.

For those facilities that have intermittent discharges, on an unannounced inspection, samples are only collected if a discharge is present during the time of the facility visit. Inspectors are required to return on an announced visit to ensure a sample is collected for every facility on the commitment list unless a special circumstance exists (i.e. facility does not discharge). Chemical and bacteriological analyses are performed, as applicable, and the results are reviewed by the appropriate regulatory entity, where they may be used to verify the accuracy of the permittee's self-monitoring program and reports, to determine compliance with discharge limitations, to determine the quantity and quality of effluents, to develop permits, and/or to provide evidence for enforcement proceedings where appropriate.

A core set of environmental indicator parameters may also be analyzed from effluent samples collected during CSIs. These data are forwarded to the Water Division for use in TMDL development and other water quality assessments. Each indicator parameter is evaluated on a systematic basis to determine its usefulness for assessing NPDES, SID, and UIC compliance status.

Core and Supplemental Water Quality Indicators

As applicable on a programmatic basis:

Core Indicators: Total alkalinity, aluminum, antimony, arsenic, atrazine, alachlor, metolachlor, aldicarb, cadmium, total organic carbon, chemical oxygen demand, chlorine, chlorophyll *a*, chromium, copper, cyanide, dissolved oxygen, *E. coli*, *Enterococci*, carbonaceous biochemical oxygen demand, hardness, iron, lead, manganese, mercury, nickel, ammonia, nitrate+nitrite, total Kjeldahl nitrogen, organo-chlorine pesticides, oil and grease, organo-phosphorus pesticides, pH, zinc, selenium, semi-volatiles, silver, total dissolved solids, total suspended solids, specific conductance, temperature, thallium, total phosphorus, dissolved reactive phosphorus, toxicity, and turbidity.

Supplemental Indicators: As required by permit.

GROUNDWATER MONITORING PROGRAM

Background

Many elements of Alabama's groundwater programs are managed by subdivisions within ADEM, including the Land, Field Operations, and Water Divisions. The Groundwater Branch in the Land Division provides the hydrogeological support for these programs. Other programs related to groundwater management and protection are managed by other state and federal agencies. The on-site sewage program is managed by the Alabama Department of Public Health (ADPH) and the Class II Underground Control Program is managed by the State of Alabama Oil and Gas Board. Groundwater quantity issues are addressed by the Alabama Department of Economic and Community Affairs (ADECA) Office of Water Resources (OWR). Other groundwater monitoring and regulatory programs are managed by the Geological Survey of Alabama (GSA) and the Alabama Surface Mining Commission (ASMC), respectively. The EPA provides oversight on all federally funded and delegated groundwater programs, except for the ASMC, which is overseen by the U.S. Department of Interior, Office of Surface Mining.

The State of Alabama recognized that there was a need to coordinate management of groundwater programs, and as a result, set up the Ground Water Programs Advisory Committee (GWPAC) in 1994 to aid in completing the requirements for EPA's Core Comprehensive State Ground Water Protection Program (CSGWPP). This committee met for several years but is not active at the present time.

The Groundwater Assessment Program (GAP) at the Geological Survey of Alabama (GSA) is a repository of Alabama water well data, state-wide monitoring of groundwater levels, and applied hydrogeologic research related to Alabama's water resources. The GSA has maintained a program to collect water levels from all of the major aquifers in the state for more than 40 years. The GAP manually measures water levels in about 400 water wells each year and maintains a real-time network of 31 wells outfitted with transducers that record water levels every two hours and transmit the data twice daily to GSA servers. In order to upgrade this program with the latest technology, the GAP has initiated implementation of the first phase of a real-time groundwater level monitoring system. Phase 1 consists of 30 wells distributed throughout the state. Water levels, measured every 30 minutes, are transmitted to GSA where the data are stored. This data is available online at the GSA-GAP website. These data indicate up-to-date pressure conditions in the state's aquifers and is critical for assessing how the aquifers respond to natural and anthropogenic stresses. Water levels from nine of these wells are supplied to ADECA's Alabama Drought Monitoring Impact Group to assist the OWR with the preparation of monthly declarations during drought season. GSA published a state-wide groundwater resource assessment in 2018. An additional component of the assessment is a systematic yearly evaluation of groundwater quality throughout the state (GSA 2018).

The following items summarize some of the other significant groundwater developments and achievements that have occurred within the last several years in Alabama:

- Regulations have been developed by ADEM and implemented to deal with Animal Feeding Operations and Concentrated Animal Feeding Operations (AFOs and CAFOs). Hydrogeologic site evaluations and groundwater monitoring requirements have been included in the regulations as part of siting and operation requirements for AFO/CAFO lagoons and land application sites.
- The U.S. Geological Survey (USGS) has also conducted a National Water Quality Assessment for two study units that include significant parts of Alabama's Mobile River and Lower Tennessee River Basins.
- The Nonpoint Source Program (NPS) has provided funding for pesticide sampling of residential wells in vulnerable areas in the southernmost half of the Coastal Plain Ground Water Province. Sampling, analysis, and reporting have been completed.
- The state Groundwater Program has provided funding for pesticide sampling of residential wells in vulnerable areas in the northernmost half of the Coastal Plain Ground Water Province. Sampling, analysis, and reporting have been completed.
- ADEM has implemented an ambient groundwater monitoring program in the Piedmont District for radionuclides. Sampling was completed and a report developed.
- ADEM has implemented an ambient groundwater monitoring program for nutrients in watersheds with heavy poultry industry.
- The Alabama Department of Agriculture and Industries (ADAI) provided funding for pesticide and metals sampling of residential wells in vulnerable areas in the Valley and Ridge and the Cumberland Plateau Provinces of central and north Alabama. Sampling

was completed and a report developed. The ADAI also provided funding for sampling of residential wells in vulnerable areas of the Tennessee River Watershed. Sampling was completed and a report developed.

- ADEM has completed a statewide ambient groundwater quality monitoring effort using the probabilistic monitoring grid approach.
- The GSA-GAP published Circular 207 entitled “Springs of Alabama” in 2022 that detailed water quality and flow characteristics of selected springs across the state (Smith and Guthrie 2023).
- The GSA-GAP published Bulletin 192 entitled “An Aquifer Recharge Potential Map for Alabama” in 2022 that detailed the potential for shallow aquifer recharge potential across the state (Guthrie et al. 2022).
- The GSA-GAP is developing an aquifer vulnerability map of the state for a project funded by the National Resource Conservation Service (NRCS). The map is based on results from a project detailed in GSA Bulletin 192 (Guthrie et al. 2022). Its goal is to produce GIS-compatible shapefiles that document the contamination potential of shallow groundwater systems from nitrates and discharges from on-site decentralized sewer systems.
- The GSA-GAP reinstituted an annual water sampling program, which was last conducted in 1994, designed to characterize non-regulatory chemical constituents of groundwaters in the state’s aquifers. Recent sampling has been completed in the majority of aquifers in the Valley and Ridge province and the Coker, Gordo, and Eutaw aquifers in the Coastal Plain province. Future sampling will be conducted yearly on selected wells throughout the state.
- The GSA-GAP, in conjunction with the Groundwater Protection Council, developed and implemented a new database for groundwater level, water quality, and well construction data. The database is in the final stages of internal testing before being made available to other state agencies and the public. The database currently contains over 45,000 well records, water levels from the periodic and real-time network, and

water quality information. The database has a searchable geospatial interface and capabilities of displaying, plotting, and downloading data.

Information that follows pertains to ADEM's statewide monitoring effort. Available funding allowed only one year of monitoring. If funding and necessary resources are available in the future the effort will be repeated.

In support of the State Pesticides in Groundwater Plan, ADEM and the ADAI have worked cooperatively to determine ambient groundwater quality in Alabama. Monitoring of selected private residential wells in targeted counties began in 1989 using conventional techniques for analysis. In 1992, ADEM began using immunoassay analyses for county-wide studies, and in 2000, it began a systematic study of the state.

Funding for the immunoassay monitoring program was through the Clean Water Act Section 106 and 104(b)(3) grant programs, ADAI, EPA Nonpoint Source Section 319 grant, and a Special Appropriation for the Tennessee Valley area.

Objectives

Objectives for this statewide ambient groundwater quality monitoring effort were as follows:

1. To characterize the ambient groundwater quality in the state.
2. To focus monitoring efforts in key agricultural counties with vulnerable aquifers.

Design

Random Sampling:

County-wide studies were developed based on aquifer-specific characteristics, such as vulnerability and use. Use was defined as drinking water, agricultural use, such as field products or poultry, and the ratio of residential homes to on-site sewage systems. Private residential wells were sampled and field parameters logged, with 30-100 wells sampled per county. Wells were randomly selected and located in rural areas (Figure 9).

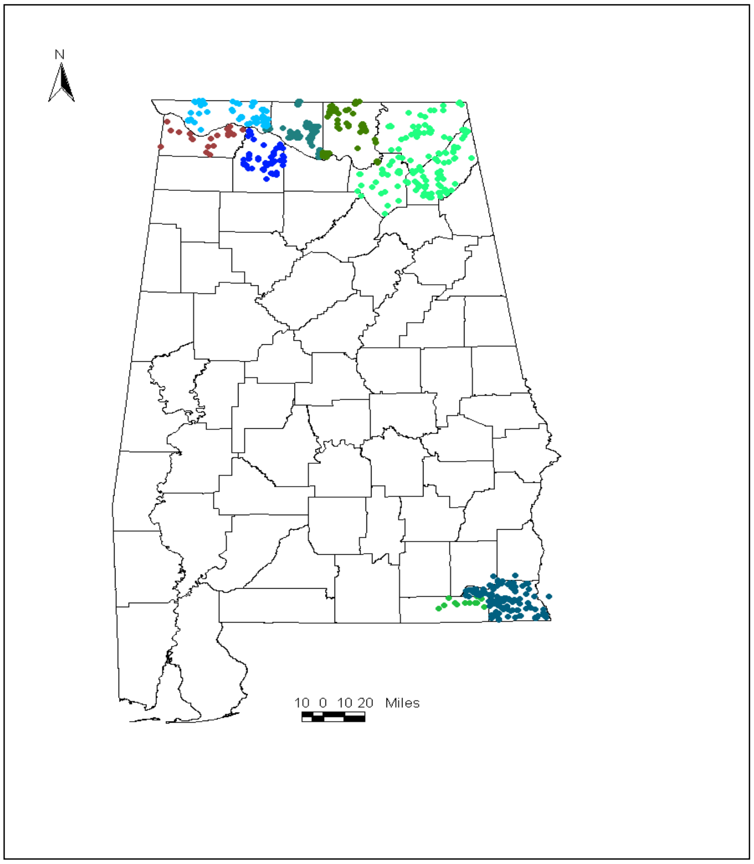

Figure 9. Counties and locations where random sampling was used.

Spatial Sampling:

The statewide study was designed similarly to two previous studies by the Center for Disease Control (CDC) and state health departments. One study was conducted in 1994 in nine Midwestern states, and a similar study was conducted in 1995 in Alabama, Georgia, and Florida. The CDC study developed an equal-area sampling design by laying a ten-mile grid over Alabama, Georgia, and Florida. The CDC monitoring program was used to estimate the extent of bacterial contamination in private wells. Samples were collected from wells at or within a 3-mile radius of the intersections of the grid lines. If a suitable well was not located within the 3-mile radius, the closest well to the nodal point was sampled (CDC 1998).

The sampling grid in Alabama was divided into three areas based on hydrologically distinct physiographic provinces. The provinces included the Lower Coastal Plain, the Upper Coastal Plain, and the Valley and Ridge. In 2000, 140 wells were sampled in the Upper Coastal Plain. In

2001, 190 wells were sampled in the Lower Coastal Plain, and in 2002, 147 samples were collected from the Valley and Ridge province (Figure 10).

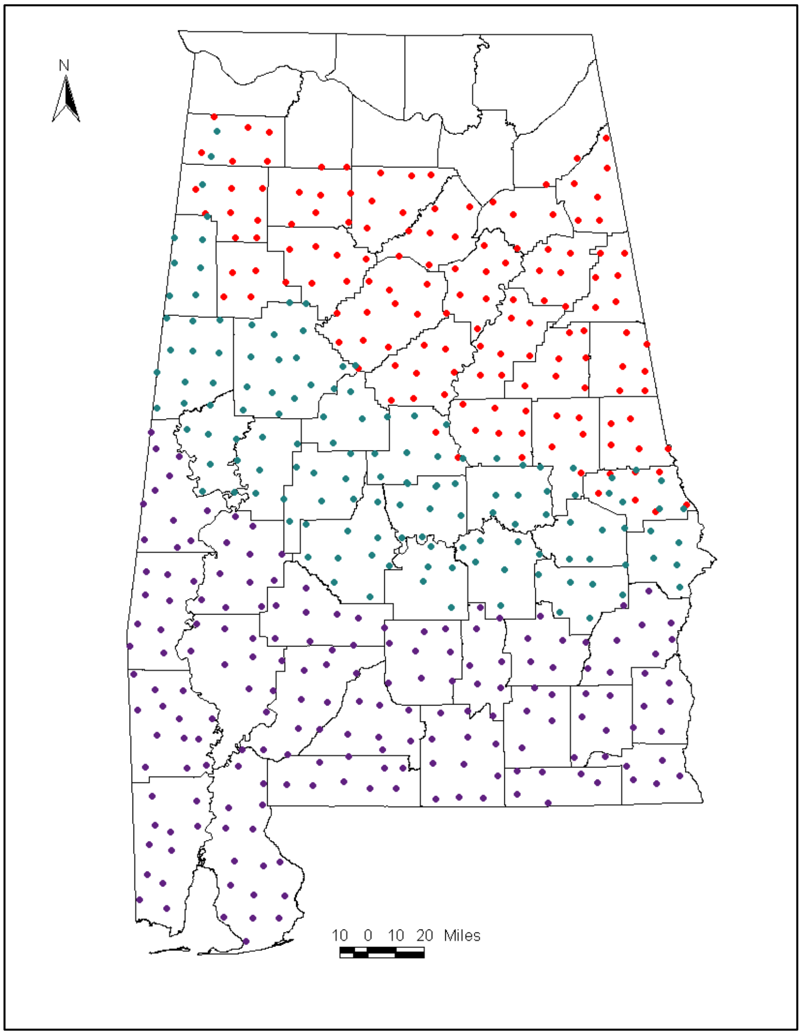

Figure 10. Spatial sampling grid. Red nodes are sampling locations for the Valley and Ridge province, green nodes are locations in the Upper Coastal Plain, and purple nodes are locations in the Lower Coastal Plain.

Core and Supplemental Water Quality Indicators

Core Indicators/Random Sampling: pH, conductivity, temperature, nitrates, atrazine, aldicarb, alachlor, and metolachlor

Core Indicators/Spatial Sampling: fecal coliform bacteria, atrazine, aldicarb, alachlor, and metolachlor, total organic carbon, sulfate, silicate, phosphate, nitrate, bromide, fluoride, chloride, and 61 metals.

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