



water resources / environmental consultants

---

# **MIDDLE WHITE RIVER WATERSHED-BASED MANAGEMENT PLAN**

**DRAFT  
March 2019**

---

MIDDLE WHITE RIVER WATERSHED-BASED  
MANAGEMENT PLAN

Prepared for

Arkansas Natural Resources Commission  
101 East Capitol Avenue, Suite 350  
Little Rock, AR 72201

Prepared by

FTN Associates, Ltd.  
3 Innwood Circle, Suite 220  
Little Rock, AR 72211

FTN No. R03015-005-056

DRAFT  
March 2019

## EXECUTIVE SUMMARY

The Middle White River watershed is located in north central Arkansas. It is the watershed for the White River from the confluence of the Buffalo River, in Baxter County, to the confluence of the Black River, in Independence County. This 1,476.2 square mile watershed also includes large areas of Baxter, Independence, IZard, and Stone Counties. There are two large towns in the watershed, Batesville and Mountain Home; however, the watershed is mostly rural. Forest covers 69% of the watershed, and includes the Sylamore District of the Ozark National Forest, in Stone County. Economic drivers in the watershed include tourism and outdoor recreation, livestock farming (18% of the watershed is pasture or hayland), poultry and timber production and processing, small manufacturing, and mining (sand, stone, and gravel).

Water quality in this watershed is generally considered to be good. This watershed includes important habitats for threatened and endangered species including caves, two springs designated as Ecologically Sensitive, and a portion of the White River designated as Critical Habitat for the Rabbitsfoot mussel. In addition, two streams in the watershed, North Sylamore Creek and Salado Creek, are designated as Extraordinary Resource Waters, and North Sylamore Creek is also designated as a Natural and Scenic Waterway.

This Middle White River watershed management plan has been developed as part of the Arkansas Natural Resources Commission Nonpoint Source Program goal of developing plans for all 57 8-digit hydrologic unit code watersheds within the state. This watershed was selected because there are two streams, Hicks Creek near Mountain Home, and Greenbrier Creek near Batesville, that were included on the approved 2016 and draft 2018 state lists of impaired waterbodies. Hicks Creek is impaired due to high *E. coli* levels from the Mountain Home wastewater treatment plant and runoff from the developed areas in and around Mountain Home. Greenbrier Creek is listed as impaired due to the number of low dissolved oxygen concentrations; however, this impairment is expected to be removed as a result of revised ADEQ water quality assessment methodology. Stakeholder concerns related to water quality include the effects of erosion, use of pesticides and other chemicals, mining, livestock and poultry waste, forest management, and sewage on surface and groundwater.

---

The focus of this watershed management plan is the **protection and improvement** of surface water quality in the White River and its tributaries through management of unregulated nonpoint sources of pollution. The mission of the watershed management plan is to increase awareness of water quality issues, outreach and education, and voluntary activities to implement good water quality management practices. The vision this plan is intended to create is: The uses of the Middle White River and its tributaries are attained and sustained, resulting in clean, healthy streams that enhance the socioeconomic and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water quality and the quality of life throughout the watershed.

Land use, water quality, and geological information was compiled and analyzed to identify tributary subwatersheds in which to focus initial management practices and activities. Based on these analyses, three subwatersheds are recommended for initial nonpoint source pollution management, and two subwatersheds are recommended for water quality evaluation (Table ES.1 and Figure ES.1).

Table ES.1. 12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources.

Hydrologic Unit Code	Watershed Name	Target Pollutants	Primary activity proposed
110100040201	Hicks Creek	Nutrients, E. coli	Implement management practices
110100040504	Miller Creek	Nutrients	Water quality evaluation
110100040604	Greenbrier Creek	Nutrients	Implement management practices
110100040605	Spring Creek	Nutrients	Water quality evaluation
110100040703	Lower Salado Creek	Nutrients	Implement management practices

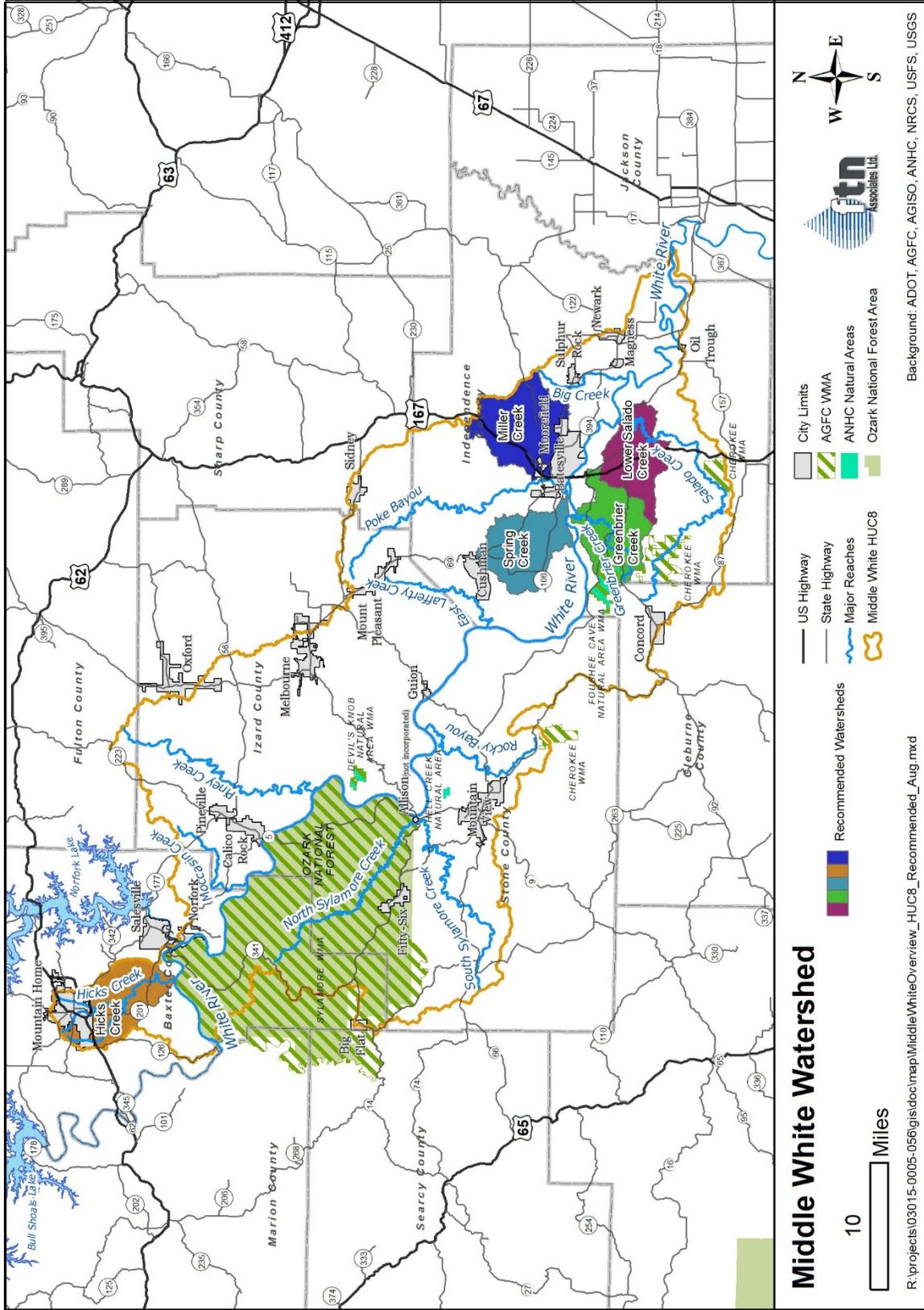


Figure ES.1 Map showing 12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources.

Through four watershed meetings, stakeholders identified nonpoint source pollution management practices that could be implemented in the recommended subwatersheds. These practices, along with estimates of associated pollutant load reductions and relative costs for their implementation, are included in the plan. Examples of available sources of technical and funding assistance for implementation of management practices are also identified. Watershed processes and systems are dynamic. Therefore, an adaptive management approach is proposed for the Middle White River watershed and outlined in this plan. As part of this approach, continued water quality and biological monitoring is recommended so that progress toward the vision and goals for the Middle White River watershed can be tracked. The proposed schedule and milestones for implementing the activities outlined in this plan are shown in Table ES.2

As part of the adaptive management process, it is recommended that implementation of this plan be evaluated at 5-year intervals. It is recommended that the first evaluation be conducted in 2024. Implementation of this plan will be considered successful if the following are achieved by 2024:

- A watershed implementation team has been formed for at least one recommended subwatershed and initiated at least one project or study;
- Greenbrier Creek is removed from the state impaired waters list;
- Salado Creek at station WHI0166 has been assessed for meeting the Delta Least-altered Stream DO standard;
- Water quality data sufficient for the ADEQ biennial assessment have been collected from Spring Creek and Miller Creek recommended subwatersheds;
- The median total nitrogen values, adjusted for flow, at the routine water quality monitoring station in the Lower Salado Creek recommended subwatershed decreases;
- All dissolved oxygen measurements at the routine water quality monitoring stations in the Hicks Creek and Greenbrier Creek recommended subwatersheds meet the applicable dissolved oxygen numeric criteria; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Middle White River watershed.

Table ES.2. Proposed implementation schedule for Middle White River watershed.

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Monitoring	Roving monitoring program (ADEQ)	2024	2026	Water quality data collection initiated	Number of sampling events	Identify and track changes in water quality Assess water quality relative to water quality standards
	Ambient monitoring program (ADEQ, USGS)	2019	Expected to continue indefinitely	Five additional years of water quality data collected	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	ADEQ aquatic invertebrate surveys (ADEQ)	2021	Expected to continue indefinitely	At least one new survey completed at routine ambient water quality monitoring stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Stream Team aquatic invertebrate surveys (Stream Teams, USGS)	2001	Expected to continue indefinitely	At least three new surveys at active stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Ozark National Forest Fish surveys (USFS)	2007	Expected to continue indefinitely	At least one new survey completed at a previously surveyed location	Number of surveys Number of locations surveyed	All surface waters in Ozark National Forest achieve aquatic life support use
	ADEQ Fish Surveys (ADEQ)	1984	Expected to continue indefinitely	At least one new survey for at least one location	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	USGS North Sylamore Creek Fish Surveys (USGS)	1993	Expected to continue indefinitely	At least one new survey	Number of surveys	North Sylamore Creek achieves aquatic life support use
	Surveys of aquatic species of concern (AGFC, USFS, ANHC)	2002	Expected to continue indefinitely	At least one new survey of a population of aquatic species of concern within the Middle White River watershed	Number of surveys Number of survey locations	Stable populations of designated Threatened and Endangered aquatic species present in Middle White River watershed
Special Studies	Water quality assessment of Spring Creek and Miller Creek (Watershed Implementation Team?)	2021	2023	Spring Creek and Miller Creek water quality assessed as part of a state biennial assessment	Number of sampling events	All surface waters in Middle White River watershed meet water quality standards
	Synoptic nutrient sampling in Lower Salado Creek subwatershed (Southside or Implementation Team)	2026	2027	Decision made about whether synoptic survey is needed	Number of sampling events Number of sampling locations Sources and critical tributaries identified	Salado Creek meets water quality standards
	Nutrient and sediment load estimates (ANRC or USGS)	2021	2023	Load estimates modeled and reported	Load estimates report completed	All surface waters in Middle White River watershed meet water quality standards
	Geomorphological study	2023	2025	Geomorphological study initiated	Geomorphological study plan developed	All surface waters in Middle White River watershed achieve designated uses

Table ES.2. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Information and Education	Outreach and education to homeowners and landscape managers regarding fertilizer use to reduce nitrogen runoff	2023	2025	Outreach initiated in Southside or Mountain Home	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	All surface waters meet water quality standards
	Stormwater pollution prevention outreach in Mountain Home (Subwatershed Implementation Team)	2020	2030	Stormwater pollution prevention outreach program developed and initiated	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	Hicks Creek meets water quality standards
	Onsite wastewater system maintenance outreach (White River Waterkeeper)	2020	2025	Outreach initiated in Hicks Creek, Greenbrier Creek, and Lower Salado Creek subwatersheds	Number of people contacted/reached	All surface waters meet water quality standards
	Outreach through Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	Two field days Four presentations Radio ads Newspaper ads Newsletters mailed & emailed	Number of field days Number of presentations Number of newsletters sent Number of radio & newspaper ads Number of people reached	All surface waters meet water quality standards
Planning	Establish subwatershed implementation teams	2020	2025	At least one team formed	Number of teams	All surface waters meet water quality standards
	Develop subwatershed implementation plans	2021	2025	Preparation of at least one subwatershed implementation plan initiated	Number of plans	All surface waters meet water quality standards
Implement Management Practices	Pasture and hayland management practices in Lower Salado Creek subwatershed through NRCS programs (Independence County Extension Service)	2014	Expected to continue indefinitely	At least two new contracts signed	Number of contracts signed Amount of practices implemented	All surface waters in meet water quality standards
	Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	At least 24 contracts signed At least 55 BMPs implemented At least 60 farm plans	Number of contracts signed Amount of practices implemented Number of farm plans	All surface waters meet water quality standards
	Controlled Access for Livestock Fencing (CALF) (Arkansas Association of Conservation Districts, US Fish and Wildlife Service)	2015	2025	At least 5 new contracts signed in Middle White River watershed	Number of contracts signed Amount of practices implemented	All surface waters meet water quality standards
	Developed and residential area management practices in Hicks Creek and Lower Salado River (Mountain Home, Southside)	2020	2025	Implementation of at least one management practice planned for at least one subwatershed	Number/amount of practices implemented	All surface waters meet water quality standards
	Petition for change of ecoregion designation for monitoring stations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0166) (ANRC)	2019	2020	Ecoregion designation for stations WHI0167 and WHI0166 officially changed.	Greenbrier Creek removed from impaired waters list	Greenbrier Creek meets applicable water quality standards

Table ES.2. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Evaluate	Biennial water quality assessment (ADEQ)	2020	Expected to continue indefinitely	EPA approved final impaired waters lists for 2020 and 2022	Attaining and non-attaining stream reaches in Middle White River watershed	All water quality criteria met in Greenbrier Creek All water quality criteria met in all monitored stream reaches in watershed
	Track implementation of management practices in Middle White River watershed	2019	2025	Information for period 2019 – 2024 compiled	Amount (acres, linear feet, number) of practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches
	Evaluation of watershed management plan	2025	2025	Data needed for evaluation compiled	Evaluation completed Evaluation made public	All water quality criteria met in all monitored stream reaches
Update watershed management plan for Middle White River watershed	Public meetings	2024	2025	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management
	Update watershed management plan	2024	2026	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan complete and approved by ANRC and EPA Recommended subwatersheds identified Stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Middle White River watershed.

---

---

## TABLE OF CONTENTS

EXECUTIVE SUMMARY .....	i
LIST OF ACRONYMS AND ABBREVIATIONS .....	xxi
1.0 INTRODUCTION .....	1-1
1.1 Plan Need and Mission .....	1-1
1.2 Watershed Vision.....	1-2
1.3 Management History.....	1-2
1.4 Process .....	1-2
1.5 Document Overview .....	1-3
2.0 WATERSHED DESCRIPTION.....	2-1
2.1 Geography.....	2-1
2.2 Socioeconomics .....	2-3
2.2.1 Population .....	2-3
2.2.2 Economics.....	2-8
2.3 Ecoregions.....	2-10
2.3.1 Climate.....	2-14
2.3.2 Geology.....	2-15
2.3.3 Topography.....	2-19
2.3.4 Soils.....	2-22
2.3.5 Land Use/Land Cover .....	2-22
2.4 Water Resources .....	2-27
2.4.1 Surface Water.....	2-27
2.4.2 Groundwater .....	2-29
2.4.3 Surface Water – Groundwater Connections .....	2-33
2.5 Wildlife Resources.....	2-33
2.5.1 Protected Species .....	2-35
2.5.2 Species of Greatest Conservation Need.....	2-35
2.5.3 Nuisance Species .....	2-37

---

---

## TABLE OF CONTENTS (CONTINUED)

2.5.4	Sensitive Areas.....	2-38
2.6	Surface Water Quality Standards for Middle White River Watershed.....	2-38
2.6.1	Designated Uses.....	2-38
2.6.2	Numeric and Narrative Criteria .....	2-39
2.6.3	Antidegradation Policy .....	2-42
3.0	WATERSHED ASSESSMENT .....	3-1
3.1	Current Surface Water Quality .....	3-1
3.1.1	Data.....	3-1
3.1.2	Assessed Water Quality Impairment .....	3-4
3.1.3	Water Quality Summary .....	3-4
3.1.4	Current Water Quality Summary .....	3-25
3.2	Water Quality Over Time .....	3-27
3.2.1	WQ stations with long data records.....	3-27
3.2.2	Trend Analysis of Data from Continuous Record Stations .....	3-28
3.2.3	Analysis of Data from Intermittent Stations .....	3-29
3.2.4	Summary of Water Quality Over Time .....	3-33
3.3	Pollutant Loads .....	3-34
3.3.1	SPARROW Model.....	3-35
3.3.2	Load Estimates using Export Coefficients.....	3-40
3.3.3	Current Load Estimates.....	3-43
3.3.4	Data gaps.....	3-45
3.3.5	Load Summary.....	3-46
3.4	Geomorphology and Channel Stability.....	3-46
3.5	Hydrology .....	3-47
3.6	Aquatic Habitat.....	3-50
3.7	Surveys of Aquatic Communities .....	3-52
3.7.1	Fish Communities.....	3-53

---

---

## TABLE OF CONTENTS (CONTINUED)

3.7.2	Aquatic Invertebrates .....	3-58
3.7.3	Periphyton .....	3-59
3.7.4	Aquatic Communities Data Gaps.....	3-60
3.7.5	Aquatic Communities Summary.....	3-60
3.8	Cave Aquatic Habitat and Species of Greatest Conservation Need .....	3-60
3.9	Subwatersheds Recommended for Initial Management .....	3-62
3.9.1	Approach for Identifying Recommended HUC12 Subwatersheds.....	3-62
3.9.2	Recommended HUC12 Subwatersheds .....	3-66
3.9.3	Management of Other HUC12 Subwatersheds.....	3-73
3.10	Stakeholder Concerns .....	3-73
4.0	MANAGEMENT PLAN .....	4-1
4.1	Management Concerns for Recommended Subwatersheds.....	4-1
4.1.1	Hicks Creek HUC12 Subwatershed.....	4-1
4.1.2	Greenbrier Creek HUC12 Subwatershed.....	4-2
4.1.3	Miller Creek HUC12 Subwatershed .....	4-3
4.1.4	Spring Creek HUC12 Subwatershed .....	4-3
4.1.5	Lower Salado Creek HUC12 Subwatershed.....	4-4
4.2	Management Targets for Recommended Subwatersheds.....	4-5
4.2.1	Dissolved Oxygen Management Targets .....	4-6
4.2.2	Nutrient Management Targets .....	4-7
4.3	Load Reduction Targets.....	4-7
4.4	Nonpoint Pollution Sources to be Targeted for Management .....	4-11
4.4.1	On-site Wastewater Treatment Systems .....	4-15
4.4.2	Illicit Wastewater or Sewage Discharges .....	4-16
4.4.3	Pets and Wildlife.....	4-16
4.4.4	Fertilizer.....	4-16
4.4.5	Livestock and Manure.....	4-17

---

---

## TABLE OF CONTENTS (CONTINUED)

4.5	Management Practices .....	4-20
4.5.1	Developed and Residential Areas .....	4-22
4.5.2	Pasture and Hayland .....	4-23
4.6	Meeting Reduction Goals .....	4-24
4.6.1	Developed and Residential Areas .....	4-29
4.6.2	Pasture and Hayland .....	4-31
5.0	IMPLEMENTATION STRATEGY .....	5-1
5.1	Information and Education .....	5-1
5.1.1	Existing Outreach and Education in the Middle White River Watershed .....	5-2
5.1.2	Proposed Information and Education Programs for Middle White River Watershed.....	5-7
5.2	Subwatershed Implementation Teams .....	5-15
5.3	Subwatershed Implementation Plans .....	5-16
5.4	Implement Nonpoint Source Pollution Management Strategies.....	5-16
5.5	Influencing Implementation of Management Practices and Activities.....	5-18
5.6	Monitoring .....	5-20
5.6.1	Routine Surface Water Quality Monitoring.....	5-21
5.6.2	Biological Monitoring.....	5-23
5.6.3	Special Studies .....	5-23
5.7	Evaluation .....	5-25
5.7.1	Inputs.....	5-26
5.7.2	Outputs .....	5-28
5.7.3	Outcomes .....	5-28
5.8	Update Watershed Management Plan.....	5-31
5.9	Implementation Schedule.....	5-32
6.0	IMPLEMENTATION COSTS, BENEFITS, AND ASSISTANCE.....	6-1

## TABLE OF CONTENTS (CONTINUED)

6.1	Implementation Cost Estimates .....	6-1
6.1.1	Planning .....	6-1
6.1.2	Monitoring .....	6-1
6.1.3	Proposed Special Studies .....	6-1
6.1.4	Estimated Cost of Nonpoint Source Pollution Management .....	6-2
6.2	Estimated Economic and Environmental Benefits .....	6-5
6.3	Technical Assistance.....	6-8
6.3.1	Monitoring .....	6-8
6.3.2	Information and Education .....	6-8
6.3.3	Technical Assistance for Nonpoint Source Pollution Management .....	6-8
6.4	Financial Assistance.....	6-13
6.4.1	Monitoring .....	6-13
6.4.2	Information and Education .....	6-14
6.4.3	Nonpoint Source Pollution Management.....	6-15
7.0	REFERENCES .....	7-1

## TABLE OF CONTENTS (CONTINUED)

### LIST OF APPENDICES

- APPENDIX A: Sign-in sheets from public meetings held for development of the Middle White River watershed management plan.
- APPENDIX B: Water quality trend analyses.
- APPENDIX C: Calculations for pollutant load estimates based on export coefficients from White et al. 2015.
- APPENDIX D: Calculations for pollutant load estimates based on water quality measurements from 2013-2015.
- APPENDIX E: Linear regression analysis of dissolved oxygen and nutrients at selected water quality monitoring stations.
- APPENDIX F: Social media marketing checklist.
- APPENDIX G: Calculations of cost estimates for implementation of management practices.

---

---

## LIST OF TABLES

Table ES.1	12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources. ....	ii
Table ES.2	Proposed implementation schedule for Middle White River watershed .....	v
Table 1.1	The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan.....	1-4
Table 2.1	County areas in the Middle White River watershed. ....	2-1
Table 2.2	Numbers of people in the Middle White River watershed and associated areas. ....	2-5
Table 2.3	Additional demographic information for counties associated with Middle White River watershed. ....	2-6
Table 2.4	Value of sales, shipments, receipts, revenue, or business done (\$1,000) reported in 2012 Economic Census of the U.S. ....	2-8
Table 2.5	Value (\$1,000) of agricultural products sold in counties of the Middle White River watershed.....	2-9
Table 2.6	Preliminary 2017 economic impacts of tourism/travel in counties of the Middle White River watershed .....	2-9
Table 2.7	Fiscal year 2016 economic impacts of recreation at Bull Shoals Lake and Norfork Lake, within 30 miles of the reservoirs .....	2-9
Table 2.8	Characteristics of Level IV ecoregions of the Middle White River watershed .....	2-12
Table 2.9	Stratigraphic column listing with descriptions of lithology for geologic formations underlying the Middle White River watershed.....	2-18
Table 2.10	Slope areas in the Middle White River watershed.....	2-20
Table 2.11	Characteristics of major soil associations of the Middle White River watershed. ....	2-23
Table 2.12	Statistics for discharge data from USGS gages active in 2018.....	2-29
Table 2.13	Stratigraphic geology listing with aquifers underlying the Middle White River watershed.....	2-30
Table 2.14	Arkansas endemic species present in the Middle White River watershed.....	2-34
Table 2.15	Protected species found in the Middle White River watershed .....	2-36
Table 2.16	Non-native nuisance aquatic species present in the Middle White River watershed .....	2-37

---



---

## LIST OF TABLES (CONTINUED)

Table 2.17	Numeric water quality criteria for the Middle White River watershed .....	2-41
Table 3.1	Surface water quality monitoring stations in the Middle White River watershed that were active during the period 2013 - 2017. ....	3-1
Table 3.2	Impaired waters of the Middle White River watershed .....	3-4
Table 3.3	Summary statistics for turbidity measurements (in NTU) from 2013-2017 in Middle White River watershed.....	3-9
Table 3.4	Summary statistics for TSS measurements from 2013-2017 in Middle White River watershed.....	3-11
Table 3.5	Summary statistics for suspended sediment measurements from 2013-2017 .....	3-13
Table 3.6	Summary statistics of USGS <i>E. coli</i> measurements for the period 2013-2017 .....	3-14
Table 3.7	Summary statistics of ADEQ <i>E. coli</i> measurements from 2015 Primary Contact Season.....	3-15
Table 3.8	Summary statistics of total phosphorus measurements from 2013-2017 .....	3-16
Table 3.9	Summary statistics for dissolved inorganic nitrogen measurements from 2013-2017 .....	3-19
Table 3.10	Summary statistics for total nitrogen measurements from 2013-2017 .....	3-21
Table 3.11	Summary statistics for DO measurements 2013-2017.....	3-24
Table 3.12	Active water quality monitoring stations with data records of at least 10 years .....	3-27
Table 3.13	Water quality stations where parameters of interest exhibit trends .....	3-28
Table 3.14	Sampling periods and data sets for long term stations with intermittent records .....	3-29
Table 3.15	Ozark Highlands export coefficients used to estimate loads .....	3-40
Table 3.16	Annual loads and yields estimated for White River tributaries using export coefficients.....	3-41
Table 3.17	Statistics for discharge data from USGS gages active in 2018.....	3-49
Table 3.18	ADEQ fish habitat integrity scores from fish survey locations in Middle White River watershed.....	3-50
Table 3.19	EPA habitat condition results for locations in Middle White River watershed .....	3-52

---



---

---



---

## LIST OF TABLES (CONTINUED)

Table 3.20	IBI scores and associated stream health ratings based on recent fish surveys .....	3-55
Table 3.21	Condition of aquatic invertebrate communities surveyed by EPA in the National Rivers and Streams Assessment, 2009 .....	3-58
Table 3.22	Summary ranking scores for HUC12 subwatersheds of Middle White River watershed.....	3-69
Table 3.23	Water quality issues in the Middle White River watershed identified at stakeholder meeting. ....	3-75
Table 3.24	Issues identified in Watershed Restoration Action Strategy.....	3-76
Table 4.1	Numeric criteria for dissolved oxygen in recommended subwatersheds.....	4-6
Table 4.2	Dissolved oxygen measurements from station WHI0166 2013-2017 .....	4-10
Table 4.3	Calculation of reduction target for nitrogen in lower Salado Creek.....	4-11
Table 4.4	Nonpoint nutrient sources in recommended subwatersheds.....	4-12
Table 4.5	Suitability of soils in recommended subwatersheds for septic systems .....	4-15
Table 4.6	Management practices for the Middle White River watershed recommended by stakeholders.....	4-20
Table 4.7	Examples of nonpoint source management practices implemented in the recommended Middle White River watershed since 2000. ....	4-21
Table 4.8	Summary of available information on reduction efficiencies of management practices for plan target pollutants.....	4-25
Table 4.9	Management practices for reducing nitrogen from developed and residential areas.....	4-30
Table 4.10	Management practices for reducing total nitrogen from pasture and hayland .....	4-31
Table 5.1	Middle White River watershed stakeholder groups and outreach programs .....	5-2
Table 5.2	Monetary valuation methods for ecosystem goods and services .....	5-12
Table 5.3	Freshwater Ecosystem services, type of value and applied valuation methods .....	5-14
Table 5.4	Management practices proposed for recommended subwatersheds of the Middle White River .....	5-17
Table 5.5	Domain, sub-domain, and elements that can influence behavioral change in implementing management practices and activities .....	5-18

---



---

---

---

## LIST OF TABLES (CONTINUED)

Table 5.6	Elements that might help influence implementation of pasture management practices .....	5-19
Table 5.7	Elements that might help influence implementation of stormwater management practices in developed and residential areas.....	5-20
Table 5.8	Water quality parameters monitored 2013-2017 in active monitoring programs and studies in the Middle White River watershed .....	5-21
Table 5.10	Indicators of inputs for implementation of this watershed management plan.....	5-27
Table 5.11	Indicators of outputs of implementation of this watershed management plan.....	5-29
Table 5.12	Proposed implementation schedule for Middle White River watershed .....	5-33
Table 6.1	Estimated costs for proposed special studies .....	6-2
Table 6.2	EQIP reimbursements and reported implementation costs for selected nonpoint source pollution management practices applicable in the Middle White River watershed .....	6-3
Table 6.3	Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for pasture and hayland.....	6-4
Table 6.4	Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for developed areas .....	6-4
Table 6.5	Environmental benefits and ecosystem services associated with increased soil health and best management practices .....	6-5
Table 6.6	Environmental benefits associated with implementing best management practices in the Middle White River subwatersheds.....	6-7
Table 6.7	Examples of sources of technical assistance for nonpoint source management practices for the Middle White River watershed.....	6-9
Table 6.8	Examples of programs that can provide funding assistance for recommended nonpoint source management practices.....	6-16
Table 6.9	Financial assistance provided by NRCS programs to Middle White River counties in 2017 .....	6-17

---

---

## LIST OF FIGURES

Figure ES.1	Map showing 12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources. ....	iii
Figure 2.1	Middle White River watershed .....	2-2
Figure 2.2	Ecoregions of the Middle White River watershed.....	2-11
Figure 2.3	1981-2010 Climate Normals in the Middle White River watershed .....	2-14
Figure 2.4	Physiographic regions within the Middle White River watershed .....	2-16
Figure 2.5	Surface geology map of the Middle White River watershed.....	2-17
Figure 2.6	Map of slope ranges in the Middle White River watershed.....	2-21
Figure 2.7	Map of soil associations of the Middle White River watershed .....	2-24
Figure 2.8	Land use/land cover percentages for the Middle White River watershed .....	2-25
Figure 2.9	Land use map of the Middle White River watershed .....	2-26
Figure 2.10	Active USGS flow gages in the Middle White River watershed, 2010-2015.....	2-28
Figure 2.11	Outcrop areas of aquifers within the Middle White River watershed .....	2-31
Figure 2.11	Map of Middle White River watershed showing Extraordinary Resource Waters, Natural and Scenic Waterway, and Ecologically Sensitive Waterbodies.....	2-40
Figure 3.1	Surface water quality monitoring locations active during 2013 through 2017 .....	3-3
Figure 3.2	Impaired waterbodies in the Middle White River watershed identified in the final 2016 303(d) list.....	3-5
Figure 3.3	Elements of box and whisker graphs in this report.....	3-7
Figure 3.4	Box and whisker graph of all turbidity measurements from the Middle White River watershed for the period 2013-2017.....	3-10
Figure 3.5	Box and whisker graph of base flow turbidity measurements (June through October) from the Middle White River watershed for the period 2013-2017 .....	3-10
Figure 3.6	Box and whisker graph of TSS measurements from the Middle White River watershed for the period 2013-2017 .....	3-12
Figure 3.7	Box and whisker graph of suspended sediment measurements from the Middle White River watershed for the period 2013-2017 .....	3-13

---

## LIST OF FIGURES (CONTINUED)

Figure 3.8	Box and whisker graph of total phosphorus measurements from Middle White River watershed for the period 2013-2017 .....	3-17
Figure 3.9	Box and whisker graph of inorganic nitrogen measurements from Middle White River watershed for the period 2013-2017 .....	3-20
Figure 3.10	Box and whisker graph of total nitrogen measurements from Middle White River watershed for the period 2013-2017.....	3-22
Figure 3.11	Box and whisker graph of DO measurements from Middle White River watershed for the period 2013-2017 .....	3-23
Figure 3.12	Box and whisker graph of primary season DO measurements from Middle White River watershed for the period 2013-2017 .....	3-26
Figure 3.13	Box and whisker graph of critical season DO measurements from Middle White River watershed for the period 2013-2017 .....	3-26
Figure 3.14	Comparison of dissolved inorganic nitrogen data from two sampling periods at ADEQ roving water quality stations .....	3-31
Figure 3.15	Comparison of total nitrogen data from two sampling periods at ADEQ roving water quality stations .....	3-31
Figure 3.16	Comparison of total phosphorous data from two sampling periods at ADEQ roving water quality stations.....	3-32
Figure 3.17	Comparison of DO data from two sampling periods at ADEQ roving water quality stations .....	3-32
Figure 3.18	Comparison of TKN data from two sampling periods at an ADEQ roving water quality station .....	3-33
Figure 3.19	Catchment total phosphorus loads for 2002 estimated by SPARROW .....	3-36
Figure 3.20	Catchment total nitrogen loads for 2002 estimated by SPARROW .....	3-36
Figure 3.21	Catchment total phosphorus yields for 2002 estimated by SPARROW.....	3-37
Figure 3.22	Catchment total nitrogen yields for 2002 estimated by SPARROW .....	3-37
Figure 3.23	Graph of catchment total phosphorus loads for 2002 by source estimated by SPARROW .....	3-38
Figure 3.24	Graph of catchment total nitrogen loads for 2002 by source estimated by SPARROW .....	3-39
Figure 3.25	Annual loads for White River tributaries estimated using export coefficients.....	3-42

---

---

## LIST OF FIGURES (CONTINUED)

Figure 3.26	Yields for White River tributary watersheds based on loads estimated using export coefficients.....	3-42
Figure 3.27	Estimated loads based on measurements from 2013-2015 .....	3-44
Figure 3.28	Estimated yields based on measurements from 2013-2015 .....	3-44
Figure 3.29	Active USGS flow gages in the Middle White River watershed, 2017.....	3-48
Figure 3.30	Locations of habitat surveys in Middle White River watershed.....	3-51
Figure 3.31	Locations of aquatic community surveys in the Middle White River watershed .....	3-54
Figure 3.32	USGS fish counts over time at North Sylamore Creek near Fifty-Six (Station 07060710).....	3-57
Figure 3.33	Inlander, Gallipeau, and Slay 2011 ranking of threats to Species of Greatest Conservation Need in selected cave habitat sites in the Middle White River watershed.....	3-61
Figure 3.34	HUC12 subwatersheds of the Middle White River watershed .....	3-63
Figure 3.35	Graph of HUC12 subwatershed ranking scores for data types available for entire Middle White River watershed .....	3-67
Figure 3.36	Graph of HUC12 subwatershed ranking scores for data types not available for entire Middle White River watershed .....	3-68
Figure 3.37	Middle White River HUC12 subwatersheds recommended for initial nonpoint source pollution management.....	3-74
Figure 4.1	Box and whisker graph comparing total nitrogen measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.....	4-8
Figure 4.2	Box and whisker graph comparing total phosphorus measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.....	4-9
Figure 4.3	Beef cattle reported in Baxter and Independence Counties since 1982.....	4-19
Figure 4.4	Poultry numbers reported for Baxter and Independence Counties since 1982 .....	4-19
Figure 5.1	Social media platforms use by age group .....	5-9

## LIST OF ACRONYMS AND ABBREVIATIONS

ADEQ	Arkansas Department of Environmental Quality
AGFC	Arkansas Game and Fish Commission
ANRC	Arkansas Natural Resources Commission
Avg	average
BMP	best management practice
CCPE	Conservation Practice Physical Effects program
Cfs	cubic feet per second
cfu/100mL	colony forming units per 100 milliliters
Cr	creek
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
Deg C	degrees Celcius
DO	Dissolved oxygen
E. coli	Escherichia coli
EPA	US Environmental Protection Agency
ERW	Extraordinary Resource Waters
EQIP	Environmental Quality Incentives Program of the US Natural Resources Conservation Service
FSA	Farm Services Agency
GIS	Geographic Information System
HUC	Hydrologic Unit Code
HUC12	12-digit HUC
IBI	Index of Biotic Integrity
ID	identification
Kg	kilogram
kg/ha/yr	kilograms per hectare per year
lb	pounds
ln	natural logarithm

## LIST OF ACRONYMS AND ABBREVIATIONS

mg/L	milligrams per liter
N	nitrogen
NAWQA	National Water Quality Assessment Program
NOAA	US National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	US Department of Agriculture Natural Resources Conservation Service
NTU	Nephelometric turbidity units
P	phosphorus
R	river
SARE	Sustainable Agriculture Research and Education
sq mi	square miles
SWAT	Soil and Water Assessment Tool
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
UofA	University of Arkansas
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USFS	US Forest Service
USGS	US Geological Survey
WRAS	watershed restoration action strategy
WTP	willingness to pay
WWTP	wastewater treatment plant
Yr	year

## 1.0 INTRODUCTION

This watershed management plan addresses the Middle White River watershed located in north-central Arkansas. The primary focus of this plan is protection and improvement of surface water quality in the White River and its tributaries through management of unregulated nonpoint sources of pollution.

### 1.1 Plan Need and Mission

The Arkansas Natural Resources Commission (ANRC) Nonpoint Source Pollution Management program has set itself the goal of preparing watershed management plans for all 57 of the 8-digit Hydrologic Unit Code (HUC) watersheds located partially or completely in the state of Arkansas. The Middle White River 8-digit HUC is not one of the 11 Nonpoint Source priority watersheds designated by ANRC. However, there are two stream reaches in the Middle White River watershed that are included on the most recent (2016) approved state impaired waters list (303(d) list) due in part to pollution from nonpoint sources. Therefore, the Middle White River watershed was selected by ANRC for development of a watershed management plan to address these impairments, and meet the agency goal for development of plans.

The primary focus of this plan is the **protection and improvement** of surface water quality in the White River and its tributaries through management of unregulated nonpoint sources of pollution. The mission of the watershed management plan for the Middle White River watershed is to: Increase awareness of water quality issues, outreach and education, and voluntary activities to implement good water quality management practices. There are agencies and interest groups with active outreach and education programs in the Middle White River watershed that are intended to increase public awareness of water quality issues in the watershed and encourage practices that address those issues. The intention of this plan is to support the efforts of these organizations.

## **1.2 Watershed Vision**

The vision for the Middle White River watershed is: The uses of the Middle White River and its tributaries are attained and sustained, resulting in clean, healthy streams that enhance the socioeconomic and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water quality and the quality of life throughout the watershed.

## **1.3 Management History**

Management of water quality in the upper portion of the Middle White River watershed (upstream of the Independence County line) was addressed in a Watershed Restoration Action Strategy (WRAS) developed by the Friends of the North Fork and White Rivers in 2005 (Friends of the North Fork and White Rivers, Inc. 2007). This WRAS identified perceived problems with water quality, habitat, recreation, aesthetics, and regulations in the target area, and actions to address those issues. Several of the solutions have been completed, while others are on-going.

## **1.4 Process**

Development of the Middle White River watershed-based management plan followed the steps outlined by US Environmental Protection Agency (EPA) in the Handbook for Developing Watershed Plans (EPA 2008):

1. Building partnerships,
2. Characterizing the watershed,
3. Finalizing management goals and identifying solutions, and
4. Designing an implementation program.

ANRC worked with consultants to develop this watershed management plan, utilizing the input of watershed stakeholders. Four public meetings were held as part of the process of developing the Middle White River watershed management plan. The purposes of these public meetings were to inform stakeholders of the plan and the process for developing it, and to request and obtain stakeholder input for the plan. In particular, stakeholder input was sought in

---

identifying priority issues in the watershed, and selecting management strategies for addressing nonpoint source pollution in the watershed. Stakeholders who participated in development of this plan include US Forest Service (USFS), Natural Resources Conservation Service, Arkansas Department of Environmental Quality (ADEQ), Arkansas Department of Health, Arkansas Forestry Commission, Arkansas Game and Fish Commission (AGFC), University of Arkansas (UofA) Cooperative Extension Service, County Conservation Districts, recreation and environmental interest groups, farmers, and ranchers. Sign-in sheets for the public meetings are included as Appendix A.

## **1.5 Document Overview**

This document contains elements recommended by EPA and ADEQ for watershed management plans. Section 2 describes many of the features of the watershed. Sections 3 and 4 summarize conditions in the watershed, including water quality, hydrology, and ecology. Section 5 provides information on pollutant sources in the Middle White River watershed. Section 6 identifies watershed goals and objectives, subwatersheds recommended for initial management of nonpoint pollutant sources, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the recommended subwatersheds. Section 7 outlines the overall implementation plan, with schedule, list of management and outreach activities, and identification of indicators and monitoring to track progress and effects. Section 8 discusses costs and benefits of proposed management, and assistance that is available for implementation of nonpoint source pollution management practices. Watershed-based management plans developed to meet the requirements for Clean Water Act Section 319 funding must address nine planning elements required by EPA to manage and protect against nonpoint source pollution. Table 1.1 provides a roadmap for where the required planning elements are addressed in this plan.

Table 1.1. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan.

Element	Report Section(s)
<b>Element A: Identification of Causes and Sources</b>	
1. Sources identified, described, and mapped	4.1, 4.4
2. Subwatershed sources	4.4
3. Data Sources are accurate and verifiable	3.0
4. Data gaps	3.0
<b>Element B: Expected Load Reductions</b>	
1. Load reductions achieve environmental goal	4.6
2. Load reductions linked to sources	4.6
3. Model complexity appropriate	4.3
4. Basis of effectiveness estimates explained	4.5
5. Methods and data cited and verifiable	4.5, 4.6
<b>Element C: Management Measures Identified</b>	
1. Specific management measures are identified	4.5
2. Priority areas	3.6, 4.4, 4.5, 5.4
3. Measure selection rationale documented	4.0
4. Technically sound	4.0
<b>Element D: Technical and Financial Assistance</b>	
1. Estimate of technical assistance	6.3
2. Estimate of financial assistance	6.1, 6.4
<b>Element E: Education/Outreach</b>	
1. Public education/information	5.1
2. All relevant stakeholders are identified in outreach process	5.1
3. Stakeholder outreach	1.4, 5.1
4. Public participation in plan development	1.4
5. Emphasis on achieving water quality standards	5.1
6. Operation & maintenance of BMPs	5.1
<b>Element F: Implementation Schedule</b>	
1. Includes completion dates	5.9
2. Schedule is appropriate	5.9
<b>Element G: Milestones</b>	
1. Milestones are measurable and attainable	5.7, 5.9
2. Milestones include completion dates	5.9
3. Progress evaluation and course correction	5.7
4. Milestones linked to schedule	5.9

Table 1.1. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan (continued).

Element	Report Section(s)
<b>Element H: Load Reduction Criteria</b>	
1. Criteria are measureable and quantifiable	4.3, 5.7
2. Criteria measure progress toward load reduction goal	5.7
3. Data and models identified	4.3
4. Target achievement dates for reduction	5.7, 5.9
5. Review of progress toward goals	5.7, 5.8
6. Criteria for revision	5.8
7. Adaptive management	5.6, 5.7, 5.9
<b>Element I: Monitoring</b>	
1. Description of how monitoring used to evaluate implementation	5.6, 5.7
2. Monitoring measures evaluation criteria	5.6, 5.7
3. Routine reporting of progress and methods	5.6, 5.8
4. Parameters are appropriate	5.6, 5.7
5. Number of sites is adequate	5.6
6. Frequency of sampling is adequate	5.6
7. Monitoring tied to quality assurance project plan	5.6
8. Can link implementation to improved water quality	5.6,

## 2.0 WATERSHED DESCRIPTION

### 2.1 Geography

The Middle White River watershed, identified by the U.S. Geological Survey (USGS) 8-digit HUC 11010004, covers 1,476.2 square miles (sq mi) in north central Arkansas (Center for Advanced Spatial Technologies 2006). This is the watershed for the section of the White River from the Buffalo River confluence to the Black River. This section of the White River is approximately 123 miles long, and flows southeasterly across Baxter and Independence counties, forming the boundary between Stone and IZard Counties. These four counties account for 95% of the watershed (see Table 2.1). The Middle White River watershed also includes portions of Cleburne, Fulton, Jackson, Marion, Searcy, Sharp, and White Counties at the fringes of the watershed (Figure 2.1). There are several cities located completely or partially within the watershed. The two largest are Batesville and Mountain Home (US Census Bureau 2012a). Two US Highways pass through the watershed, US Highways 62/412, and 167.

Table 2.1. County areas in the Middle White River watershed.

Counties	County area (sq mi)	Area within watershed (sq mi)	Percent of County within watershed	Percent of watershed within County
Baxter	586.28	190.56	32.50%	12.92%
Cleburne	591.78	34.99	5.91%	2.37%
Fulton	620.18	5.63	0.91%	0.38%
Independence	771.23	461.22	59.80%	31.27%
IZard	583.54	384.02	65.81%	26.04%
Jackson	641.36	1.48	0.23%	0.10%
Marion	639.77	0.12	0.02%	0.01%
Searcy	667.79	0.12	0.02%	0.01%
Sharp	606.44	28.50	4.70%	1.93%
Stone	609.19	368.35	60.47%	24.97%
Totals	6317.57	1474.98	23.30%	100%

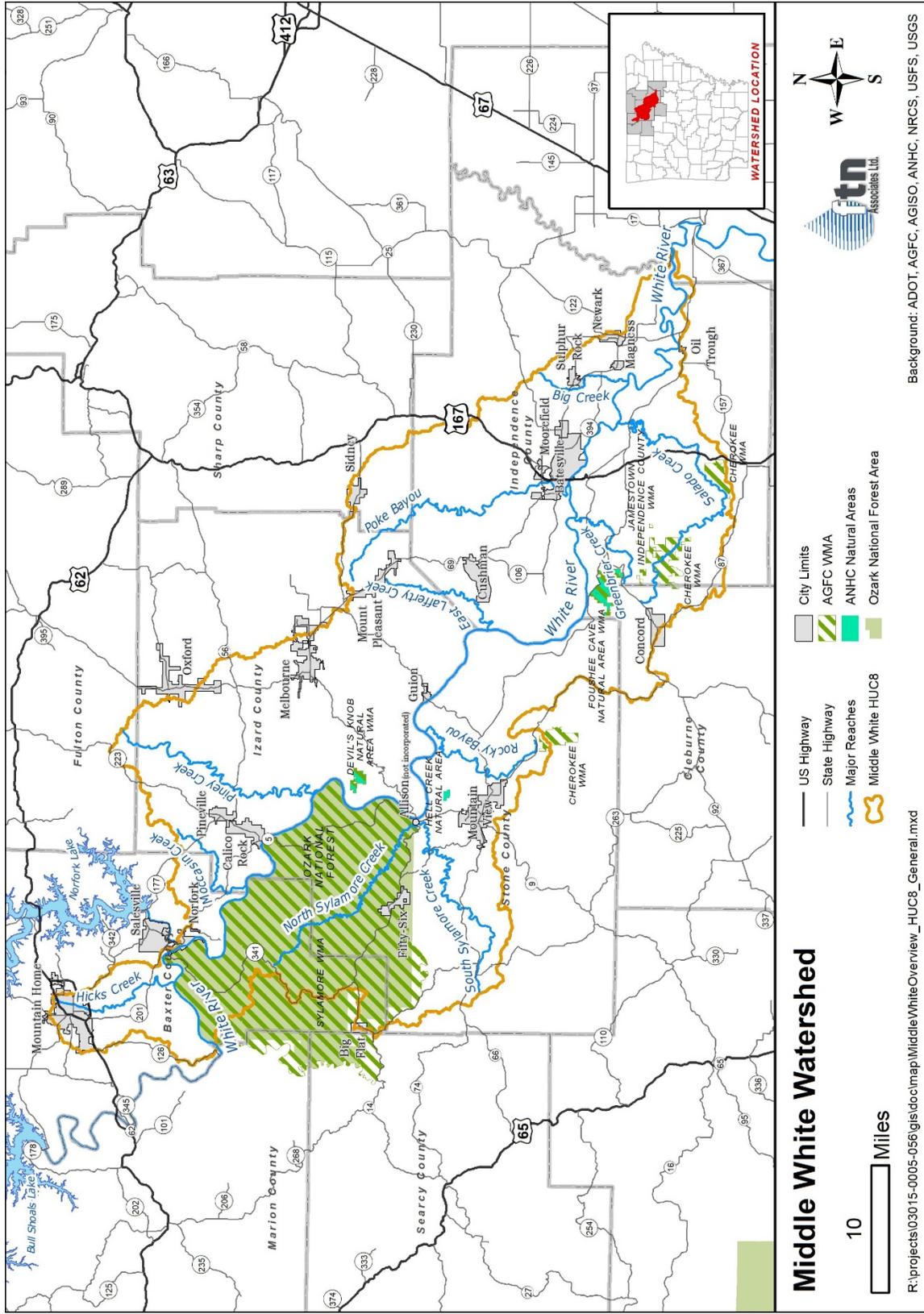


Figure 2.1. Middle White River watershed.

Around 15% of the Middle White River watershed is within one or more publicly owned areas: the Ozark-St. Francis National Forest, AGFC Wildlife Management Areas, or Arkansas Natural Heritage Commission Natural Areas. Note that several publicly owned areas are under the jurisdiction of more than one agency (Figure 2.1).

## **2.2 Socioeconomics**

This section summarizes demographic and economic information for the Middle White River watershed. Demographic information from the US Census Bureau for the counties of the Middle White River watershed is presented.

### **2.2.1 Population**

Numbers of people in the counties of the Middle White River watershed are presented in Table 2.2. All of the counties associated with the Middle White River watershed experienced population increases between 2000 and 2010. Population estimates for 2017 indicate population declines since 2010 in eight of the 10 counties associated with the watershed. The population in IZard County is projected to continue to decline through 2025, while the population in Independence and Stone Counties is projected to increase by 2025. For the remaining 7 counties, it is uncertain whether population will increase or decrease.

The majority of the watershed is classified as rural. There are two urban clusters, as defined by the US Census Bureau, within the watershed, Batesville and Mountain Home (US Census Bureau 2012a). The population in Batesville and Mountain Home increased between 2000 and 2010 (Table 2.2). However, the city population estimates for 2016 (the most recent available) indicate a decline in the population of Mountain Home. The Batesville population continued to increase through 2016. Population projections for these cities were not located.

Additional demographic information for the counties associated with the Middle White River watershed is listed in Table 2.3. This includes percentages of the population for characteristics of commuting, household structure, age, gender, race, median income, poverty, fields of employment, and education level. In the counties associated with the watershed, about two-thirds of households are families, and most of these include two parents. The population of

the watershed is older than the state-wide profile. There are lower percentages of persons under age 18, 18 to 34 years, and 35 to 49 years; while there are higher percentages of persons aged 50 to 64 years and 65 and older. The majority of persons in the watershed consider themselves White (non-Hispanic).

Per-capita incomes in most of the counties associated with the Middle White River watershed are below the state level, but in two counties, Baxter and Cleburne, the per-capita income is higher than for the state. The percentage of families below the poverty level in the counties of the watershed ranges from 9.2% (Baxter County) to 21.4% (Jackson County), with most counties having percentages that are higher than the state 14.2%. The same is true for the percentage of people below the poverty level. The unemployment rates in the counties of the watershed range from 4.2% (Searcy County) to 10% (Marion County), with half of the counties having unemployment rates higher than the state overall. The percentages of bachelor's, and graduate degree holders are lower than the state-wide values. However, two of the counties have higher percentages of high school graduates than the state as a whole.

Table 2.2. Numbers of people in the Middle White River watershed and associated areas.

Area	2000 <sup>a</sup> Total population	Population Density <sup>b</sup> (avg/sq mi)	2010 <sup>a</sup> Total Population	Population Density <sup>a</sup> (avg/sq mi)	2017 population estimate <sup>c</sup>	2025 projection <sup>d</sup>
Baxter County	38,386	69.2	41,513	74.9	41,040	35,242 - 44,981
Mountain Home City	11,012	-	12,448	-	12,312 (2016)	-
Cleburne County	24,046	43.5	25,970	46.9	25,048	21,982 - 27,174
Fulton County	11,642	18.8	12,245	19.8	12,055	11,373 - 13,808
Independence County	34,233	44.8	36,647	48.0	37,504	37,534 - 42,024
Batesville City	9,445	-	10,248	-	10,579 (2016)	-
Izard County	13,249	22.8	13,696	23.6	13,686	11,114 - 12,695
Jackson County	18,418	29.1	17,997	28.4	17,135	14,883 - 18,416
Marion County	16,140	27.0	16,653	27.9	16,428	13,003 - 17,361
Searcy County	8,261	12.4	8,195	12.3	7,938	6,829 - 8,760
Sharp County	17,119	28.3	17,264	28.6	17,393	14,415 - 18,361
Stone County	11,499	19.0	12,394	20.4	12,456	13,030 - 15,003
State of Arkansas	2,673,400	51.4	2,915,918	56.0	2,958,208	3,148,708

<sup>a</sup> (US Census Bureau 2012a)

<sup>b</sup> (US Census Bureau 2003)

<sup>c</sup> (US Census Bureau 2018)

<sup>d</sup> (UALR Institute for Economic Advancement 2015)

Table 2.3. Additional demographic information for counties associated with Middle White River watershed.

	Baxter County	Cleburne County	Fulton County	Independence County	Izard County	Jackson County	Marion County	Searcy County	Sharp County	Stone County	State of Arkansas
<b>Commuting (percent of workers 16 and older)<sup>a</sup></b>											
Drove alone	83.8%	81.6%	84.1%	79.4%	79.9%	86.2%	80.3%	75.0%	77.2%	74.0%	82.7%
Carpooled	9.6%	10.9%	10.0%	14.6%	13.5%	8.0%	13.7%	14.8%	16.4%	12.1%	10.8%
Public Transportation	0.4%	0	0.5%	0	0	0.2%	0.2%	0.3%	0	0	0.4%
Walk or other	3.6%	2.9%	1.7%	3.1%	2.3%	2.5%	1.4%	6.0%	3.1%	7.6%	3.0%
Mean travel time (minutes)	16.9	26.2	23.6	19.0	20.9	19.5	21.4	27.7	27.3	24.3	21.6
Worked at home	2.9%	4.7%	3.5%	2.8%	4.2%	3.1%	4.3%	3.8%	3.2%	6.4%	3.2%
<b>Household Structure (percent of all households)<sup>b</sup></b>											
Family households	66.0%	68.7%	67.9%	69.6%	66.7%	65.8%	67.3%	65.8%	67.8%	67.4%	67.6%
Two parent families	53.8%	55.6%	54.6%	53.7%	54.9%	46.1%	55.5%	53.8%	53.8%	55.9%	49.5%
Single parent families	12.2%	13.1%	13.3%	15.8%	11.8%	19.7%	11.9%	12.0%	14.0%	11.5%	18.1%
Single person household	29.5%	26.9%	28.1%	25.9%	29.7%	30.2%	28.3%	30.3%	28.2%	28.9%	27.1%
Other non-family household	4.5%	4.4%	4.0%	4.5%	3.6%	4.0%	4.4%	3.9%	4.0%	3.7%	5.3%
<b>Age (percent of population)<sup>a</sup></b>											
Median age	51.8	47.9	48.2	39.2	48.1	40.8	51.5	47.5	47.9	49.1	37.7
Under 18	17.7%	19.7%	20.1%	24.1%	18.5%	20.2%	17.7%	19.9%	21.1%	20.1%	23.8%
18 to 24 years	5.6%	6.7%	6.7%	8.5%	7.0%	7.9%	6.1%	6.1%	6.7%	6.8%	9.7%
25 to 44 years	18.8%	20.2%	19.0%	24.4%	20.5%	27.3%	18.0%	21.1%	18.8%	18.9%	25.2%
45 to 64 years	27.8%	28.1%	29.2%	26.4%	29.2%	27.7%	31.8%	28.8%	27.9%	28.9%	25.4%
65 and older	30.1%	25.5%	25.0%	16.7%	24.8%	16.8%	26.5%	24.2%	25.5%	25.3%	15.7%
<b>Gender (percent of population)<sup>a</sup></b>											
Female	51.6%	50.2%	50.5%	51.4%	48.1%	51.0%	50.6%	49.9%	51.0%	49.3%	50.9%
Male	48.4%	49.8%	49.5%	48.6%	51.9%	49.0%	49.4%	50.1%	49.0%	50.7%	49.1%
<b>Race (percent of population)<sup>a</sup></b>											
White non-Hispanic	95.2%	95.0%	95.7%	89.3%	95.6%	77.4%	94.9%	93.7%	94.0%	95.2%	73.4%
Hispanic	2.0%	2.4%	1.3%	6.0%	1.9%	2.7%	2.1%	1.3%	2.1%	1.7%	7.0%
Black non-Hispanic	0.2%	0.6%	0.1%	1.9%	1.2%	17.1%	0.4%	0.4%	0.3%	0.1%	15.4%
Native American	0.5%	0.4%	0.7%	0.3%	0.2%	0.4%	0.7%	1.2%	0.6%	0.3%	0.5%
Asian	0.6%	0.6%	0.1%	0.9%	0.2%	0.1%	0.3%	1.2%	0.6%	0.2%	1.4%
Other race	0	0	0	0	0	0.1%	0	0	0	0	0.3%
>1 race, non-Hispanic	1.4%	1.1%	2.1%	1.6%	0.9%	2.3%	1.7%	2.1%	2.5%	2.5%	2.0%
<b>Income<sup>a</sup></b>											
Per capita income	\$23,068	\$25,078	\$19,082	\$22,035	\$18,964	\$18,316	\$18,706	\$20,618	\$19,404	\$19,616	\$22,798
Families below poverty level	9.2%	10.9%	14.6%	14.7%	16.7%	21.4%	13.5%	16.4%	16.4%	15.5%	14.2%
People below poverty level	13.8%	15.5%	23.2%	19.2%	22.0%	27.1%	19.9%	20.7%	22.2%	23.6%	19.3%

Table 2.3. Additional demographic information for counties associated with Middle White River watershed (continued).

	Baxter County	Cleburne County	Fulton County	Independence County	Izard County	Jackson County	Marion County	Searcy County	Sharp County	Stone County	State of Arkansas
<b>Employment (percent of civilian labor force)<sup>a</sup></b>											
Unemployed	6.2%	8.5%	7.3%	6.7%	9.6%	7.7%	10.0%	4.2%	7.9%	8.1%	7.7%
Mgmt, business, science, arts	30.1%	26.4%	28.1%	29.7%	30.9%	23.8%	21.4%	26.0%	26.6%	32.8%	32.0%
Service	19.7%	18.1%	20.0%	17.8%	20.0%	16.3%	23.4%	10.7%	22.0%	19.0%	17.1%
Sales, office	21.7%	21.3%	21.4%	19.6%	21.1%	21.3%	19.6%	26.2%	18.4%	12.7%	23.9%
Natural resources, construction, maintenance	9.6%	12.7%	15.5%	13.8%	10.0%	15.6%	11.7%	19.0%	15.9%	23.3%	10.7%
Production, transportation, material moving	19.0%	21.5%	15.0%	19.1%	18.0%	22.9%	24.0%	18.1%	17.2%	12.2%	16.4%
Self-employed	7.8%	8.9%	10.4%	6.3%	11.6%	6.5%	13.0%	17.6%	10.7%	19.7%	9.4%
<b>Education (population 25 or older)<sup>a</sup></b>											
High School graduate (or higher)	87.2%	83.3%	83.9%	84.5%	83.9%	76.6%	86.0%	84.6%	83.2%	76.5%	85.2%
Bachelor's degree (or higher)	17.7%	15.4%	11.0%	17.6%	12.4%	8.6%	15.3%	14.4%	10.1%	14.4%	21.5%
Graduate degree	5.4%	5.7%	4.2%	6.4%	4.0%	2.5%	5.3%	5.5%	3.8%	6.5%	7.6%

<sup>a</sup> U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates, accessed via American FactFinder ([https://factfinder.census.gov/faces/nav/jsf/pages/community\\_facts.xhtml?src=bkmk](https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk)) August 2018

<sup>b</sup> U.S. Census Bureau, 2010 Census, accessed via American FactFinder, August 2018

## 2.2.2 Economics

Drivers of the economy in the Middle White River watershed include tourism and outdoor recreation (such as hiking, canoeing, hunting, and fishing), livestock farming, poultry and timber production and processing, and small manufacturing. In Izard County, sand mining is also identified as an important contributor to the economy (Association of Arkansas Counties 2018). The values of sales and receipts reported for selected economic sectors in the four counties that account for the majority of the Middle White River watershed, in the 2012 economic census, are summarized in Table 2.4. Agriculture and timber are not economic sectors reported in the economic census. However, they contribute value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (UofA Divison of Agriculture 2012). Table 2.5 lists the value of sales of agricultural products reported for the same four counties of the Middle White River watershed in the 2012 census of agriculture. Table 2.6 summarizes economic inputs to the counties of the Middle White River watershed from tourism. The US Army Corps of Engineers (USACE) has estimated the regional economic impact of the Norfolk Lake and Bull Shoals Lake reservoirs. Impacts for fiscal year 2016 to areas within 30 miles of these reservoirs are listed in Table 2.7.

Table 2.4. Value of sales, shipments, receipts, revenue, or business done (\$1,000) reported in 2012 Economic Census of the U.S. (US Census Bureau 2012b).

Industry category	Baxter County	Independence County	Izard County	Stone County
Manufacturing	\$574,423	\$1,211,422	D	\$10,458
Wholesale trade	D	D	D	\$34,139
Retail trade	\$476,645	\$441,118	\$108,729	\$107,472
Transportation & warehousing	D	\$92,575	\$21,164	\$2,008
Real estate, rental	\$43,717	\$10,849	\$5,611	\$646
Professional, scientific, technical service	\$30,088	\$20,698	\$2,732	\$2,680
Administrative, support, waste management, remediation	\$18,268	\$29,203	\$1,883	-
Education	\$1,157	D	D	\$211
Health care, social assistance	\$337,450	\$282,052	\$32,691	\$31,873
Arts, entertainment, recreation	\$9,189+	D	\$961+	D
Accommodation, food service	\$61,602	\$48,817	D	\$14,776
Other services	\$25,403	\$17,828	\$3,079	\$1,775+

D – revenue not reported due to privacy issues

Table 2.5. Value (\$1,000) of agricultural products sold in counties of the Middle White River watershed (USDA National Agricultural Statistics Service 2018).

Commodity	Baxter County	Independence County	Izard County	Stone County
All agricultural products	\$20,367	\$131,867	\$49,402	\$53,664
All crops	\$601	\$33,891	\$63+	\$841
Hay	\$489	\$1,714	D	\$764
Grains & beans	D	\$31,670	D	-
All livestock	\$19,766	\$97,976	\$27,652+	\$52,823
Cattle & calves	\$12,238	\$17,322	D	\$21,965
Poultry & eggs	\$6,381	\$79,982	\$27,273	\$30,666
Hogs & pigs	D	\$18	D	D
Horses, etc.	\$218	\$328	\$355	\$76
Sheep, goats products	\$36	\$92	\$24	\$34

D – revenue not reported due to privacy issues.

Table 2.6. Preliminary 2017 economic impacts of tourism/travel in counties of the Middle White River watershed (Arkansas Department of Parks and Tourism 2017).

Commodity	Baxter County	Independence County	Izard County	Stone County
Travel expenditures (\$1,000)	\$261,360	\$50,611	\$29,759	\$95,342
Travel-generated payroll (\$1,000)	\$47,933	\$9,942	\$4,413	\$18,127
Travel-generated jobs	2,349	527	213	871
Travel-generated state tax (\$1,000)	\$15,289	\$3,011	\$1,759	\$5,506
Travel-generated local tax (\$1,000)	\$4,806	\$986	\$747	\$2,021

Table 2.7. Fiscal year 2016 economic impacts of recreation at Bull Shoals Lake and Norfolk Lake, within 30 miles of the reservoirs (USACE 2018).

Commodity	Bull Shoals Lake	Norfolk Lake
Visitor spending (\$1,000)	\$82,041	\$44,264
Sales (\$1,000)	\$42,707	\$24,758
Jobs supported/created	706	387
Labor income (\$1,000)	\$17,416	\$8,991
Value added (\$1,000)	\$22,484	\$12,306

### **2.3 Ecoregions**

Four Level III, and eight Level IV ecoregions occur in the Middle White River watershed (Figure 2.2). Table 2.8 summarizes the characteristics of these ecoregions. These characteristics are described in greater detail in the following subsections.

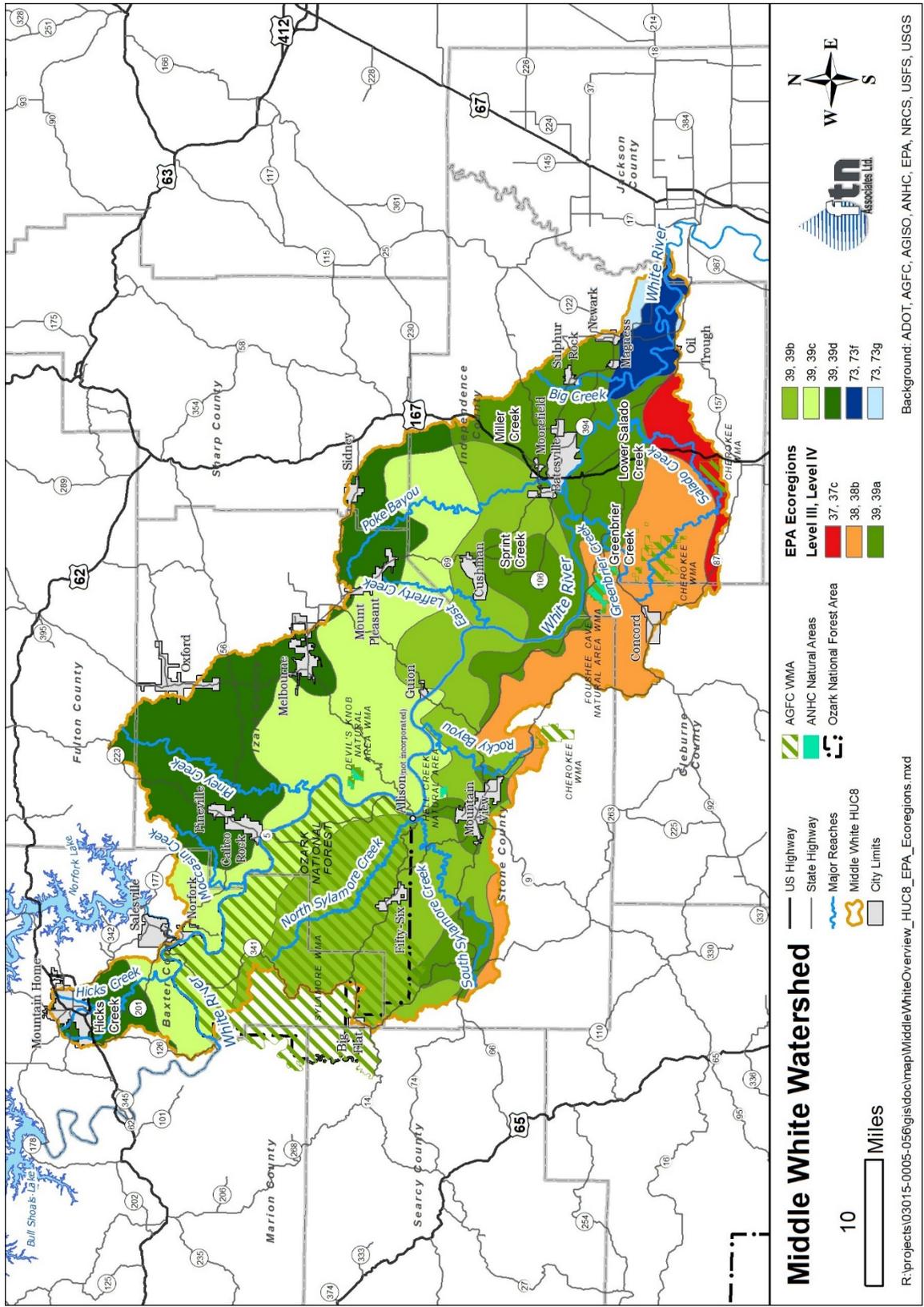


Figure 2.2. Ecoregions of the Middle White River watershed.

Table 2.8. Characteristics of Level IV ecoregions of the Middle White River watershed (from Woods et al. 2004).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
38 – Boston Mountains	38b - Lower Boston Mountains	Low mountains, rounded high hills, and undulating plateaus.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 200-1,900; up to 2,300/ 150-800	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops are usually capped by resistant sandstone. Side slopes are often underlain by interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Mountainburg, Steprock, Nella, Linker, Sidon; in east, Steprock and Linker are more widespread than in west. On floodplains and terraces: Ceda, Cleora, Razort, Spadra. Upland soils have low natural fertility.	46-52. The east is moister than the west.	Potential natural vegetation: oak–hickory–pine forest and oak– hickory forest. Mixed oak and oak–pine forests, woodland, or savanna occur on uplands; northern red oak, white oak, post, scarlet, black, blackjack oak, pignut hickory, shagbark hickory, mockernut hickory, and shortleaf pine are native. On lower, drier south- and west-facing sites: shortleaf pine. On narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak
39 – Ozark Highlands	39a -Springfield Plateau	Nearly level to rolling, undissected or slightly dissected portion of the Springfield Plateau. Karst features including caves, sinkholes, and solution valleys occur.	Springs are common and contribute substantially to streamflow in the summer and fall. Many streams flow year-round, but some dry valleys occur.	260-1,600; uplands are lowest in the east/ mostly 50-200	Quaternary cherty clay solution residuum and limited amounts of alluvium. Extensive limestone and interbedded chert of the Mississippian Boone Formation. Karst	On uplands underlain by cherty limestone: Noark, Clarksville, Nixa, Captina, Tonti. On uplands underlain by sandstone: Linker, Mountainburg. On floodplains or low terraces: Secesh, Razort	44-48. Parts are in the rain shadow of the Boston Mountains.	Potential natural vegetation: oak–hickory forest and some oak– hickory–pine forest. Prior to the 19th century, savanna or tall grass prairies were common and maintained by fire. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) with some mixed deciduous–shortleaf pine forest. Native on floodplains and low terraces: willows, maples, hickories, birch, American elm, and American sycamore.
39 – Ozark Highlands	39b - Dissected Springfield Plateau – Elk River Hills	Moderately to highly dissected, hilly part of the Springfield Plateau. Gently sloping, narrow ridge tops are separated by steep V-shaped valleys. Karst features occur.	Springs are common and contribute to streamflow in the summer and fall. Streams are usually perennial but some dry valleys occur.	300-1,850/ 50-800	Quaternary cherty clay solution residuum, colluvium, and alluvium. On uplands: limestone and interbedded chert of the Mississippian Boone Formation. Along deeply entrenched rivers: earlyMississippian or Devonian Chattanooga Shale and Ordovician Cotter Dolomite. Rock outcrops.	Clarksville, Nixa, Noark, Arkana, Moko, Portia, Estate	44-48. Parts are in the rain shadow of the Boston Mountains	Potential natural vegetation: oak–hickory–pine forest and oak– hickory forest. Native on uplands: oak–woodland, mixed deciduous forest, or mixed deciduous–pine forest containing black oak, white oak, blackjack oak, post oak, hickories, and shortleaf pine. Native on north-facing slopes and in ravines: mesic forest containing sugar maple, white oak, northern red oak, and beech.
39 – Ozark Highlands	39c - White River Hills	Moderately to highly dissected portion of the Salem Plateau containing hills, ridges, karst features, and entrenched, narrow valleys. Flat land is uncommon, but benches and bottomlands flank the White River.	Streams generally flow year-round, reflecting the influence of ground water, but dry valleys occur.	540-1,800/ 150-800	Quaternary cherty silty to sandy clay solution residuum, silty sand to sandy silt decomposition residuum, colluvium, and limited amounts of alluvium. Dolomite, chert, and limestone occur and are sometimes interbedded with sandstone and shale. Ordovician Cotter Dolomite and Jefferson City Dolomite are common but, near the southern boundary, Mississippian Boone Formation occurs.	On uplands: Arkana, Moko, Doniphan, Gassville, Nixa, Clarksville, Noark, Estate, Portia. On floodplains: Razort, Elsah.	42-47	Potential natural vegetation: oak–hickory forest, cedar glades, and, in the west, oak–hickory–pine forest. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) and also mixed deciduous–shortleaf pine forest. Native on driest sites with shallow, rocky soils over dolomite and limestone: glades consisting of eastern redcedar, Ashe juniper, native grasses, and sparse populations of post oak and elm.
39 – Ozark Highlands	39d - Central Plateau	Undulating to hilly part of the Salem Plateau containing hollows, ridges, knobs, and karst features including caves and sinkholes; along major rivers, narrow corridors of nearly level bottomland occur. Generally, slightly to moderately dissected, but steep, highly dissected terrain is found near major rivers.	Springs are common in some areas and contribute substantially to streamflow in the summer and fall. On bottomlands, floodwaters rise and recede quickly.	Mostly 250-1,400; maximum 1,700/ 100-600	Quaternary cherty silty to sandy clay solution residuum, silty sand and sandy silt decomposition residuum, colluvium, and alluvium. Dolomite and limestone are extensive and often cherty; interbedded sandstone and shale also occur. Includes Ordovician Jefferson City Dolomite, Cotter Dolomite, Powell Dolomite, Everton Formation, and St. Peter Sandstone.	On uplands underlain by cherty carbonates: Gepp, Doniphan, Arkana, Agnos, Ventris, Gassville, Moko, Captina, Eldon. On cherty ridgetops and upper slopes: Clarksville. On sandstone uplands: Boden, Brockwell, Brocket, Lily, Portia. On floodplains or low terraces: Hontas, Sturkie, Razort. Upland soils are stony, thin, droughty, and shallower than bottomland soils.	4-49. West facing slopes receive more precipitation than valleys	Potential natural vegetation: oak–hickory forest, oak–hickory–pine forest, and scattered cedar glades. Forest, savanna, glades, barrens, and upland prairies occurred prior to the nineteenth century. Native on uplands: mixed forest containing blackjack oak, post oak, black oak, white oak, hickories. On droughty, rocky slopes: post oak, blackjack oak, and shortleaf pine. On thin soils: barrens with sparse tree cover with herbaceous ground cover. Native on north-facing slopes and in hollows: mesic forests containing sugar maple, white oak, northern red oak, and beech. On shallow, rocky, droughty soils underlain by dolomite or limestone: cedar glades. Native on floodplains and low terraces: southern red oak, white oak, American sycamore, willow, eastern cottonwood, maples, birch, and ash.

Table 2.8. Characteristics of Level IV ecoregions of the Middle White River watershed (continued).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
37 – Arkansas Valley	37c - Arkansas Valley Hills	Undulating plains with occasional hills and ridges. Plains are open in the west but become increasingly interrupted by hills and ridges toward the east.		Mostly 295-600; maximum 900/ 50-200	Quaternary terrace deposits and alluvium. Pennsylvanian shale, sandstone, coal, and siltstone. Bituminous coal is found in the west and grades to semi-anthracite coal in the east.	Mostly Leadvale, Wrightsville, Taft; also Falkner, Pickwick, Ora, Cane, Guthrie. On terraces and floodplains: Barling. On scattered hills and ridges: Mountainburg, Linker.	42-49; driest in the west. In the rain shadow of the Fourche Mountains.	Potential natural vegetation: oak–hickory forest, oak–hickory–pine forest, and in the extreme western part of Arkansas, cross timbers (dominants: little bluestem–blackjack oak–post oak). Prior to the 19th century, on broad, dry, fire-prone plains in the west, extensive prairie and scattered large oaks were found on shallow, droughty soils. To the east, less extensive prairies and prairie–savanna occurred. In upland depressions and on flats with impermeable, clay-rich soils or pans, wetlands occur. Today, woodlands composed of post oak, black oak, white oak, hickories, maple, beech, elm, loblolly pine, shortleaf pine, and redcedar occur. Near Fort Smith: several thousand acres of Cherokee Prairie still remain and are maintained by regular fires. On prairie mounds: sumac and sassafras.
73 – Mississippi Alluvial Plain	73f - Western Lowlands Holocene Meander Belts	Flat to nearly flat floodplain containing the meander belts of the present and past courses of the White, Black, and Cache rivers. Point bars, natural levees, swales, and meander scars occur.	Oxbow lakes, and low gradient rivers occur.	130-300/ 5-20	Holocene sandy, silty, clayey, and gravelly alluvium.	Kobel, Commerce, Sharkey, Foley, Egam, Staser, Dundee, Forestdale, Rexor, Tichnor, Mhoon	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest and woodland dominated by oak communities. Eastern cottonwood, green ash, cherrybark oak, Nuttall oak, water oak, willow oak, and sweetgum are common
73 – Mississippi Alluvial Plain	73g - Western Lowlands Pleistocene Valley Trains	Wide, flat to irregular terraces with relict patterns of branching channels, irregular braided bars, dunes, interdunal depressions, and interfluves.	Includes low gradient, extensively channelized rivers, and creeks that have silty substrates. Drainage ditches occur.	150-320/ 5-20	Quaternary windblown silt (i.e., loess) veneers Quaternary sand sheets, Quaternary sand dunes, Pleistocene terrace deposits (composed of unconsolidated alluvial sand, silt, and gravel), and Pleistocene glacial outwash deposits.	Calloway, Henry, Loring, Memphis, Grenada, Calhoun, Jackport, Foley, Hillemann	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest with an abundance of green ash, bottomland oaks, American elm, cottonwood, sugarberry, sweetgum, water tupelo, and bald cypress; in limited areas, loblolly pine also occurred. Native on Pleistocene dunes: white oak–black oak–southern red oak forest or post oak woodland. In dune depressions or sandponds: forests dominated by overcup oak, water hickory, and pin oak with the federally-endangered shrub, pondberry, in the understory.

### 2.3.1 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the United States by the National Oceanic and Atmospheric Administration’s (NOAA) National Centers for Environmental Information. For the Middle White River watershed, the 1981-2000 climate normals are estimated using weather stations at Batesville, Calico Rock, Melbourne, Mountain Home, and Mountain View, Arkansas. The average annual precipitation is approximately 49 inches. The lowest average monthly precipitation occurs in August, with the highest occurring in May and November. The warmest average monthly temperatures occur in August, while the coldest occur in January. The average monthly precipitation and the average monthly minimum and maximum temperatures are shown on Figure 2.3 (NOAA, et al. 2018).

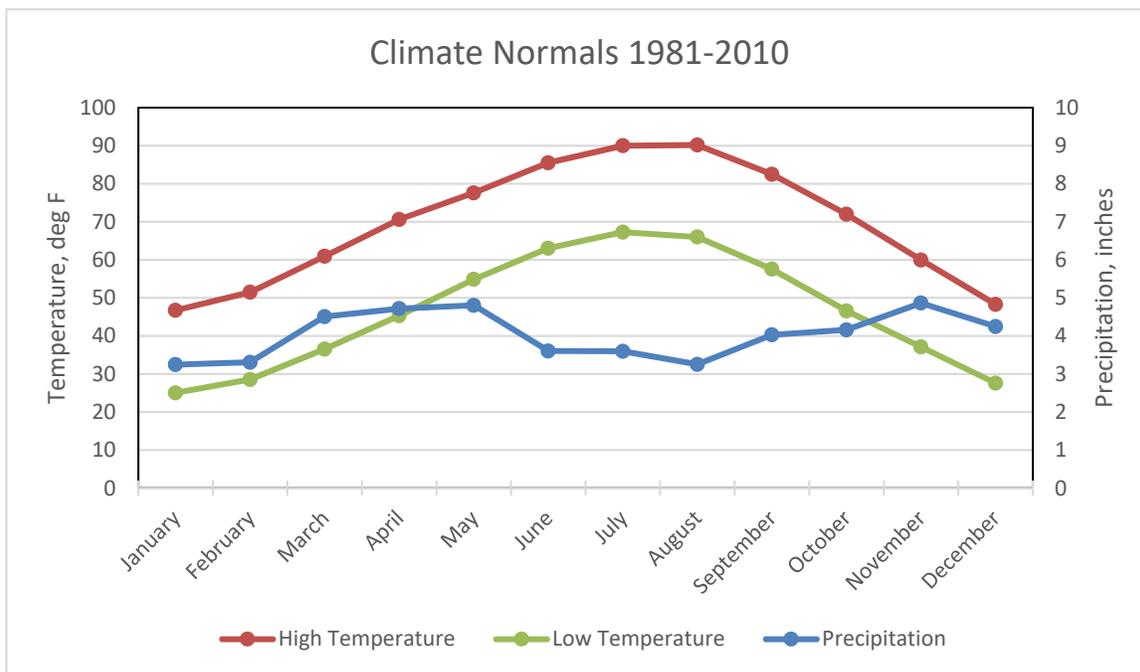


Figure 2.3. 1981-2010 Climate normals in the Middle White River watershed.

### **2.3.2 Geology**

The majority of the Middle White River watershed is located in the Ozark Plateaus physiographic region, extending at the downstream end into the Mississippi Alluvial Plain physiographic region. The upstream end of the watershed originates in the Salem Plateau physiographic region of the Ozark Plateaus, and passes through the eastern Springfield Plateau, with small areas in the eastern watershed in the Boston Mountains physiographic region (Figure 2.4). The geology of the Ozark Plateaus consists of sedimentary rock that was deposited in shallow marine seas during the Ordovician through Pennsylvanian periods. The geology of the Salem Plateau is dominated by Ordovician dolostone, sandstone and limestone, while the Springfield Plateau is predominantly Mississippian limestone, and the Boston Mountains region is Pennsylvanian sandstone (McFarland 2004). Surface geology of the Mississippi Alluvial Plain within the watershed is unconsolidated river sediment deposits. A surface geology map of the Middle White River watershed is shown on Figure 2.5. Table 2.9 is a stratigraphic listing of the geologic formations present in the Middle White River watershed.

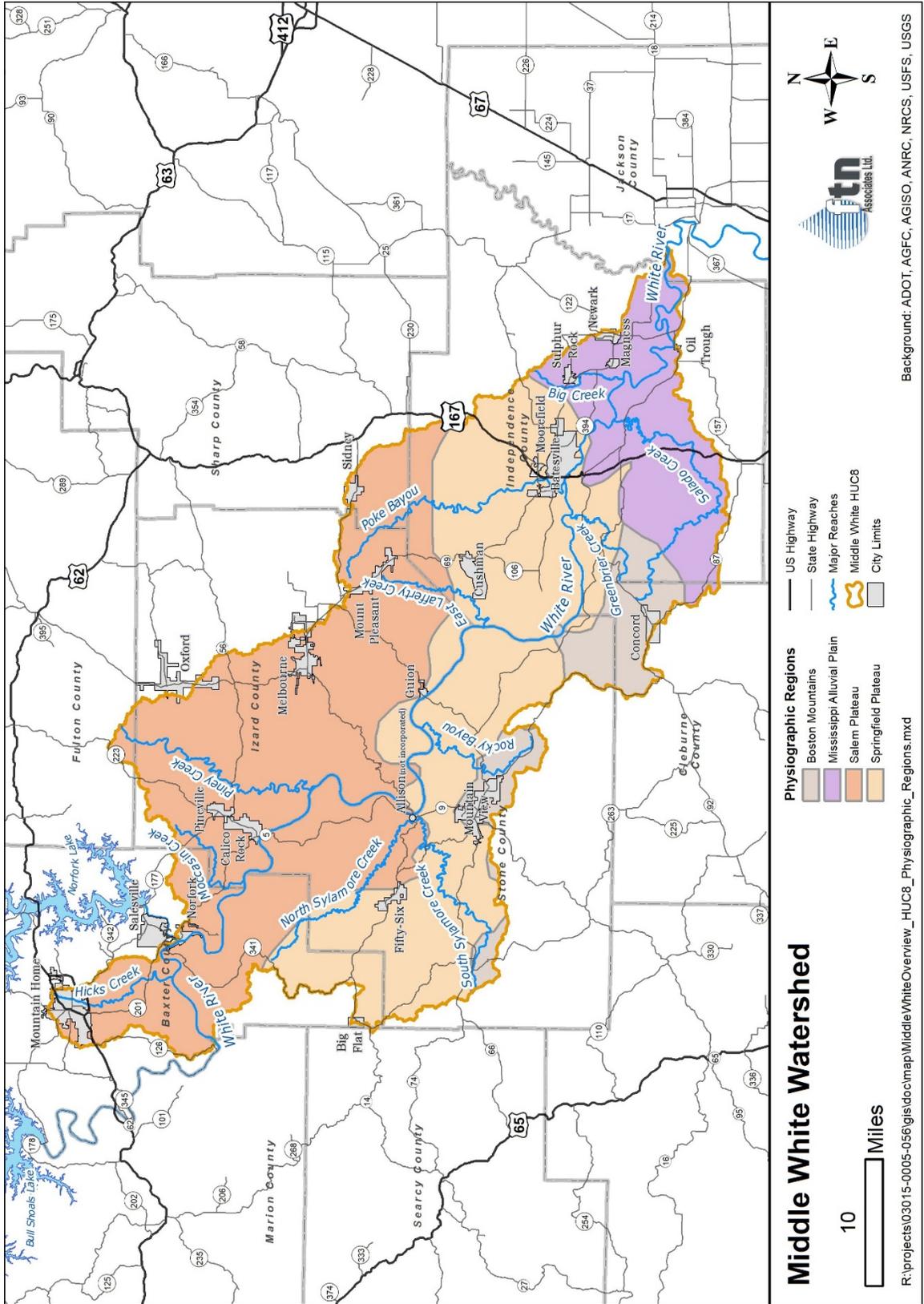


Figure 2.4. Physiographic regions within the Middle White River watershed.

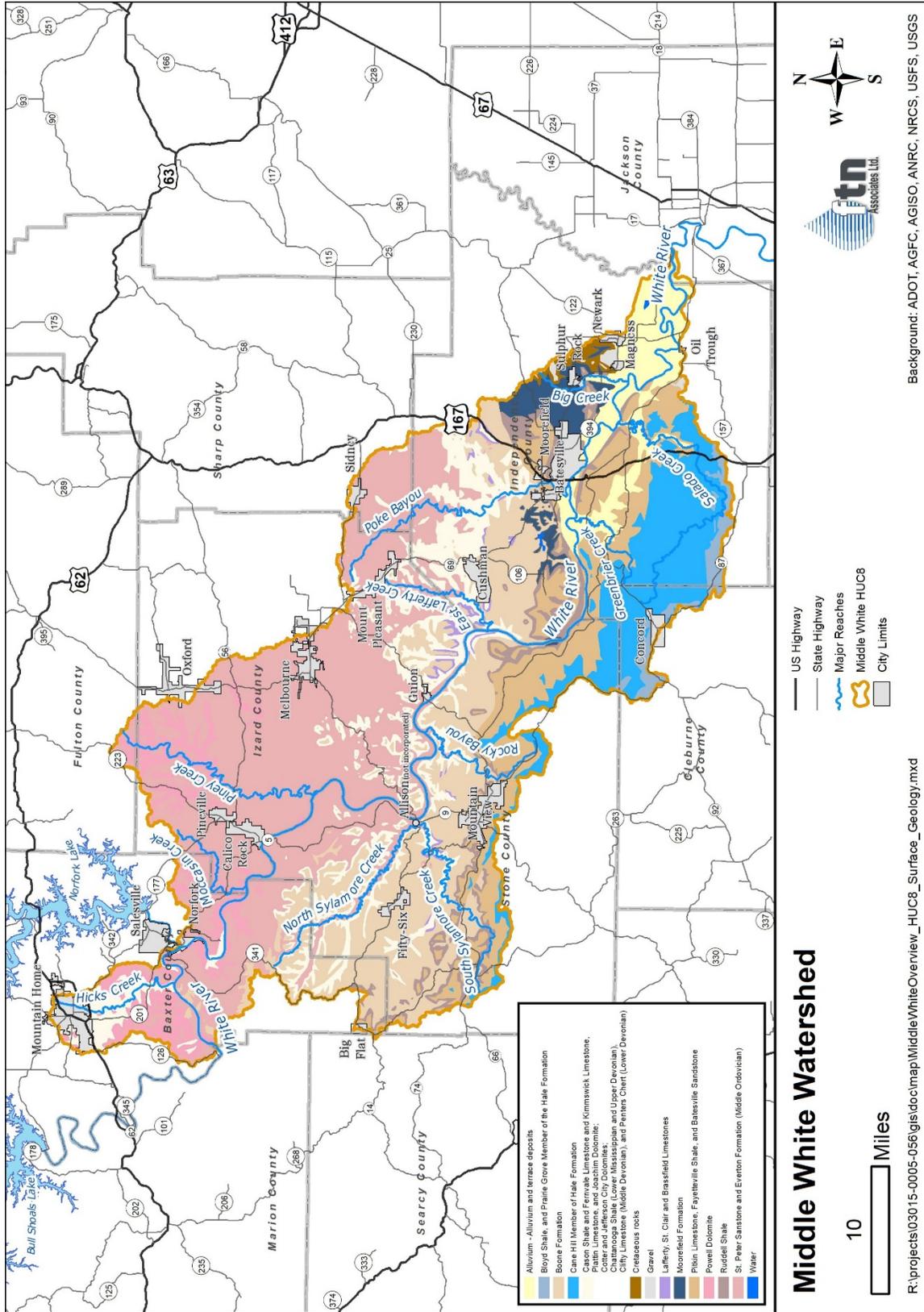


Figure 2.5. Surface geology map of the Middle White River watershed.

Table 2.9. Stratigraphic column listing with descriptions of lithology for geologic formations underlying the Middle White River watershed (Arkansas Geological Survey 2015).

Era	Period	Geologic Unit	Lithology	Thickness, feet
Quaternary	Pleistocene & Holocene	Alluvial deposits	Unconsolidated sand, gravel, silt, clay	Not reported
Tertiary	Tertiary	Alluvial deposits	Gravel	Not reported
Cretaceous	Upper Cretaceous	Cretaceous rocks	Shaley clay, gravel	Not reported
Paleozoic	Pennsylvanian	Bloyd Shale	Sandstone, shale, siltstone	175-200
		Prairie Grove	Sandstone, limestone	2-300
		Cane Hill	Shale, siltstone, sandstone	
	Mississippian	Imo Shale (member of Pitkin Limestone)	Sandstone, shale	0-140
		Pitkin Limestone	Limestone, shale	<1 - >400
		Fayetteville Shale	Shale, limestone	10-400
		Batesville Sandstone	Sandstone, shale	<1 - >200
		Ruddell Shale	Shale	0- 300
		Moorefield Formation	Shale, limestone	
		Boone Formation	Limestone, chert	300-390
		St. Joe Limestone	Limestone	0-110
	Devonian	Chatanooga Shale	Shale	0-85
		Penters Chert	Chert, limestone	0-90
	Silurian	Lafferty Limestone	Limestone	5-95
		St. Clair Limestone	Limestone	0-100
		Brassfield Limestone	Limestone	0-38
	Ordovician	Cason Shale	Shale, sandstone, limestone	0- 23
		Fernvale Limestone	Limestone	0-100
		Kimmswick Limestone	Limestone	0-55
		Plattin Limestone	Limestone (micrite)	0- 250
		Joachim Dolomite	Dolostone, limestone	0-100
		St. Peter Sandstone	Sandstone	20-300
		Everton Formation	Limestone, dolostone, sandstone	300-650
Calico Rock Sandstone		Sandstone		
Powell Dolomite		Shaley dolostone, sandstone	0- 215	
Cotter Dolomite		Dolostone, chert	0- 500	
Jefferson City Dolomite		Dolostone, chert		
Roubidoux Formation		Sandstone and sandy dolomite	Not present at surface	
Gasconade Formation		Dolomite, cherty and sandy dolomite, and sandstone.		

The Middle White River watershed encompasses areas where lead, manganese, phosphate rock, and zinc deposits have been found (Arkansas Geological Survey 2001, Myers 2012). Manganese mining was important in this area from just after the Civil War to 1959 (Smith 2017). Manganese ore is associated mostly with Fernvale Limestone and Cason Shale (Suhm 1968). The only active mining in the watershed is of sand, gravel, limestone, and dolostone (Arkansas Geological Survey 2018).

Because much of the geology underlying the Middle White River watershed is comprised of carbonate formations, karst features are common. In areas north and east of the White River around Mountain Home and Batesville, there are roughly 1 to 10 sinkholes per 100 sq mi (Adamski, et al. 1995). There are a number of caves in the watershed, some of which are open to the public. The Sylamore District of the Ozark National Forest, the majority of which is located within the Middle White River watershed, contains approximately 10% of the known caves in Arkansas (Graening, Slay and Tinkle 2003). Springs are also common (see Section 2.5).

### **2.3.3 Topography**

Elevations within the Middle White River watershed range from 197 feet above sea level where the Black River joins the White River, to 1,584 feet above sea level in the Boston Mountains region of the watershed, near Mountain View (Center for Advanced Spatial Technologies 2006). The gradient of the White River from the upstream end of the watershed (elevation 380 feet above sea level) to the downstream end (elevation 197 feet above sea level), 123.4 river miles, is approximately 1.5 feet/mile.

Land slopes in the Middle White River watershed range from < 3 degrees in valley bottoms and hill tops, to > 45 degrees on cliff faces and hill sides. Slopes of 14% or more are considered steep, while areas with slopes of 7% or less are considered flat lands. Geographic Information System (GIS) analysis indicates that approximately 44% of the watershed has slopes steeper than 14%. Table 2.10 lists the proportion of the Middle White River watershed considered flat lands, steep, and in between. Figure 2.6 shows a map of the locations of areas within the three slope ranges.

Table 2.10. Slope areas in the Middle White River watershed.

<b>Slope ranges, degrees</b>	<b>Area within the watershed, Acres</b>	<b>Percent of watershed</b>
<7%	302,209	32%
7-14%	229,565	24%
>14%	412,212	44%

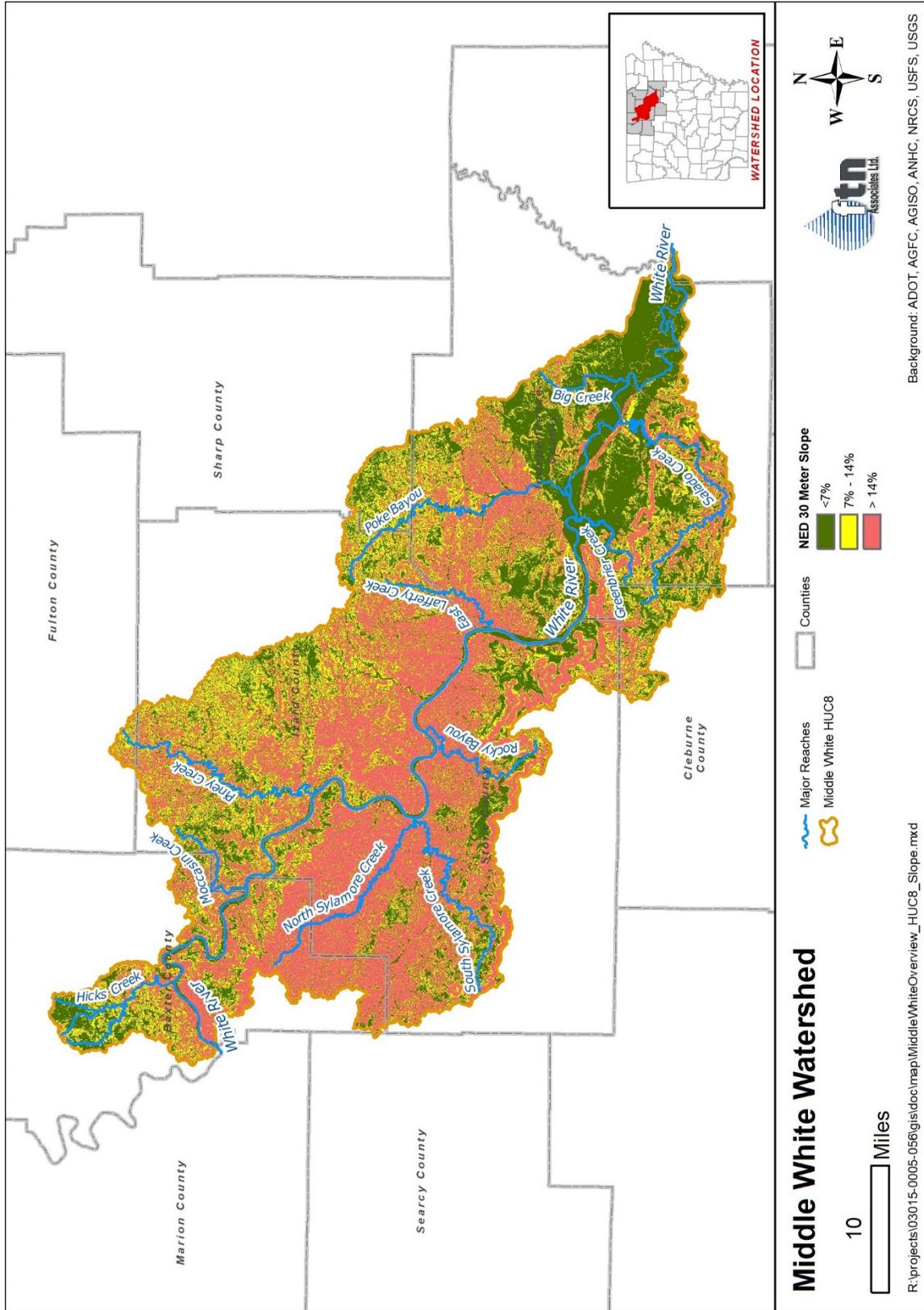


Figure 2.6. Map of slope ranges in the Middle White River watershed.

Each of the four physiographic regions in the watershed is characterized by differences in topography (Figure 2.4). Forty-four percent of the watershed is in the Salem Plateau physiographic region, where the characteristic terrain is rugged and relief can be as much as 500 feet. Thirty-six percent of the watershed is in the Springfield Plateau physiographic region. In this area of the watershed, elevations range from 1,500 to 200 feet above sea level and local relief can be as much as 300 feet. Seven percent of the watershed is in the Boston Mountains physiographic region. This area of the watershed is characterized by rugged terrain with steep-sided valleys (Adamski, et al. 1995). Thirteen percent of the watershed is in the Mississippi Alluvial Plain physiographic region. This region is characterized by flat to gently rolling plains with little relief. Elevations in this area of the watershed are around 200 feet above sea level.

#### **2.3.4 Soils**

Soils in the upland areas of the Middle White River watershed tend to be stony, and have low fertility and high erosion potential. In river valleys and the Delta lowlands, soils are deeper and more fertile, but prone to flooding (Friends of the North Fork and White Rivers, Inc. 2007). Four soil associations cover 76% of the Middle White River watershed – Brockwell-Boden-Portia, Clarksville-Noark-Nixa, Linker-Enders-Steprock, and Portia-Estate-Moko (Figure 2.7). The Clarksville-Noark-Nixa occurs on just over one-quarter of the watershed (27%). Characteristics of the major soils present in the watershed are summarized in Table 2.11.

#### **2.3.5 Land Use/Land Cover**

The majority of the land in the Middle White River watershed, 69%, is forested (Figure 2.8). Pasture and haylands is the next most common land use in the watershed. Pasture and haylands in the Middle White River watershed are primarily located on relatively flat land in river valleys and on ridge tops (Figure 2.9).

Table 2.11. Characteristics of major soil associations of the Middle White River watershed.

Name	Drainage	Character	Depth	Erosion hazard	Natural fertility	Sanitation limitation
Amagon-Dundee-Sharkey <sup>3</sup>	Poorly drained	Silt loam	Deep	-	Moderate	Severe
Arkana-Moko-Gassville <sup>1,2,3</sup>	Moderately well drained	Very cherty and stony silt loam	Moderately deep to shallow	Severe	Low - moderate	Severe
Brockwell-Boden-Portia <sup>2,3</sup>	Well drained	Fine sandy loam	Deep	Severe	Low	Moderate to severe
Clarksville-Nixa-Captina <sup>2,3</sup>	Moderately to excessively well drained	Very cherty silt loam	Deep	Severe	Low	None to severe
Clarksville-Noark-Nixa <sup>2,3</sup>	Somewhat excessively well drained	Very cherty silt loam	Deep	Severe	Low	Moderate to severe
Enders-Nella-Mountainburg <sup>2,3,4</sup>	Well drained	Fine sandy loam, gravelly, and stony	Deep to shallow	Severe	Low	Moderate to severe
Foley-Jackport-Crowley <sup>3</sup>	Poorly to somewhat poorly drained	Silty clay loam	Deep	Minimum	Moderate	Severe
Gepp-Doniphan-Agnos <sup>2,3</sup>	Well drained	Very cherty silt loam	Deep	Severe	low	Moderate
Kobel-Commerce-Dubbs <sup>3</sup>	Well drained	Silt loam	Deep	Moderate	Moderate	None
Linker-Enders-Steprock <sup>3,4</sup>	Well drained	Fine sandy loam, gravelly, and stony	Deep to shallow	Severe	Low	Severe
Loring-Oakalimeter-Tichnor <sup>2</sup>	Moderately well drained	Silt loam	Deep	Moderate	Moderate	Severe
Newnata-Eden-Moko <sup>3,4</sup>	Well drained	Silty clay loam	Deep to shallow	Severe	Moderate	Severe
Portia-Estate-Moko <sup>2</sup>	Well-drained	Stony and loamy	Deep to shallow	-	Low - moderate	-

<sup>1</sup> (US Soil Conservation Service 1984)  
<sup>2</sup> (US Soil Conservation Service 1983a)  
<sup>3</sup> (US Soil Conservation Service 1982)  
<sup>4</sup> (US Soil Conservation Service 1983b)

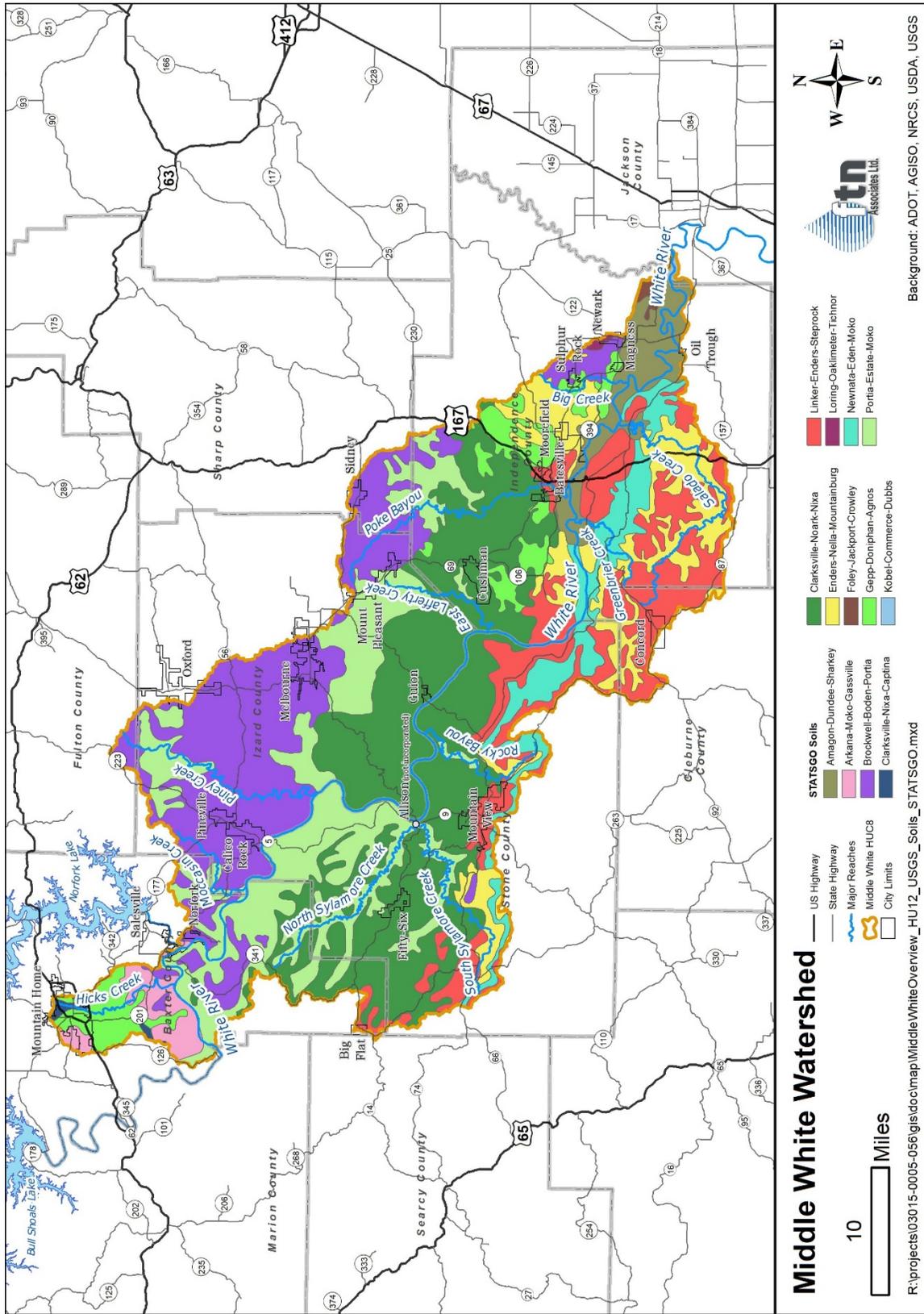


Figure 2.7. Map of soil associations in the Middle White River watershed.

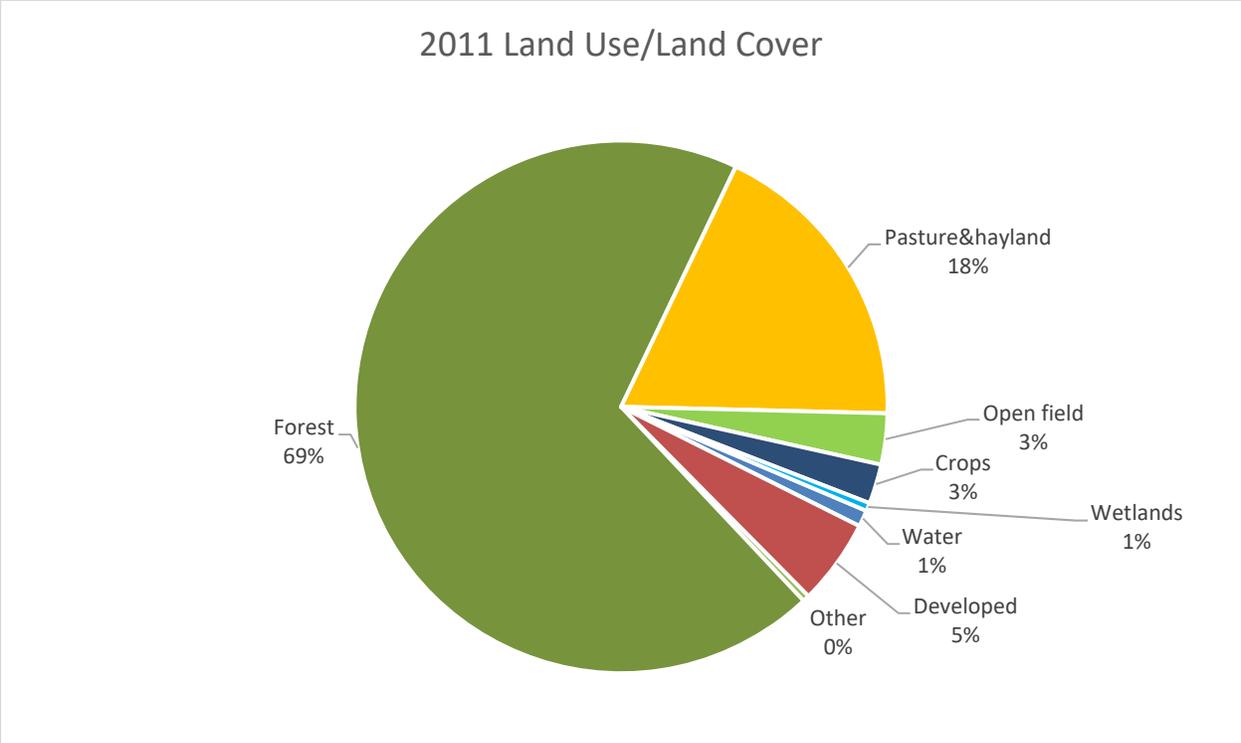


Figure 2.8. Land use/land cover percentages for the Middle White River watershed (Homer, et al. 2015).

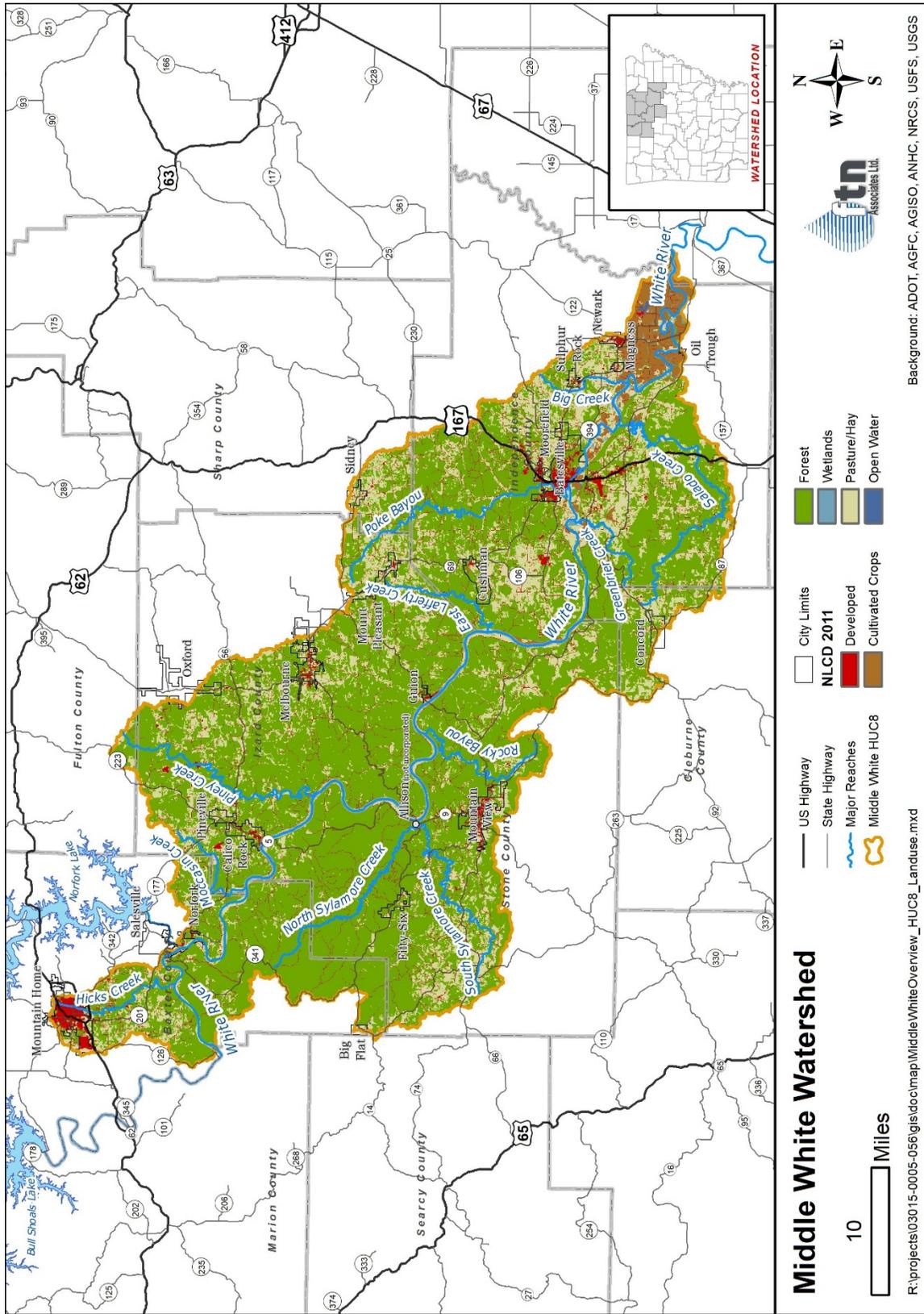


Figure 2.9. Land use map of the Middle White River watershed (Homer, et al. 2015).

## **2.4 Water Resources**

Surface water and groundwater resources of the Middle White River watershed are described in this section.

### **2.4.1 Surface Water**

There are over 2,300 miles of streams in the Middle White River watershed (Center for Advanced Spatial Technologies 2006). There were four active USGS flow gages in the Middle White River watershed in 2018 (Figure 2.10). The flow gages on the White River are also part of the USACE river stage monitoring network. Table 2.12 lists summary statistics for flow measurements from these gages. The farthest downstream USGS flow gage on the White River in this watershed is at Batesville. The largest tributary subbasin in this watershed is Sylamore Creek (North and South Sylamore Creek combined), which accounts for approximately 15% of the watershed. Subwatersheds for Piney Creek and Poke Bayou are about the same size, and each account for another 12% of the watershed.

The Middle White River watershed receives releases from the USACE reservoirs Bull Shoals Lake and Norfolk Lake. These reservoirs contribute the majority of the White River flow in this watershed. Minimum flow releases have recently been set for both of these reservoirs; 800 cubic feet/second for Bull Shoals Lake and 300 cubic feet/second for Norfolk Lake (USACE Little Rock District 2016).

Surface water is used as the municipal drinking water supply by several communities in the Middle White River watershed including Mountain Home, Batesville, Mountain View, Cushman, as well as the Sylamore Valley Water Association (Arkansas Department of Health 2017). Surface water sources used by communities in the Middle White River watershed for drinking water are the White River and Norfolk Lake.

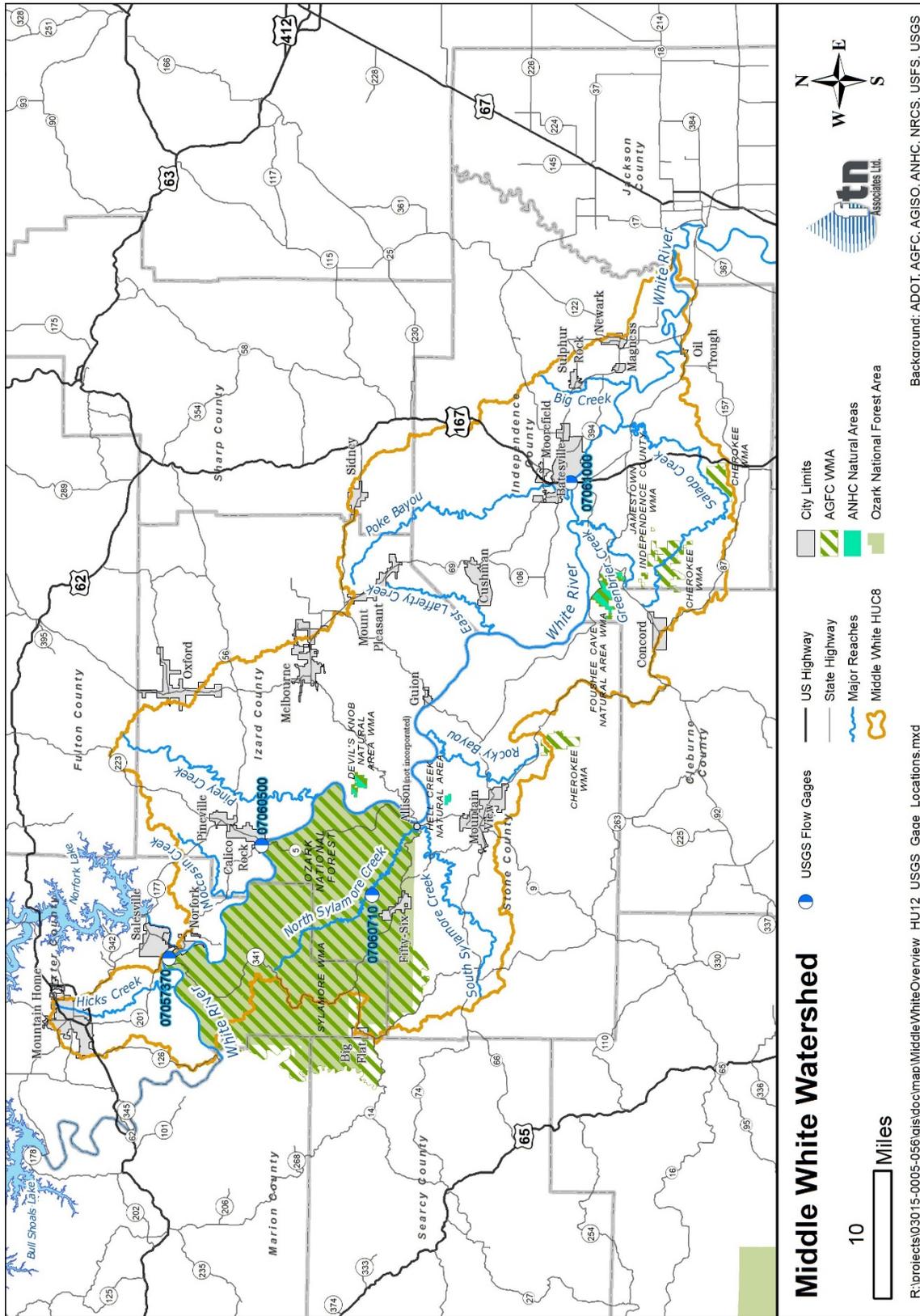


Figure 2.10. Active USGS flow gages in the Middle White River watershed, 2018.

Table 2.12. Statistics for discharge data from USGS gages active in 2018 (USGS 2018a).

Site Number	Year Established	Site Name	Annual Average Discharge (cfs*)	Lowest Mean Monthly Discharge, (cfs*)	Highest Mean Monthly Discharge (cfs*)	7Q10 Flow, (cfs*)	90% Exceeds Flow, (cfs*)	Peak Flow, (cfs*)
07057370	1996	White River near Norfolk, AR	8,727	1,060	44,940	649	1,850	196,000
07060500	1939	White River at Calico Rock, AR	10,795	1,905	37,470	950	2,710	202,000
07060710	1965	North Sylamore Creek near Fifty-Six, AR	54.4	2.31	471	1.8	4.1	28,200
07061000	1937	White River at Batesville, AR	12,604	2,160	45,210	1,104	3,360	208,000

\* Calculated for period 2004-2016, longest period when all stations have data. Annual average calculated for calendar year.

## 2.4.2 Groundwater

The Middle White River watershed is underlain by three aquifers, the Springfield Plateau aquifer and the Ozark aquifer in the uplands, and the Mississippi River Valley alluvial aquifer in the lowlands of the downstream end of the watershed. The Western Interior Plains Confining System is a series of geologic formations present at the surface in the lower and western areas of the watershed that is also a locally important water supply source (Kresse, et al. 2014).

Table 2.13 shows the geologic formations associated with each of these aquifers, and their relative position with regard to depth. Figure 2.11 shows where these aquifers are unconfined. The Ozark aquifer is present beneath the Springfield Plateau aquifer. The Springfield Plateau aquifer is present beneath the Western Interior Plains confining system as well as where it is unconfined (Westerman, et al. 2016).

Table 2.13. Stratigraphic geology listing with aquifers underlying the Middle White River watershed (Kresse, et al. 2014).

Era	Period	Geologic Unit	Lithology	Regional Aquifer
Quaternary	Pleistocene & Holocene	Alluvial deposits	Unconsolidated sand, gravel, silt, clay	Mississippi River Valley alluvial aquifer
Tertiary	Tertiary	Alluvial deposits	Gravel	
Cretaceous	Upper Cretaceous	Cretaceous rocks	Shaley clay, gravel	
Paleozoic	Pennsylvanian	Bloyd Shale	Sandstone, shale, siltstone	
		Prairie Grove	Sandstone, limestone	
		Cane Hill	Shale, siltstone, sandstone	
	Mississippian	Imo Shale (member of Pitkin Limestone)	Sandstone, shale	
		Pitkin Limestone	Limestone, shale	
		Fayetteville Shale	Shale, limestone	
		Batesville Sandstone	Sandstone, shale	
		Ruddell Shale	Shale	
		Moorefield Formation	Shale, limestone	
		Boone Formation	Limestone, chert	Springfield Plateau aquifer
	Devonian	St. Joe Limestone	Limestone	Ozark confining unit
		Chatanooga Shale	Shale	
	Silurian	Penters Chert	Chert, limestone	Upper Ozark aquifer
		Lafferty Limestone	Limestone	
		St. Clair Limestone	Limestone	
	Ordovician	Brassfield Limestone	Limestone	
		Cason Shale	Shale, sandstone, limestone	
		Fernvale Limestone	Limestone	
		Kimmswick Limestone	Limestone	
		Plattin Limestone	Limestone (micrite)	
Joachim Dolomite		Dolostone, limestone		
St. Peter Sandstone		Sandstone		
Everton Formation		Limestone, dolostone, sandstone		
Calico Rock Sandstone		Sandstone		
Powell Dolomite		Shaley dolostone, sandstone		
Cotter Dolomite		Dolostone, chert		
Jefferson City Dolomite		Dolostone, chert		
Roubidoux Formation		Sandstone and sandy dolomite	Lower Ozark aquifer	
Gasconade Formation		Dolomite, cherty and sandy dolomite, and sandstone.		

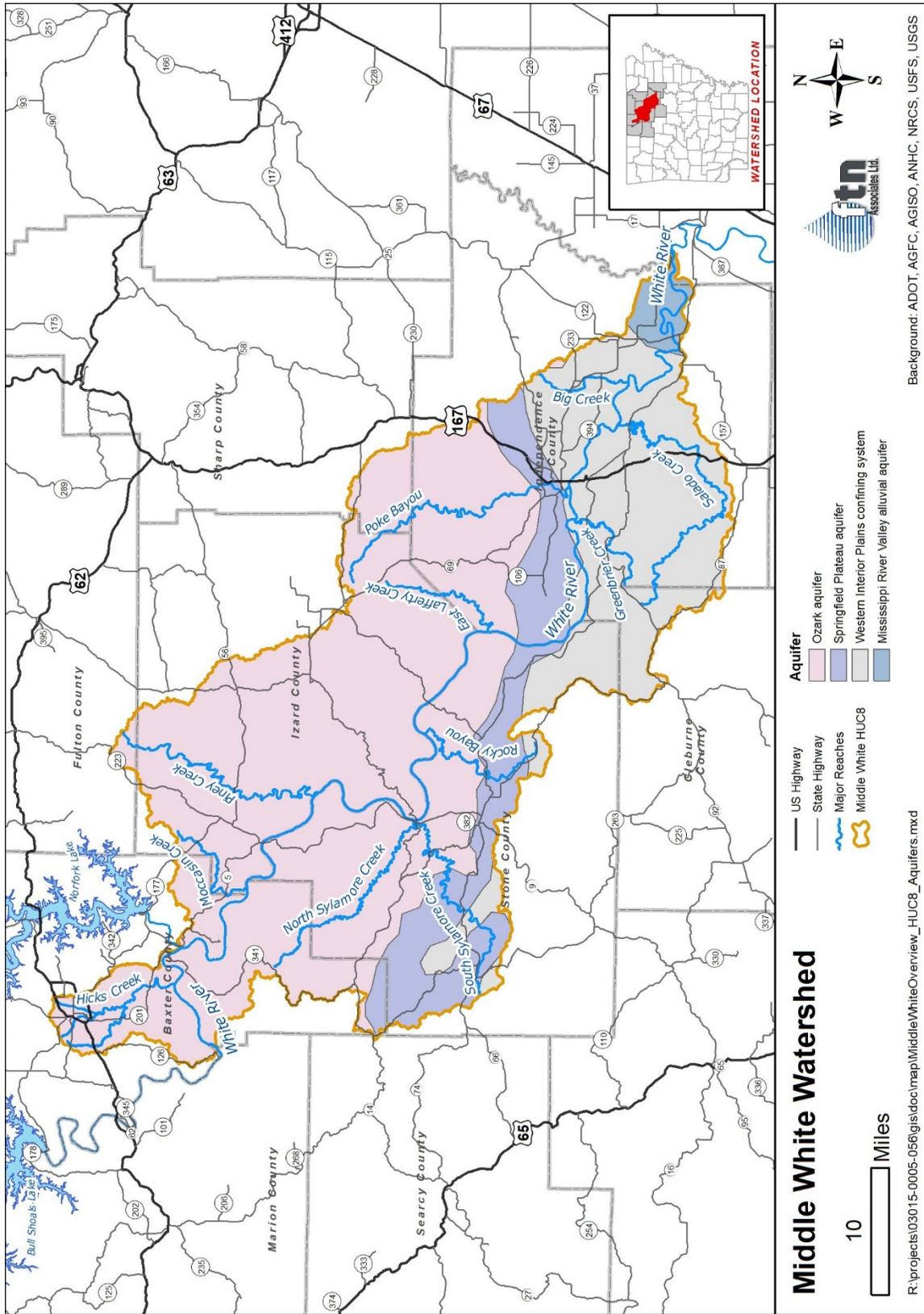


Figure 2.1.1. Outcrop areas of aquifers within the Middle White River watershed.

The Ozark aquifer is the largest aquifer and most important source of fresh groundwater in the Ozark region of northern Arkansas and southern Missouri. This aquifer is a thick sequence of water-bearing rock ranging in age from the Late Cambrian to Middle Devonian. The Ozark aquifer is unconfined, occurring at or near the surface, over large areas of the Middle White River watershed (Figure 2.11). Where this aquifer is unconfined, it receives direct recharge from precipitation, primarily through sinkholes and rock fractures. In the southern and western Middle White River watershed, the Ozark aquifer is confined, and receives only indirect recharge from the unconfined region and the overlying Springfield Plateau aquifer. Well yields from the upper Ozark aquifer are usually 5-10 gallons/minute (gpm). The lower Ozark aquifer receives recharge primarily from the areas where it is at the surface in Missouri, with some contribution from the upper Ozark aquifer. Wells in the lower Ozark aquifer are some of the most productive in the region with yields usually ranging from 50 to 600 gpm. This is the aquifer most often used for municipal water supply (Kresse, et al. 2014).

The Springfield Plateau aquifer is associated with the Mississippian Boone Formation, which underlies the southern half of the Middle White River watershed. The Springfield Plateau aquifer is unconfined over a relatively small area of the Middle White River watershed (Figure 2.11). This aquifer is recharged primarily by rainwater via sinkholes, fractures and conduits, and losing stream reaches. Well yields from this aquifer are commonly between 10 and 100 gpm (Kresse, et al. 2014).

The Western Interior Plains Confining System is composed of low to moderately permeable formations of Mississippian and Pennsylvanian age. This system is unconfined and present at the surface in the southern area of the watershed (Figure 2.11). Water yields from this system are adequate only for household use (Kresse, et al. 2014).

The Mississippi River Valley alluvial aquifer is a primarily unconfined aquifer in unconsolidated coarse sands and gravels of the Mississippi River Alluvial Plain. Primary recharge to this aquifer is from precipitation. In some areas, a layer of fine sand, silt, and clay occurs over the coarse sands and gravels and acts as a confining layer, blocking precipitation from the aquifer. Reported yields from this aquifer range from 500 to 5,000 gpm (Kresse, et al. 2014).

There are 18 community water systems and 17 noncommunity systems in the Middle White River watershed that use groundwater as their drinking water supply (Arkansas Department of Health 2017). Marcella Spring in Stone County has been used as a source for commercially bottled water by the Marcella Natural Springs company of Jonesboro, AR (Arkansas Geological Survey 2018).

### **2.4.3 Surface Water – Groundwater Connections**

The karst geology present in the Middle White River watershed makes exchanges between surface water and groundwater common in the watershed. An important concern in areas of karst geology is contamination of groundwater by surface water runoff or infiltration. Surface water travels through karst geology too quickly to be cleaned of contaminants like bacteria, nutrients, or chemicals like pesticides, so contaminants from the surface of the land can easily end up in groundwater, springs, and caves. Recharge areas have been delineated for several cave/spring systems in the Middle White River watershed, including Blanchard Springs Cavern (Aley 1980), Nesbitt Spring Cave (Gilip, Galloway and Hart 2009), Hell Creek Cave (Aley and Aley 1985, Stewart 1988), and Foushee Cave (Rupar and Slay 2011). No studies were found identifying streams or stream segments in the watershed that go to groundwater, i.e., losing streams.

There are a number of springs in the Middle White River watershed, through which groundwater is discharged to surface waters. The largest of these is Blanchard Springs in the Ozark National Forest in Stone County. In the Middle White River watershed, springs have been identified that carry contaminants from outside of the watershed to streams within the watershed (Mott, Hudson and Aley 2000). While possible, no such situations have been identified in the Middle White River watershed.

## **2.5 Wildlife Resources**

Several of the species present in the Middle White River watershed are found only within the interior highlands of Arkansas (Table 2.14). A number of native species present in the watershed are listed as threatened or endangered by the state or federal government. There are

also a number of native species present that the state has identified as species of greatest conservation need. In addition, there are plants and animals present in the watershed that are not native and that are believed to pose a threat to native species.

Table 2.14. Arkansas endemic species present in the Middle White River watershed (McCallister 2018, Arkansas Natural Heritage Commission 2018, NatureServe 2018).

Common name	Scientific name	Category	Location in watershed
None	<i>Dictyostelium caveatum</i>	Fungi, slime mold	Blanchard Springs Cavern, Stone County
Foushee Cave Snail	<i>Amnicola cora</i>	Invertebrate	Foushee Cave, Independence County
None	<i>Nocomis biguttatus</i>	Fish gill parasite	White River at Sylamore, Izard County
White lipstooth	<i>Daedalochila peregrine</i>	Invertebrate, snail	Izard and Stone Counties
Calico Rock oval	<i>Patera clenchi</i>	Invertebrate, snail	Izard County
Arkansas Wedge	<i>Xolotrema occidentale</i>	Invertebrate, snail	Independence and Stone Counties
Boston Mountains crayfish	<i>Cambarus causeyi</i>	Invertebrate, crayfish	Stone County
Hell Creek crayfish	<i>Cambarus zophonastes</i>	Invertebrate, crayfish	Stone County
None	<i>Neoleptoneta arkansa</i>	Spider	Blanchard Springs Cavern, Stone County
None	<i>Apochthonius titanicus</i>	pseudoscorpion	Blanchard Springs Cavern, Stone County
Causey's Cave millipede	<i>Causeyella causeyae</i>	Millipede	Independence, Izard, and Stone Counties
None	<i>Chaetaspis attenuatus</i>	Millipede	Cushman Cave, Independence County; Clay Cave, Izard County
None	<i>Typhlogastrura fousheensis</i>	Springtail	Foushee Cave, Independence County
None	<i>Speleochus blanchardensis</i>	Beetle	Blanchard Springs Cavern, Stone County
None	<i>Anillinus alleni</i>	Beetle	Blanchard Springs, Stone County
Ozark Pocket Gopher	<i>Geomys bursarius ozarkensis</i>	Mammal	Izard and Stone Counties

Fish communities of the Middle White River watershed are overall more similar to fish communities of the Ouachita Mountains than to fish communities of the upper White River watershed in northwest Arkansas (Matthews and Robison 1988).

### **2.5.1 Protected Species**

There are 21 species that have been found in the Middle White River watershed that are listed as threatened or endangered by the state and/or federal government (Table 2.15). The USFS routinely surveys populations of a number of protected species that are present in the National Forest. Populations of protected bat species are surveyed regularly in the Sylamore District of the Ozark National Forest (USFS 2016).

### **2.5.2 Species of Greatest Conservation Need**

There are 377 species of native amphibians, birds, crayfish, fish, insects, invertebrates, mammals, mussels, and reptiles present in Arkansas that are identified as Species of Greatest Conservation Need in the Arkansas Wildlife Action Plan (Fowler 2015). Around 140 Species of Greatest Conservation Need have been reported in the Middle White River watershed (Arkansas Natural Heritage Commission 2018, NatureServe 2018). Excluding those listed as threatened or endangered, this includes 60-80 plant species, two bird species, four species of mammal, nine species of mussels, 4-13 species of insects, 16 species of other types of invertebrates (e.g., snails, crayfish), and 7-10 species of reptiles and amphibians. Nine fish Species of Greatest Conservation Need have been identified in the Middle White River watershed. Only two watersheds in the state have a greater number (Adams and Adams 2015). The Nature Conservancy has identified 13 cave and karst animal Species of Greatest Conservation Need, in addition to bats, in the Middle White River watershed. Nine of these are aquatic species, and four are terrestrial (Inlander, Gallipeau, and Slay 2011).

Table 2.15. Protected species found in the Middle White River watershed (Arkansas Natural Heritage Commission 2018, NatureServe 2018).

Common name	Scientific name	Category	State Status	Federal status	Counties (ANHC)
Snuffbox	<i>Epioblasma triquetra</i>	Invertebrate	Endangered	Endangered	Baxter, Independence, Izard
Rabbitsfoot	<i>Quadrula cylindrica cylindrica</i>	Invertebrate	Endangered	Threatened	Independence, Izard, Stone
Pink Mucket	<i>Lampsilis abrupta</i>	Invertebrate	Endangered	Endangered	Baxter, Independence
Foushee Cave Snail	<i>Amnicola cora</i>	Invertebrate		Endangered	Independence
Opaque Prairie Sedge	<i>Carex opaca</i>	Plant	Endangered	None	Izard
Dwarf Bristle Fern	<i>Trichomanes petersii</i>	Plant	Threatened	None	Stone
Ovate-leaf Catchfly	<i>Silene ovate</i>	Plant	Threatened	None	Baxter, Stone
Royal Catchfly	<i>Silene regia</i>	Plant	Threatened	None	Stone
Heartleaf Plantain	<i>Plantago cordata</i>	Plant	Threatened	None	Baxter, Stone
Interrupted Fern	<i>Osmunda claytonia</i>	Plant	Threatened	None	Stone
Winterberry	<i>Ilex verticillate</i>	Plant	Threatened	None	Independence
Yellow Coneflower	<i>Echinacea paradoxa var. paradoxa</i>	Plant	Threatened	None	Baxter, Stone
Spinulose Wood Fern	<i>Dryopteris carthusiana</i>	Plant	Threatened	None	Stone
Open-ground Whitlow-grass	<i>Draba aprica</i>	Plant	Threatened	None	Stone
Showy Lady's Slipper	<i>Cypripedium reginae</i>	Plant	Endangered	None	Baxter, Stone
Gray Bat	<i>Myotis grisescens</i>	Vertebrate	Endangered	Endangered	Baxter, Independence, Izard, Stone
Indiana Bat	<i>Myotis sodalists</i>	Vertebrate	Endangered	Endangered	Independence, Izard, Stone
Northern Long-eared Bat	<i>Myotis septentrionalis</i>	Vertebrate	Endangered	Threatened	Baxter, Independence, Izard, Stone
Hell Creek Cave crayfish	<i>Cambarus zophonastes</i>	Invertebrate		Endangered	Stone
Ozark Hellbender	<i>Cryptobranchus alleganiensis bishop</i>	Vertebrate	Endangered	Endangered	Baxter, Independence

### 2.5.3 Nuisance Species

There are a number of non-native species of plants and animals present in the Middle White River watershed that have been classified as posing a threat to native communities and ecosystems present in the watershed. A list of non-native nuisance aquatic species that have been identified within the Middle White River watershed is included as Table 2.16.

Feral hogs are a nuisance species throughout Arkansas, including the Middle White River watershed. They compete directly with many native animals for food. The rooting and wallowing of feral hogs damages pasture; destroys sensitive natural areas and habitats, including glades, marshes, and springs; and can cause erosion that affects water quality (Arkansas Agriculture Department 2018).

Table 2.16. Non-native nuisance aquatic species present in the Middle White River watershed (USGS 2018b, University of Georgia Center for Invasive Species and Ecosystem Health 2018).

Common name	Scientific name	Category	Source*
Freshwater jellyfish	<i>Craspedacusta sowerbyi</i>	Invertebrate	Exotic
Redbreast sunfish	<i>Lepomis auritus</i>	Fish	Native transplant
Common carp	<i>Cyprinus carpio</i>	Fish	Exotic
Silver carp	<i>Hypophthalmichthys molitrix</i>	Fish	Exotic
Bighead carp	<i>Hypophthalmichthys nobilis</i>	Fish	Exotic
Yellow perch	<i>Perca flavescens</i>	Fish	Native transplant
Rock bass	<i>Ambloplites rupestris</i>	Fish	Native transplant
Goldfish	<i>Carassius auratus</i>	Fish	Exotic
Arkansas River shiner	<i>Notropis girardi</i>	Fish	Native transplant
Striped bass	<i>Morone saxatilis</i>	Fish	Native transplant
Western mosquitofish	<i>Gambusia affinis</i>	Fish	Native transplant
Asian clam	<i>Corbicula fluminea</i>	Mollusk	Exotic
Brittle waternymph	<i>Najas minor</i>	Aquatic plant	Exotic
Watercress	<i>Nasturtium officinale</i>	Aquatic plant	Exotic
Water purslane	<i>Ludwigia palustris</i>	Aquatic plant	Exotic

\* Exotic indicates the species is from outside of the US; Native transplant indicates the species is native to the US, but is not native to this watershed.

#### **2.5.4 Sensitive Areas**

The Arkansas Natural Heritage Commission has identified several habitats present in Baxter, Independence, IZard, and Stone Counties as being of conservation concern. These habitats include Central Interior Highlands Calcareous and Acidic Glade and Barrens, fens, mesic hardwood forest, dry-mesic oak forest, colonial nesting sites for water birds, and caves (Arkansas Natural Heritage Commission 2018).

Caves and other karst features in the Middle White River watershed are important habitats for several protected species and Species of Greatest Conservation Need.

The White River from Batesville to the mouth of this watershed is designated as critical habitat for the threatened Rabbitsfoot mussel (US Fish and Wildlife Service 2015).

ADEQ has designated North Sylamore Creek and Salado Creek as “Extraordinary Resource Waters”. North Sylamore Creek is also designated as “Natural and Scenic Waterway”. There are two springs in the watershed designated as “Ecologically Sensitive Waterbodies”, and the White River from Bull Shoals Dam to Dam 3 is designated as trout fishery (Arkansas Pollution Control and Ecology Commission 2014).

## **2.6 Surface Water Quality Standards for Middle White River Watershed**

Arkansas state water quality standards consist of Designated Uses for waterbodies, numeric standards for selected water pollutants or water quality indicators, narrative criteria for pollutants or indicators without numeric standards, and an antidegradation statement. State water quality standards that apply to surface waters in the Middle White River watershed are described below.

### **2.6.1 Designated Uses**

Designated uses of all the streams in the watershed are primary contact recreation (watersheds >10 sq. mi); secondary contact recreation; Domestic, Industrial and Agricultural Water Supply; Perennial Ozark Highlands (OH) or Boston Mountain (BM) Fisheries (watersheds >10 sq. mi); or Seasonal Ozark Highlands or Boston Mountain Fisheries (watersheds <10 sq. mi.) (Arkansas Pollution Control and Ecology Commission 2014).

North Sylamore Creek and Salado Creek are designated as “Extraordinary Resource Waters”. North Sylamore Creek is also designated as “Natural and Scenic Waterway”. There are two springs in the watershed designated as “Ecologically Sensitive Waterbodies”, and the White River from Bull Shoals Dam to Dam 3 is designated as trout fishery (Figure 2.11) (Arkansas Pollution Control and Ecology Commission 2014).

### **2.6.2 Numeric and Narrative Criteria**

Numeric water quality criteria for selected parameters that apply in the Middle White River watershed are listed in Table 2.17. Numeric water quality criteria for toxic substances and metals can be found in Regulation 2 of the Arkansas Pollution Control and Ecology Commission (Arkansas Pollution Control and Ecology Commission 2014). In addition to numeric water quality criteria, state narrative criteria have been developed for the following: nuisance species; color; taste and odor; solids, floating material, and deposits; toxic substances; oil and grease; temperature; turbidity; and nutrients. Site specific numeric water quality criteria for nutrients have not yet been developed for the Middle White River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Turbidity criteria that apply in the Middle White River watershed are listed in Table 2.17. Separate turbidity criteria are specified for baseflow conditions. The baseflow criteria should not be exceeded in more than 20% of samples collected June to October. The “all flow” criteria should not be exceeded in more than 25% of all samples collected over an entire year (Arkansas Pollution Control and Ecology Commission 2014).

Fecal indicator bacteria (i.e., *Eschericia coli* [*E. coli*] and fecal coliform) water quality criteria that apply in the Middle White River watershed are summarized in Table 2.17. These criteria are considered to be met if less than 25% of no less than eight samples collected during the season (primary contact season or secondary contact season) are above the criteria.

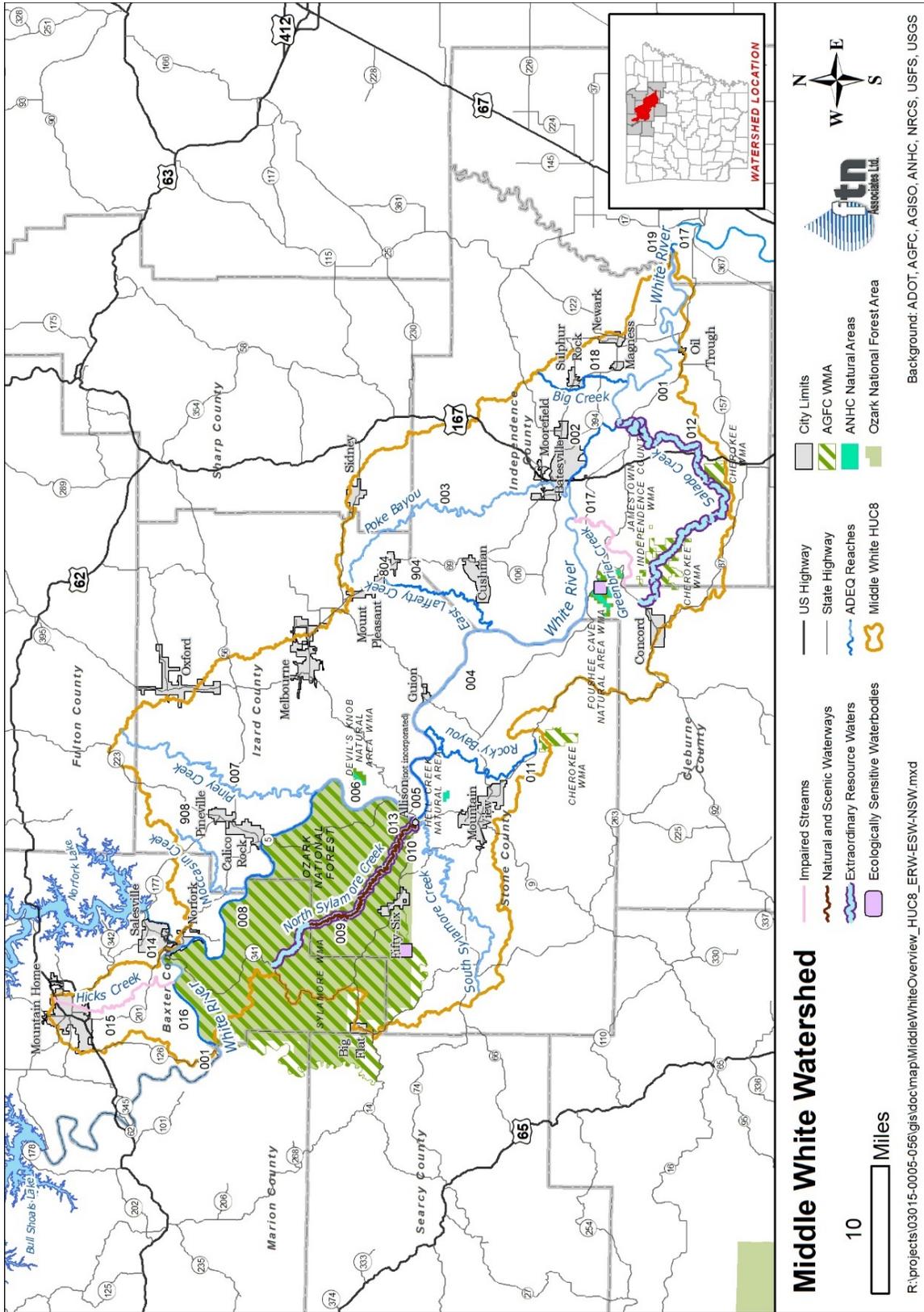


Figure 2.11. Map of Middle White River watershed showing Extraordinary Resource Waters, Natural and Scenic Waterway, and Ecologically Sensitive Waterbodies.

Table 2.17. Numeric water quality criteria for the Middle White River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Parameter	Season	Location	Conditions	Criteria
Temperature	All	OH <sup>a</sup>	All	29 deg C
		BM <sup>b</sup>	All	31 deg C
		Trout waters	All	20 deg C
Turbidity	Baseflow <sup>c</sup>	Watershed	All	10 NTU
	All flows <sup>d</sup>	OH	All	17 NTU
		BM	All	19 NTU
pH	All	Watershed	All	6 – 9 su
Dissolved oxygen	Primary season <sup>e</sup>	Watershed	All	6 mg/L
	Critical season <sup>f</sup>	Watershed	Watershed < 10 sq mi	2 mg/L
		OH	Watershed 10-100 sq mi	5 mg/L
		Moccasin Creek	Below Highway 177	5 mg/L
		OH	Watershed > 100 sq mi	6 mg/L
		BM	Watershed > 10 sq mi	6 mg/L
		Trout waters	All	6 mg/L
<i>E. coli</i>	Primary contact <sup>g</sup>	Extraordinary resource waters, natural and scenic waterways, reservoirs	Individual sample	298 colonies/100 mL
			Geometric mean	126 colonies/100 mL
			Other waters	410 colonies/100 mL
	Secondary contact <sup>h</sup>	Extraordinary resource waters, natural and scenic waterways, reservoirs	Individual sample	1,490 colonies/100 mL
			Geometric mean	630 colonies/100 mL
			Other waters	2,050 colonies/100 mL
Fecal coliform	Primary contact <sup>g</sup>	Watershed	Individual sample	400 colonies/100 mL
			Geometric mean	200 colonies/100 mL
	Secondary contact <sup>h</sup>	Watershed	Individual sample	2,000 colonies/100 mL
			Geometric mean	1,000 colonies/100 mL

<sup>a</sup> Ozark Highlands ecoregion, which includes White River and all but 2 major tributaries in this watershed

<sup>b</sup> Boston Mountains ecoregion, which includes Greenbrier and Salado Creeks in this watershed

<sup>c</sup> Baseflow = June- October

<sup>d</sup> All flows = entire year

<sup>e</sup> Primary season = when water temperature is 22 deg C or less, usually September – May

<sup>f</sup> Critical season = when water temperature is > 22 deg C, usually May – September

<sup>g</sup> Primary contact = May 1 to September 30

<sup>h</sup> Secondary contact = October 1 to April 30

### **2.6.3 Antidegradation Policy**

The antidegradation policy of the Arkansas water quality standards is summarized below:

- Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected;
- Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses;
- For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected; and
- For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

## 3.0 WATERSHED ASSESSMENT

### 3.1 Current Surface Water Quality

#### 3.1.1 Data

Data collected by ADEQ and the USGS from 2013 through 2017 were used to characterize current water quality conditions in the watershed. The data used for this summary were downloaded in April 2018 from online databases managed by ADEQ ([https://www.adeq.state.ar.us/techsvs/env\\_multi\\_lab/water\\_quality\\_station.aspx](https://www.adeq.state.ar.us/techsvs/env_multi_lab/water_quality_station.aspx)), USGS (<https://waterdata.usgs.gov/nwis/qw>), and EPA (<https://www.waterqualitydata.us/>). During the period 2013 – 2017, ADEQ collected water quality data at two locations on the White River, and 24 locations on 12 tributaries. During this period, the USGS collected data at one location on the White River and one location on a tributary. Information about these sampling locations is summarized in Table 3.1, and they are mapped on Figure 3.1.

Table 3.1. Surface water quality monitoring stations in the Middle White River watershed that were active during the period 2013 - 2017.

Entity	Program	Station Id	Stream	Location	Ecoregion*	Start Year	End Year	Number of dates
ADEQ	Special	BUFET002	N. Sylamore Cr	Barkshed Recreation Area	BM	2001	2014	11
ADEQ	Special	WHI0090	S. Sylamore Cr	CR283 near Mt. View	OH	1991	2014	38
ADEQ	Special	WHI0090A	S. Sylamore Cr	Holiday Mt. Resort crossing	OH	2013	2014	9
ADEQ	Special	WHI0144A	N. Sylamore Cr	CR76 Barkshed Recreation Area	OH	2013	2015	7
ADEQ	Special	WHI0144B	N. Sylamore Cr	CR93	OH	2015	2015	1
ADEQ	Special	WHI0144F	Roasting Ear Cr	CR86	OH	2013	2015	12
ADEQ	Special	WHI0145B	S. Sylamore Cr	1.5mi downstream of Hwy 87	OH	1997	2014	30
ADEQ	Special	WHI0159	W. Livingston Cr	SR5 near Optimus	OH	1998	2014	10

Table 3.1. Surface water quality monitoring stations in the Middle White River watershed that were active during the period 2013 – 2017 (continued).

Entity	Program	Station Id	Stream	Location	Ecoregion*	Start Year	End Year	Number of dates
ADEQ	Special	WHI0161	Piney Cr	CR263	OH	1999	2014	8
ADEQ	Special	WHI0162	Wideman Cr	CR13	OH	1999	2014	10
ADEQ	Roving	WHI0168	Piney Cr	Near Boswell	OH	2001	2014	22
ADEQ	Special	WHI0202	N. Sylamore Cr	Off SR14 near Allison	OH	2013	2014	13
ADEQ	Special	WHI0065A	Hicks Cr	Hicks Rd	OH	2015	2015	2
ADEQ	Special	WHI0139	Hicks Cr	Downstream of Mt. Home Waste Water Treatment Plant	OH	2004	2015	6
ADEQ	Special	WHI0140	Hicks Cr	Upstream of Big Cr	OH	2015	2015	3
ADEQ	Special	WHI0141	Big Cr	Upstream Hicks Cr	OH	2015	2015	4
ADEQ	Special	WHI0205	Big Cr	SR201	OH	2015	2015	2
ADEQ	Special	WHI0206	Dodd Cr	Upstream Hicks Rd	OH	2015	2015	3
ADEQ	Special	WHI0151	Salado Cr	Logging road SW of Batesville	BM	2013	2016	19
ADEQ	Roving	WHI0166	Salado Cr	Hwy 14	BM	2001	2016	29
ADEQ	Roving	WHI0167	Greenbrier Cr	Hwy 25	BM	2001	2016	26
ADEQ	Special	WHI0201	Salado Cr	Hwy 167	OH	2013	2016	20
ADEQ	Special	WHI0204	Wolf Bayou	SR14	BM	2015	2016	9
ADEQ	Ambient	WHI0011	S. Sylamore Cr	Downstream of Lick Fork Cr	OH	1993	2017	290
ADEQ	Ambient	WHI0029	White River	Oil Trough	BM	1990	2017	345
ADEQ	Ambient	WHI0046	White River	Norfork	OH	1990	2017	329
ADEQ	Ambient	WHI0065	Hicks Cr	Downstream of Mt. Home	OH	1990	2017	349
USGS	Routine	07060500	White River	Calico Rock	OH	1945	2017	585
USGS	Routine	07060710	N. Sylamore Cr	Near Fifty-Six	OH	1966	2018	659

\*OH Ozark Highlands.  
BM Boston Mountains.

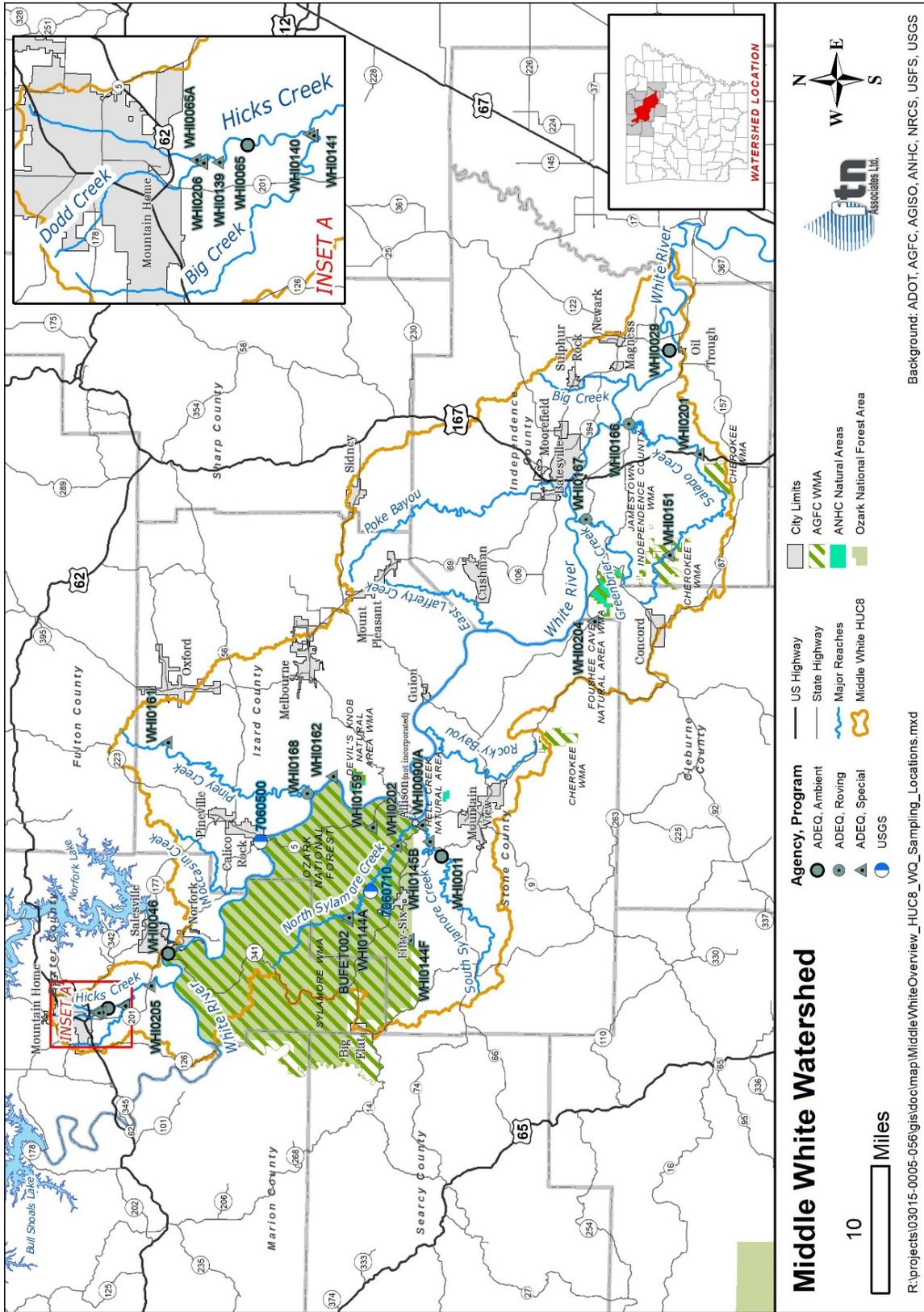


Figure 3.1. Surface water quality monitoring locations active during 2013 through 2017.

### 3.1.2 Assessed Water Quality Impairment

Impaired waters in the Middle White River watershed from the 2018 list are given in Table 3.2 and mapped on Figure 3.2 (water quality standards for the Middle White River watershed are included in Section 2.7). The most recent Arkansas state impaired waters list (i.e., 303(d) list) approved by EPA is from 2016 (ADEQ 2017). The impairments listed for the Middle White River watershed are the same on both the 2016 and 2018 lists. Almost 26 miles of streams in the watershed are classified as impaired. These streams have been on the state impaired waters list since 2008 (2004 for Hicks Creek) (ADEQ 2008).

Table 3.2. Impaired waters of the Middle White River watershed from the draft 2018 Arkansas 303(d) list (ADEQ 2018a).

Stream name	ADEQ Stream Segment Number	Impaired use	Pollutant	Pollutant source	Priority
Hicks Creek	015	Primary Contact	Pathogens	Municipal point source, urban runoff	Low
Greenbrier Creek	017	Fishery	Low dissolved oxygen	Unknown	Low

### 3.1.3 Water Quality Summary

Selected parameters of concern were examined, including parameters related to current assessed water quality impairments (dissolved oxygen, nutrients, and *E. coli*), and parameters such as turbidity and sediment, about which stakeholders have expressed concern (Friends of the North Fork and White Rivers, Inc. 2007). Only USGS collects flow measurements with water quality samples, so it is not possible to partition the majority of the data between baseflow and high flow conditions.

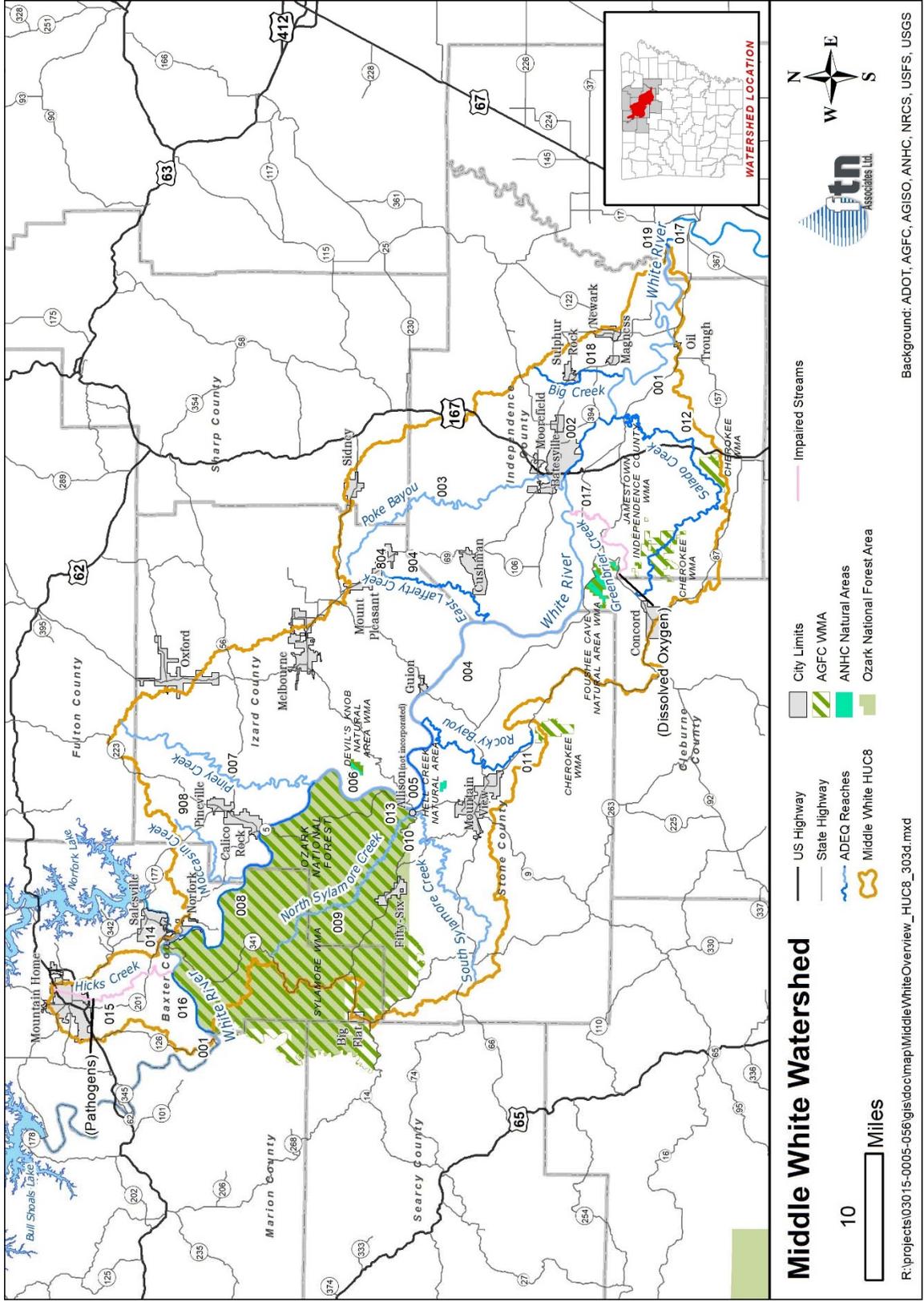


Figure 3.2. Impaired waterbodies in the Middle White River watershed identified in the final 2016 303(d) list (ADEQ 2017).

This plan section includes several box and whisker graphs. Box and whisker graphs show the range and distribution of values. They show the minimum and maximum values as well as the 25th percentile, median or 50th percentile, and 75th percentile. Figure 3.3 illustrates the elements of the box and whisker graphs in this plan. Note that the interquartile range is equal to the 75th percentile value minus the 25th percentile value. Also note that when a measurement is reported as not detected, a value equal to half of the detection limit has been used in calculating statistics.

On the box and whisker graphs associated with this section, water quality monitoring stations are differentiated by where they are located, on the White River, on a tributary of the White River, or on a tributary to a tributary of the White River. An example of a tributary to a tributary of the White River is Hicks Creek, which is a tributary of Big Creek, which drains to the White River (i.e., Big Creek is a White River tributary). Similarly, Roasting Ear Creek is a tributary of South Sylamore Creek, which we have classified as a White River tributary.

### **3.1.3.1 Sediment Parameters**

ADEQ monitors turbidity and total suspended solids (TSS) as indicators of sediment water quality issues. The USGS measures suspended sediment concentrations at its water quality stations in the Middle White River watershed, rather than turbidity or TSS. Turbidity is an optical property of water related to the cloudiness of water caused by particles in the water. It is measured by how much light can pass through water. A higher turbidity value means less light can pass through the water. Turbidity in the Middle White River watershed is primarily the result of sediment or other solid materials suspended in the water. Arkansas water quality standards include numeric criteria for turbidity, but not TSS or sediment concentration. However, turbidity cannot be converted to a load, so TSS and sediment concentration measurements are needed to calculate sediment loads.

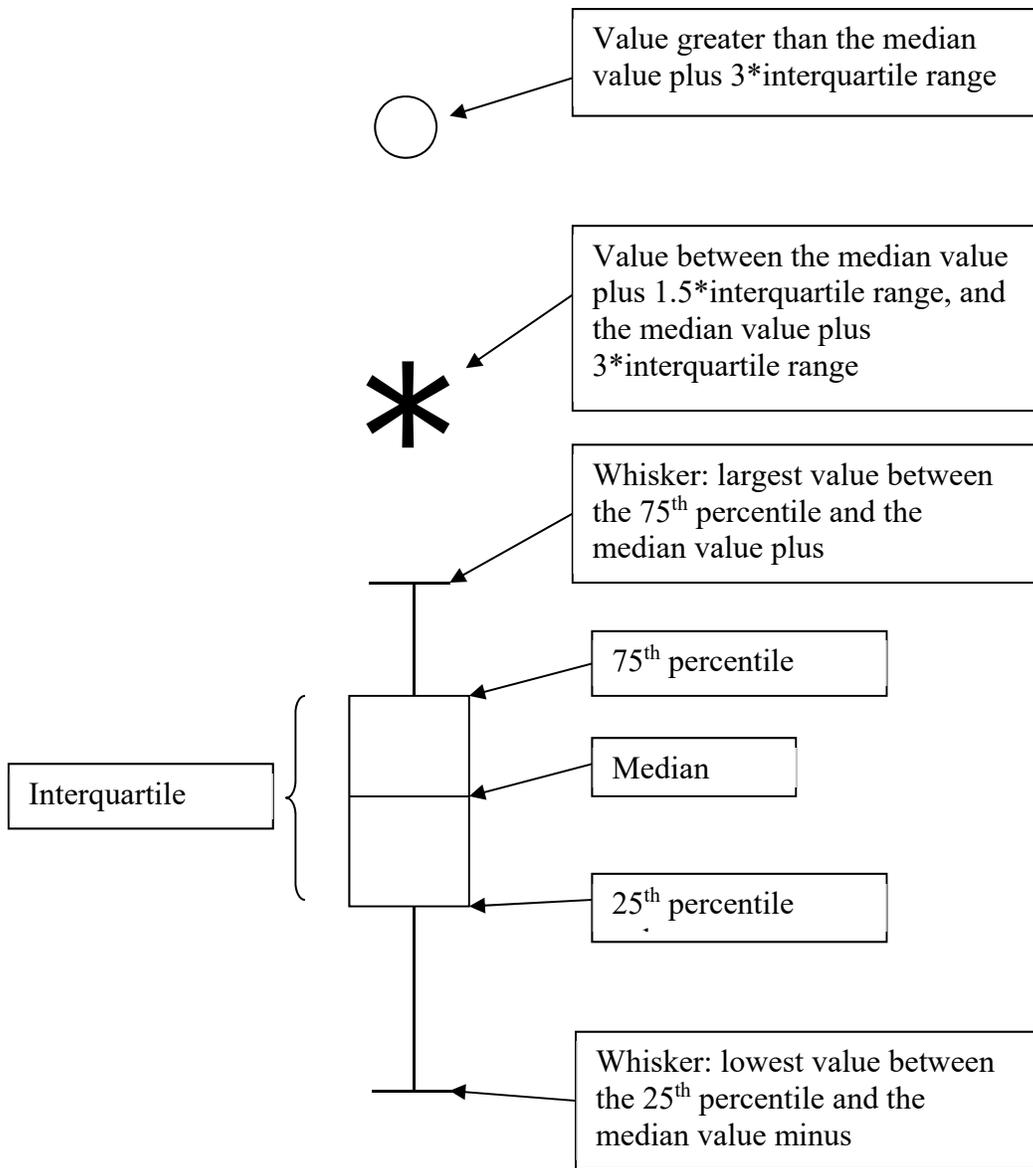


Figure 3.3. Elements of box and whisker graphs in this report.

### 3.1.3.1.1. Turbidity

Table 3.3 lists summary statistics for turbidity measurements from the period 2013-2017. Figure 3.4 shows a box and whisker graph of turbidity measurements from the Middle White River watershed for the period 2013-2017. The numeric turbidity water quality standard for the Ozark Highlands and Boston Mountain all flows is also shown on the plot. The Boston Mountain standard of 19 NTU applies to the monitoring locations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0151, WHI0166, and WHI0201).

On Figure 3.4, median turbidity values appear to increase downstream in the White River, Big Creek, North Sylamore Creek, and Salado Creek. Mean turbidity values appear to decrease downstream in Piney Creek. No overall downstream trend is apparent in median turbidity values from stations on Hicks Creek or South Sylamore Creek.

The highest median turbidity levels for the period 2013-2017 are at stations on tributaries to the White River. The Greenbrier Creek station (WHI0167) has the highest median turbidity level, followed by Salado Creek at Highway 14 (WHI0166). The lowest median turbidity levels for this period are at tributary stations; upper North Sylamore Creek stations (8 of the 27 watershed stations) have at least one turbidity measurement that exceeds the all flows numeric turbidity standard. The 75th percentile turbidity values for all of the stations are below the standard).

Figure 3.5 shows a box and whisker graph of base flow turbidity measurements (from June through October) for the period 2013-2017 with the base flow numeric turbidity standard, which is the same for both the Ozark Highlands and the Boston Mountain ecoregions. The base flow turbidity criterion is exceeded at least once at eight of the monitoring locations. At the Greenbrier Creek monitoring station (WHI0167), over 50% of the turbidity measurements exceed the base flow criterion, and between 50% and 25% of the turbidity measurements from Wideman Creek (WHI0162) and Salado Creek at Highway 14 (WHI0166) exceed the base flow standard.

Table 3.3. Summary statistics for turbidity measurements (in NTU) from 2013-2017 in Middle White River watershed.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum	No. Values Exceed All Flow Standard
07060710	15	1.0	1.0	1.0	1.2	1.0	4.5	0
BUFET002	2	0.33	--	--	--	--	0.86	0
WHI0011	59	0.34	0.89	1.09	2.33	2.19	16.50	0
WHI0029	63	0.98	3.43	4.70	9.54	8.75	61.20	10
WHI0046	59	0.56	1.06	1.54	5.20	2.56	62.0	5
WHI0065	61	0.48	1.10	1.63	4.23	3.19	47.30	4
WHI0065A	2	2.01	--	--	--	--	2.33	0
WHI0090	9	0.45	0.47	1.51	1.44	1.69	3.72	0
WHI0090A	9	0.16	0.34	0.69	0.89	0.99	2.96	0
WHI0139	3	2.38	2.43	2.59	2.57	2.70	2.74	0
WHI0140	3	1.21	1.24	1.34	1.45	1.68	1.80	0
WHI0141	3	0.90	1.04	1.46	1.32	1.56	1.60	0
WHI0144A	7	0.23	0.32	0.61	0.69	0.89	1.62	0
WHI0144B	1	1.46	--	--	--	--	--	0
WHI0144F	9	0.41	0.57	0.70	0.95	1.29	1.84	0
WHI0145B	7	0.26	0.33	1.40	1.33	2.11	3.06	0
WHI0151	16	0.55	1.24	1.80	1.68	2.09	2.55	0
WHI0159	8	0.33	0.58	0.74	0.77	1.00	1.17	0
WHI0161	7	1.28	1.70	2.48	3.39	3.37	9.92	0
WHI0162	9	0.25	0.96	1.78	5.97	5.52	35.20	1
WHI0166	16	3.85	5.88	8.81	11.19	13.50	41.60	1
WHI0167	13	3.92	8.78	11.60	14.39	14.32	37.70	2
WHI0168	9	0.81	1.29	1.72	3.44	2.84	15.4	0
WHI0201	18	0.64	1.63	2.00	6.15	2.79	75.60	1
WHI0202	10	0.55	0.58	0.82	1.37	2.02	3.63	0
WHI0204	7	1.20	1.34	1.64	6.44	6.37	29.8	1
WHI0205	3	1.24	1.31	1.51	1.54	1.79	1.88	0
WHI0206	3	2.83	3.23	4.43	6.12	9.43	11.0	0

Surface Water Quality 2013-2017

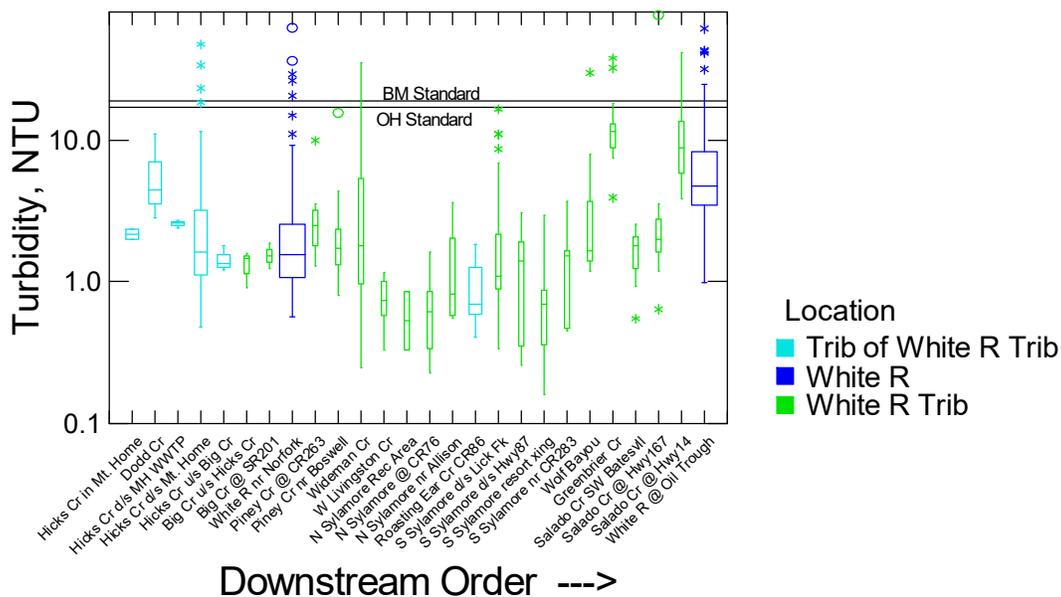


Figure 3.4. Box and whisker graph of all turbidity measurements from the Middle White River watershed for the period 2013-2017.

Base Flow Surface Water Quality 2013-2017

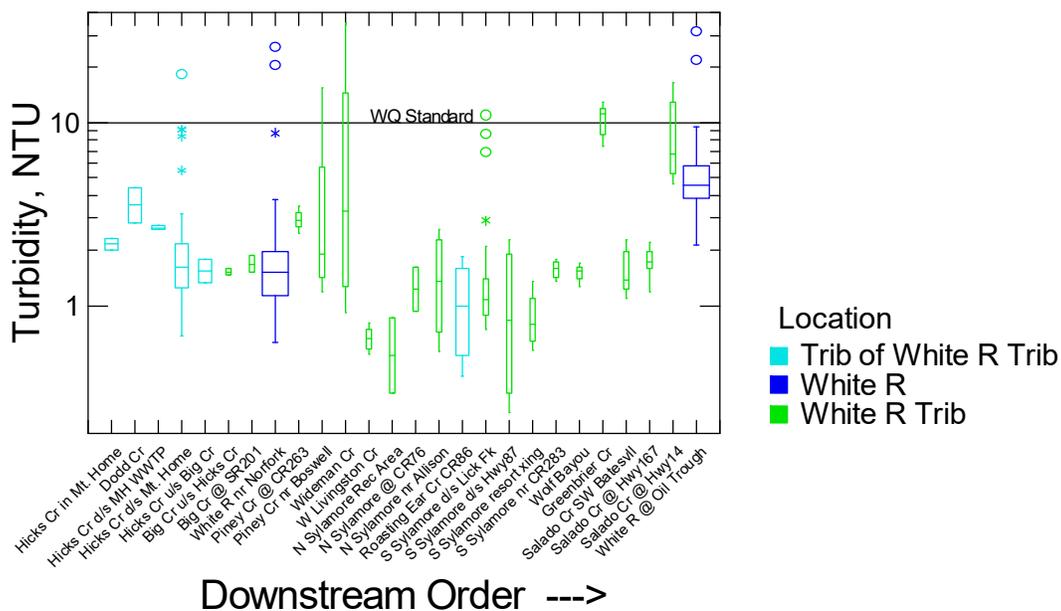


Figure 3.5. Box and whisker graph of base flow turbidity measurements (June through October) from the Middle White River watershed for the period 2013-2017.

### 3.1.3.1.2. TSS

Table 3.4 lists summary statistics for TSS measurements from the Middle White River watershed during the period 2013-2017. Figure 3.6 shows a box and whisker graph of these TSS measurements. Median TSS values appear to increase downstream in the White River, Piney Creek, and Salado Creek. No overall downstream trend is apparent in median TSS values from stations on other streams with multiple monitoring locations. In general, TSS concentrations throughout the watershed are relatively low.

Table 3.4. Summary statistics for TSS measurements (in mg/L) from 2013-2017 in Middle White River watershed.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
BUFET002	2	0.5	--	--	--	--	4.5
WHI0011	59	0.5	0.5	1.0	1.6	1.5	15.3
WHI0029	63	0.5	3.5	6.0	9.2	13.1	37.5
WHI0046	59	0.5	1.0	2.0	5.2	3.4	67.3
WHI0065	61	0.5	1.0	1.5	2.6	2.6	22.3
WHI0065A	2	1.5	--	--	--	--	1.8
WHI0090	9	0.5	0.5	0.5	1.3	1.6	4.5
WHI0090A	9	0.5	0.5	0.5	0.7	0.6	1.5
WHI0139	3	3.2	3.3	3.5	3.4	3.5	3.5
WHI0140	3	0.5	0.8	1.5	1.3	1.9	2.0
WHI0141	3	1.0	1.1	1.5	2.1	3.2	3.8
WHI0144A	7	0.5	0.5	0.5	0.7	0.9	1.5
WHI0144B	1	1.0	--	--	--	--	--
WHI0144F	9	0.5	0.5	0.5	0.9	0.5	4.5
WHI0145B	7	0.5	0.5	0.5	0.7	0.5	2.0
WHI0151	16	0.5	0.5	0.5	0.9	1.0	2.5
WHI0159	8	0.5	0.5	0.5	0.9	1.0	3.0
WHI0161	7	0.5	1.1	1.5	1.5	2.0	2.5
WHI0162	9	0.5	0.9	1.8	3.1	5.6	7.0
WHI0166	16	3.2	5.6	8.5	9.4	10.0	29.0
WHI0167	13	2.7	6.6	11.0	11.9	17.1	27.5
WHI0168	9	0.5	0.5	2.3	3.1	3.6	11.8
WHI0201	18	0.5	0.5	1.0	6.0	1.5	91.3
WHI0202	10	0.5	0.5	0.5	0.7	0.5	2.0
WHI0204	7	0.5	0.5	1.0	4.7	4.3	23.5
WHI0205	3	1.0	1.1	1.5	1.9	2.8	3.2
WHI0206	3	4.0	4.2	5.0	9.3	15.4	18.8

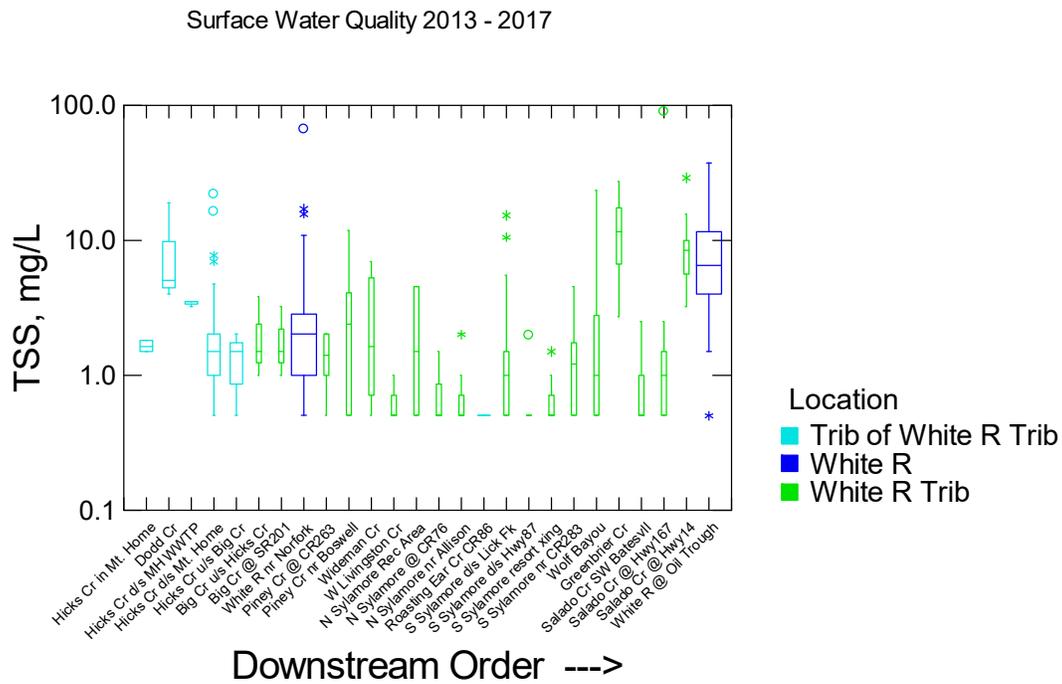


Figure 3.6. Box and whisker graph of TSS measurements from the Middle White River watershed for the period 2013-2017.

The highest median TSS concentration for the period 2013-2017 is at Greenbrier Creek (WHI0167), followed by Salado Creek at Highway 14 (WHI0166). These monitoring locations also have the highest median turbidity levels for this period. The lowest median TSS concentrations for this period are also at tributary stations. Eight tributary stations have median TSS concentrations less than the detection level (1 mg/L).

### 3.1.3.1.3. Suspended Sediment

Table 3.5 list summary statistics for suspended sediment measurements from 2013-2017. Figure 3.7 shows a box and whisker graph of suspended sediment measurements from the two USGS monitoring locations in the Middle White River watershed. As would be expected, suspended sediment concentrations in the White River (07060500) are higher than those in North Sylamore Creek (07060710).

Table 3.5. Summary statistics for suspended sediment measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
07060500	17	1.0	3.0	7.0	8.4	9.8	25.0
07060710	14	0.5	1.0	2.0	2.4	3.0	7.0

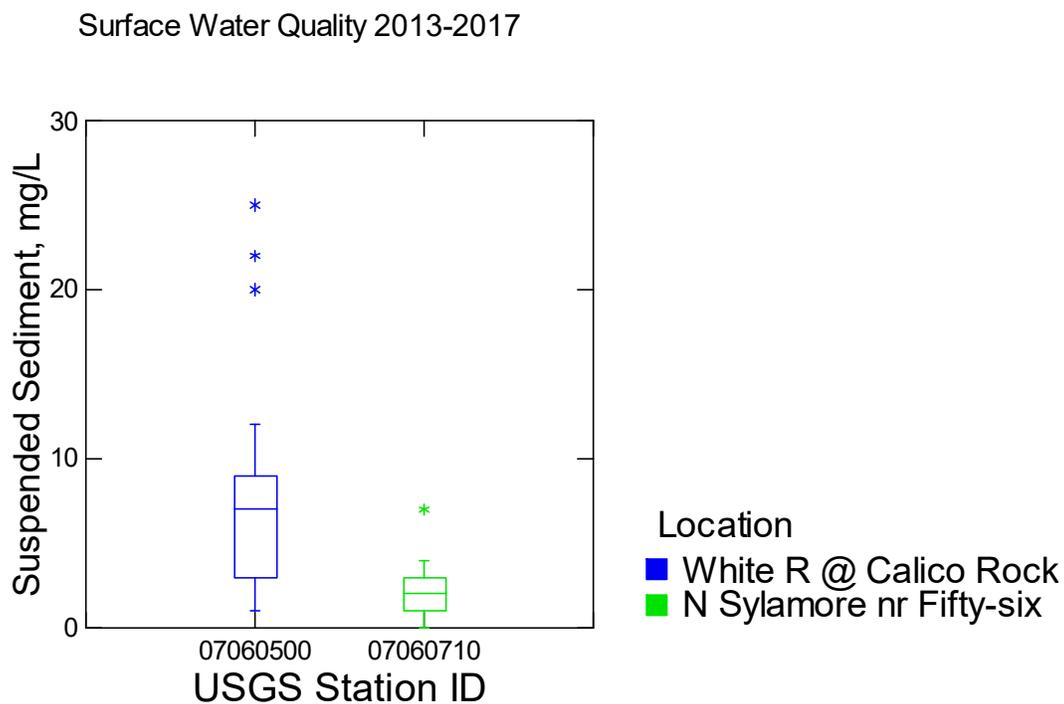


Figure 3.7. Box and whisker graph of suspended sediment measurements from the Middle White River watershed for the period 2013-2017.

### 3.1.3.2 *E. coli*

*E. coli* bacteria are monitored as an indicator of the risk to human health from contact with pathogens in the water. The *E. coli* water quality standards are intended to protect the health of people involved in recreational activities that involve both primary contact with the water (e.g., swimming) and secondary contact recreation (e.g., boating).

*E. coli* measurements were collected during the period 2013-2017 by the USGS and ADEQ. During this period, USGS measured *E. coli* quarterly at the water quality station on the White River at Calico Rock (07060500). Table 3.6 lists summary statistics for these measurements from the primary and secondary contact seasons. All of these measurements are less than the applicable state numeric criteria.

Table 3.6 Summary statistics of USGS *E. coli* measurements (in cfu/100mL) for the period 2013-2017.

Statistic	Primary Contact (May-September)	Secondary Contact (October-April)
Number of measurements	7	11
Minimum	8.0	3.0
25 <sup>th</sup> Percentile	9.2	5.0
Median	10.0	22.0
Mean	28.3	26.9
75 <sup>th</sup> Percentile	49.5	46.8
Maximum	85.0	75.0

In 2015, ADEQ collected *E. coli* measurements from impaired waters in the Middle White River watershed. These data were not included in the ADEQ online water quality database at the time we did our search, but were provided to us by ADEQ personnel (J. Wise, ADEQ, personal communication, 8/7/2018). Eight measurements were collected from May through September. Measurements were collected at six stations in the Big Creek and Hicks Creek watershed, from the Mountain Home WWTP effluent, and from the station on Greenbrier Creek. A statistical summary of these measurements is given in Table 3.7. There is at least one measurement from all but one station that is greater than the primary season *E. coli* criterion. Two stations, WHI0139 and WHI0065, do not meet the *E. coli* water quality standard criteria (see Section 2.7).

Table 3.7. Summary statistics of ADEQ *E. coli* measurements (in cfu/100mL) from 2015 Primary Contact Season.

Station ID	Location Description	No. of Measures	Minimum	Mean	Median	Maximum	No. Values Exceed Standard
WHI0206	Dodd Cr	8	28	525	180	>2,000	2
WHI0065A	Hicks Cr upstream of WWTP	7	41	388	184	1,350	1
HIC02E	WWTP effluent	7	41	197	104	725	1
WHI0139	Hicks Cr downstream of WWTP	8	140	653	371	>2,000	3
WHI0065	Hicks Cr downstream	8	55	372	140	1,175	3
WHI0140	Hicks Cr downstream	4	14	174	104	475	1
WHI0205	Big Cr downstream of Hicks Cr	6	<1	62	66	96	0
WHI0167	Greenbrier Cr	8	48	150	86	625	1

### 3.1.3.3 Total Phosphorus

Total phosphorus is a nutrient that is not harmful to humans or animals itself. However, it can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off oxygen in the water is depleted to levels that can be harmful to fish and other aquatic organisms. There are no numeric water quality standards for any phosphorus compounds, including total phosphorus, that apply in the Middle White River watershed.

Table 3.8 lists summary statistics for total phosphorus measurements from 2013-2017. Figure 3.8 shows a box and whisker graph of total phosphorus measurements in the Middle White River watershed from the period 2013-2017. The locations with the highest median total phosphorus values for the period 2013-2017 are on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141) and Big Creek downstream of the Hicks Creek inflow (WHI0205). The lowest median total phosphorus concentrations during this period are less than the detection level. Locations where median concentrations are less than detection level include White River near Norfolk (WHI0046) and at Calico Rock (07060500), North Sylamore Creek near Fifty-Six (07060710), and Wolf Bayou (WHI0204). Median total phosphorus concentrations in Salado Creek (WHI0151, WHI0201, WHI0166) appear to increase downstream, and the median total phosphorus concentration at the downstream White River station (WHI0029 at Oil Trough) is higher than the upstream White River stations (near Norfolk, WHI0046, and at Calico Rock, 07060500).

Table 3.8. Summary statistics of total phosphorus measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
07060500	19	0.010	0.010	0.010	0.018	0.020	0.070
07060710	17	0.002	0.002	0.002	0.003	0.002	0.009
BUFET002	2	0.025	--	--	0.027	--	0.029
WHI0011	58	0.005	0.042	0.055	0.062	0.070	0.239
WHI0029	63	0.005	0.005	0.031	0.094	0.042	2.700
WHI0046	58	0.005	0.005	0.005	0.053	0.050	0.340
WHI0065	60	0.128	0.599	0.885	1.313	1.975	5.430
WHI0065A	2	0.005	0.005	0.014	0.014	0.023	0.023
WHI0090	9	0.034	0.045	0.052	0.059	0.055	0.141
WHI0090A	9	0.024	0.039	0.048	0.056	0.053	0.154
WHI0139	3	0.605	0.949	1.980	2.125	3.338	3.790
WHI0140	3	0.449	0.719	1.530	1.890	3.150	3.690
WHI0141	3	0.031	0.032	0.034	0.067	0.111	0.137
WHI0144A	7	0.005	0.022	0.025	0.024	0.028	0.038
WHI0144B	1	0.175	--	--	--	--	--
WHI0144F	9	0.033	0.038	0.040	0.041	0.046	0.052
WHI0145B	7	0.036	0.047	0.052	0.049	0.053	0.055

Table 3.8. Summary statistics of total phosphorus measurements (in mg/L) from 2013-2017 (continued).

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
WHI0151	16	0.005	0.005	0.013	0.054	0.028	0.628
WHI0159	8	0.005	0.015	0.026	0.026	0.036	0.048
WHI0161	7	0.005	0.022	0.032	0.029	0.040	0.042
WHI0162	9	0.005	0.026	0.029	0.032	0.039	0.065
WHI0166	16	0.005	0.025	0.052	0.158	0.071	1.170
WHI0167	13	0.005	0.058	0.086	0.169	0.118	1.230
WHI0168	9	0.027	0.028	0.031	0.034	0.035	0.060
WHI0201	18	0.005	0.005	0.024	0.028	0.032	0.127
WHI0202	10	0.005	0.024	0.026	0.089	0.038	0.495
WHI0204	7	0.005	0.005	0.005	0.130	0.076	0.750
WHI0205	3	0.185	0.257	0.472	0.412	0.552	0.579
WHI0206	3	0.021	0.022	0.023	0.030	0.040	0.045

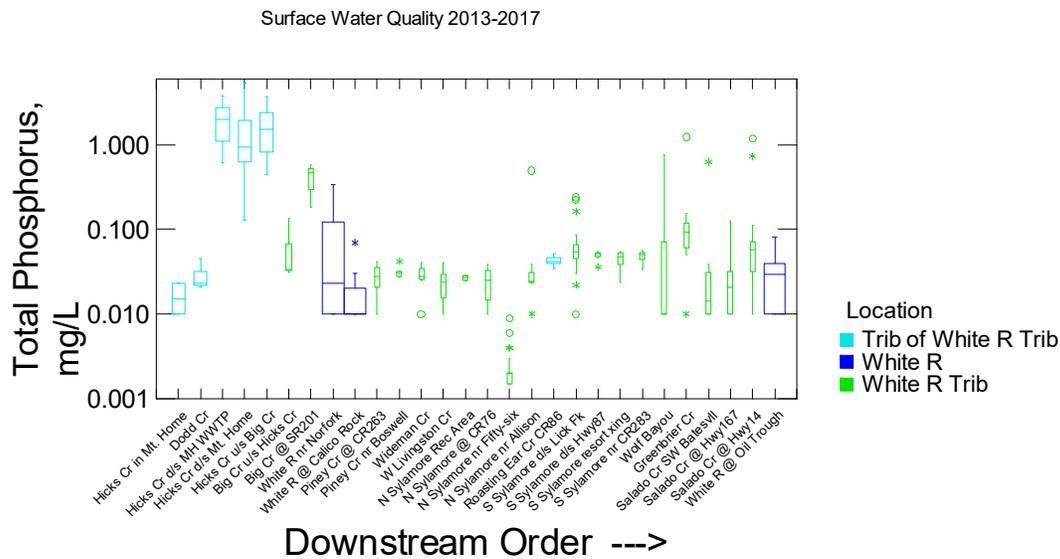


Figure 3.8. Box and whisker graph of total phosphorus measurements from Middle White River watershed for the period 2013-2017.

### 3.1.3.4 Dissolved Inorganic Nitrogen

Dissolved inorganic nitrogen is the sum of nitrate and nitrite nitrogen in water. Nitrate can be harmful to babies. The Federal drinking water quality standard for nitrate nitrogen is 10 mg/L. Dissolved inorganic nitrogen is also a nutrient that can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off oxygen in the water is depleted to levels that can be harmful to fish and other aquatic organisms. There are no numeric water quality standards for dissolved inorganic nitrogen to protect against increased algal growth that apply in the Middle White River watershed.

Table 3.9 lists summary statistics for dissolved inorganic nitrogen measurements from 2013-2017. Figure 3.9 shows a box and whisker graph of dissolved inorganic nitrogen measurements in the Middle White River watershed from the period 2013-2017. All dissolved inorganic nitrogen measurements in the Middle White River watershed from the period 2013-2017 are less than the nitrate drinking water quality standard. The highest median dissolved inorganic nitrogen concentrations from this period are tributary monitoring locations, on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141), and Big Creek downstream of the Hicks Creek inflow (WHI0205). The median dissolved inorganic nitrogen concentrations in Roasting Ear Creek (WHI0144F) and its receiving stream, South Sylamore Creek (WHI0011, WHI0145B, WHI0090, WHI0090A), are also higher than the rest of the monitoring locations in the watershed.

Median dissolved inorganic nitrogen concentrations are relatively similar at all of the White River monitoring locations. In Hicks Creek downstream of the Mountain Home WWTP and South Sylamore Creek downstream of Roasting Ear Creek median dissolved inorganic nitrogen concentrations appear to decline in the downstream direction, suggesting dilution.

Table 3.9. Summary statistics for dissolved inorganic nitrogen measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
07060500	19	0.118	0.182	0.295	0.281	0.366	0.443
07060710	49	0.020	0.040	0.060	0.062	0.080	0.150
BUFET002	2	0.015	--	--	--	--	0.081
WHI0011	43	0.265	0.418	0.560	0.597	0.688	1.300
WHI0029	45	0.118	0.232	0.303	0.295	0.341	0.446
WHI0046	43	0.084	0.222	0.273	0.304	0.346	0.713
WHI0065	45	0.229	1.422	1.930	1.994	2.330	4.300
WHI0065A	2	0.138	--	--	--	--	0.799
WHI0090	7	0.147	0.305	0.438	0.465	0.618	0.882
WHI0090A	7	0.157	0.320	0.443	0.479	0.663	0.885
WHI0139	3	1.940	2.155	2.800	2.733	3.295	3.460
WHI0140	3	1.210	1.350	1.770	1.787	2.228	2.380
WHI0141	3	0.434	0.435	0.439	0.460	0.491	0.508
WHI0144A	4	0.015	0.015	0.022	0.030	0.044	0.058
WHI0144F	7	0.327	0.683	0.804	0.840	1.076	1.260
WHI0145B	7	0.230	0.367	0.463	0.535	0.712	0.954
WHI0151	14	0.015	0.054	0.112	0.162	0.164	0.562
WHI0159	7	0.015	0.015	0.035	0.037	0.054	0.076
WHI0161	6	0.015	0.015	0.049	0.045	0.056	0.087
WHI0162	8	0.015	0.0465	0.066	0.068	0.094	0.115
WHI0166	15	0.015	0.136	0.173	0.200	0.242	0.517
WHI0167	12	0.092	0.179	0.360	0.358	0.471	0.770
WHI0168	8	0.073	0.101	0.118	0.148	0.204	0.260
WHI0201	17	0.015	0.015	0.051	0.069	0.088	0.261
WHI0202	8	0.033	0.119	0.168	0.154	0.196	0.231
WHI0204	7	0.015	0.045	0.054	0.060	0.063	0.137
WHI0205	3	0.671	0.734	0.925	0.842	0.928	0.929
WHI0206	3	0.033	0.057	0.129	0.206	0.375	0.457

Surface Water Quality 2013-2017

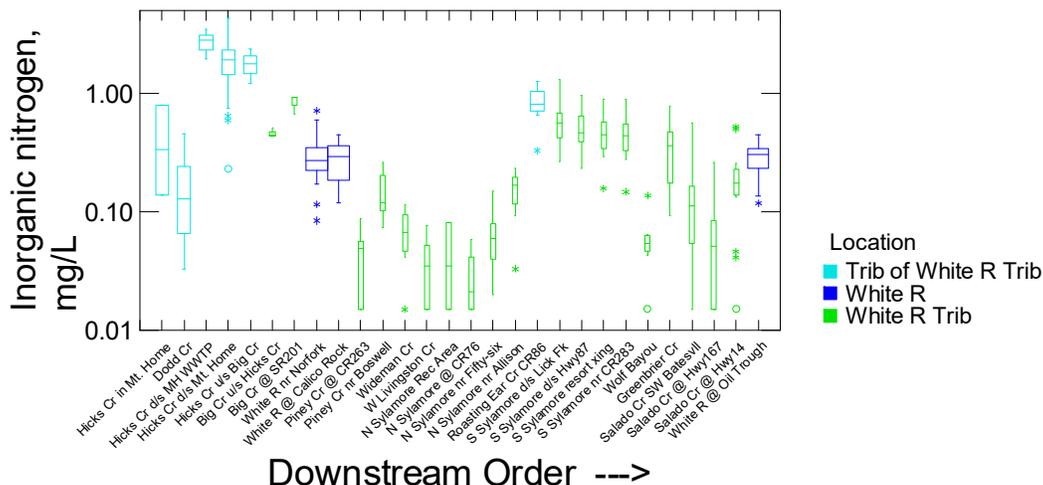


Figure 3.9. Box and whisker graph of dissolved inorganic nitrogen measurements from Middle White River watershed for the period 2013-2017.

### 3.1.3.5 Total Nitrogen

Total nitrogen is the sum of nitrate, nitrite, and total Kjeldahl nitrogen in water. Nitrogen is a nutrient that can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off oxygen in the water is depleted to levels that can be harmful to fish and other aquatic organisms. There are no numeric water quality standards for total nitrogen to protect against increased algal growth that apply in the Middle White River watershed.

Table 3.10 lists summary statistics for total nitrogen measurements from 2013-2017. Figure 3.10 shows a box and whisker graph of total nitrogen measurements in the Middle White River watershed from the period 2013-2017. The highest median total nitrogen concentrations from this period are tributary monitoring locations, on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141), and Big Creek downstream of the Hicks Creek inflow (WHI0205). The median total nitrogen concentrations in Roasting Ear Creek (WHI0144F) and its receiving stream, South Sylamore Creek (WHI0011, WHI0145B, WHI0090, WHI0090A), are also higher than the rest of the monitoring locations in the watershed. The lowest median total nitrogen concentration for this period is in North Sylamore Creek at County Road 93 (WHI0144A).

Median total nitrogen concentrations at White River stations increase in the downstream direction (Figure 3.10). Median total nitrogen concentrations decrease in Hicks Creek downstream of the Mountain Home discharge, and in South Sylamore Creek downstream of Roasting Ear Creek. In Piney Creek, North Sylamore Creek, and Salado Creek, median total nitrogen concentrations are lower at upstream locations and highest at the farthest downstream locations.

Table 3.10. Summary statistics for total nitrogen measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum
07060500	19	0.270	0.400	0.530	0.538	0.580	1.400
07060710	16	0.060	0.073	0.095	0.114	0.140	0.300
BUFET002	2	0.079	--	--	--	--	0.170
WHI0011	58	0.338	0.607	0.722	0.790	0.937	1.820
WHI0029	69	0.301	0.460	0.558	1.093	0.638	12.550
WHI0046	58	0.256	0.452	0.494	0.543	0.621	1.000
WHI0065	60	0.482	1.810	2.455	2.826	3.300	8.250
WHI0065A	2	0.247	--	--	--	--	0.965
WHI0090	9	0.336	0.397	0.597	0.611	0.740	1.040
WHI0090A	9	0.342	0.408	0.588	0.613	0.764	1.050
WHI0139	3	2.300	2.668	3.770	3.383	4.002	4.080
WHI0140	3	1.500	1.718	2.370	2.233	2.715	2.830
WHI0141	3	0.549	0.604	0.768	0.705	0.791	0.799
WHI0144A	7	0.030	0.071	0.120	0.141	0.188	0.303
WHI0144B	1	0.922	--	--	--	--	--
WHI0144F	9	0.378	0.733	0.926	0.919	1.125	1.400
WHI0145B	7	0.383	0.485	0.628	0.696	0.912	1.150
WHI0151	16	0.171	0.274	0.328	0.383	0.486	0.670
WHI0159	8	0.000	0.127	0.168	0.161	0.220	0.259
WHI0161	7	0.130	0.147	0.244	0.242	0.288	0.457
WHI0162	9	0.117	0.146	0.200	0.243	0.323	0.438
WHI0166	16	0.299	0.434	0.520	0.563	0.654	1.230
WHI0167	13	0.271	0.623	0.788	0.780	0.972	1.360
WHI0168	9	0.218	0.263	0.356	0.336	0.386	0.435
WHI0201	18	0.124	0.251	0.319	0.328	0.358	0.818
WHI0202	10	0.093	0.219	0.278	0.274	0.362	0.403
WHI0204	7	0.118	0.191	0.255	0.296	0.321	0.637
WHI0205	3	1.000	1.025	1.100	1.157	1.302	1.370
WHI0206	3	0.290	0.298	0.322	0.426	0.581	0.667

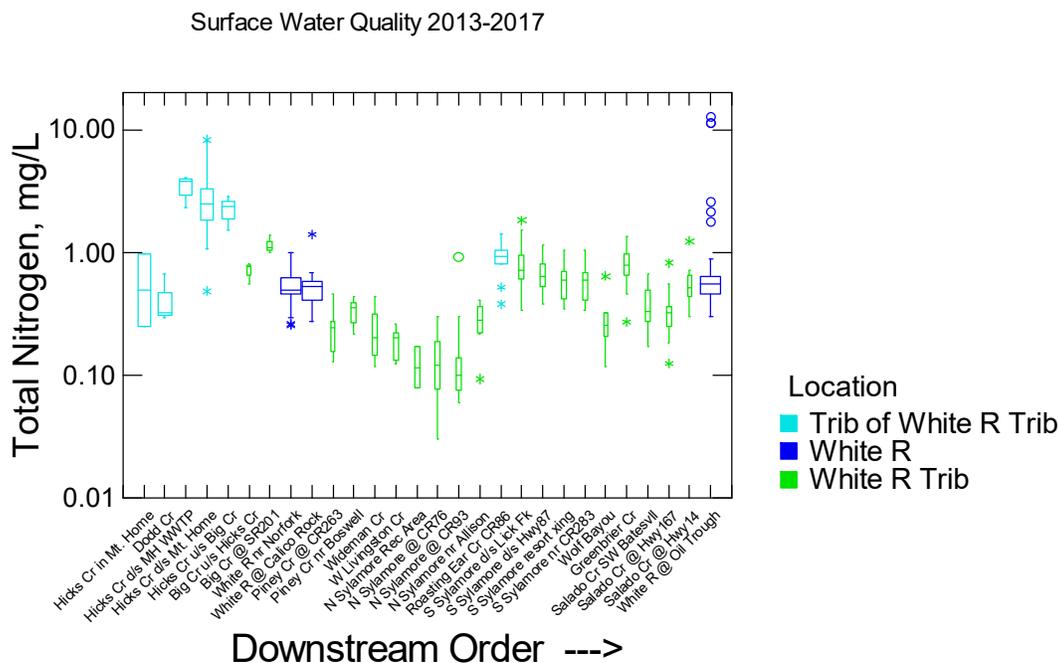


Figure 3.10. Box and whisker graph of total nitrogen measurements from Middle White River watershed for the period 2013-2017.

### 3.1.3.6 Dissolved Oxygen (DO)

DO in water is used by fish and other aquatic creatures living in streams. Figure 3.11 shows a box and whisker graph of DO measurements from the Middle White River watershed during the period 2013-2017. For the most part, DO concentrations at monitored locations in the White River watershed ranged from 5 mg/L to 15 mg/L during this period. The lowest median DO concentration during this period is from Greenbrier Creek. The highest median DO concentration during this period is from Big Creek at State Road 201 (WHI0205). Table 3.11 lists summary statistics for DO measurements from the period 2013-2017.

Surface Water Quality 2013-2017

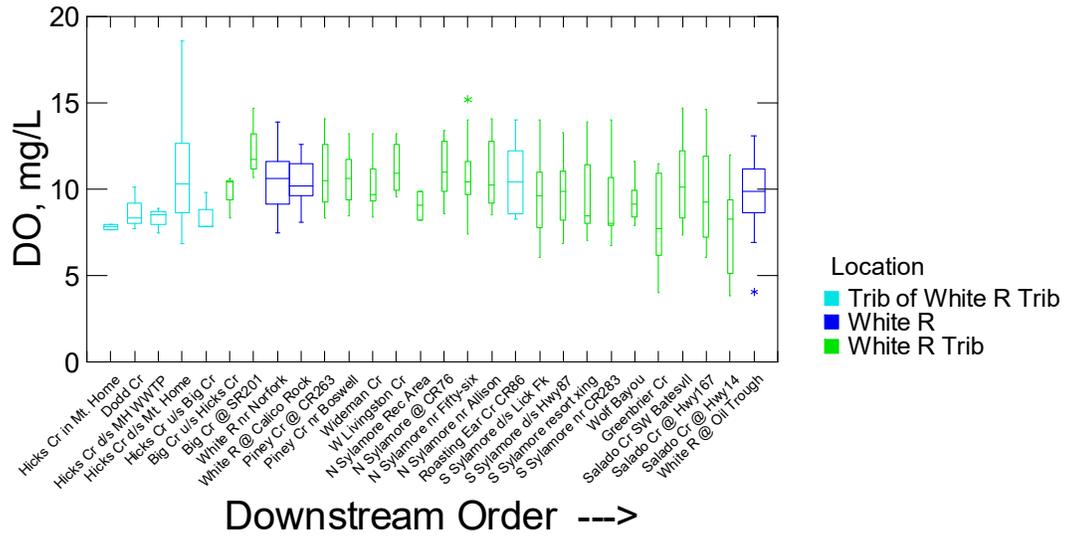


Figure 3.11. Box and whisker graph of DO measurements from Middle White River watershed for the period 2013-2017.

Table 3.11. Summary statistics for DO measurements (in mg/L) 2013-2017.

Station ID	No. of measures	Minimum	25 <sup>th</sup> percentile	Median	Mean	75 <sup>th</sup> percentile	Maximum	No. Values <5mg/L
WHI0144B	1	12.8	--	--	--	--	--	0
WHI0065A	2	7.66	--	--	--	--	7.98	0
WHI0206	3	7.74	7.89	8.35	8.73	9.66	10.1	0
WHI0139	3	7.48	7.74	8.50	8.29	8.78	8.88	0
WHI0065	59	6.85	8.60	10.3	11.0	12.7	18.6	0
WHI0140	3	7.84	7.84	7.85	8.50	9.31	9.80	0
WHI0141	3	8.36	8.87	10.4	9.79	10.6	10.6	0
WHI0205	3	10.7	11.0	11.7	12.4	14.0	14.7	0
WHI0046	57	7.48	9.10	10.6	10.6	11.6	13.9	0
07060500	19	8.10	9.55	10.2	10.4	11.5	12.6	0
WHI0161	7	8.35	9.10	10.5	11.0	13.0	14.1	0
WHI0168	9	8.45	9.36	10.6	10.8	12.0	13.2	0
WHI0162	9	8.40	9.09	9.68	10.4	11.6	13.2	0
WHI0159	8	9.55	9.91	11.0	11.2	12.6	13.2	0
BUFET002	2	8.20	--	--	--	--	9.89	0
WHI0144A	7	8.56	9.40	11.0	11.2	13.0	13.4	0
07060710	53	7.40	9.70	10.4	10.7	11.6	15.2	0
WHI0202	10	8.49	9.21	10.3	10.8	12.8	14.1	0
WHI0144F	9	8.24	8.56	10.4	10.5	12.4	14.0	0
WHI0144B	1	12.8	--	--	--	--	--	0
WHI0011	57	6.07	7.78	9.61	9.60	11.0	14.0	0
WHI0145B	7	6.88	8.21	9.89	9.80	11.3	13.3	0
WHI0090A	9	7.03	7.84	8.48	9.61	11.6	13.9	0
WHI0090	9	6.70	7.72	8.02	9.38	11.1	14.0	0
WHI0204	7	7.93	8.24	9.15	9.34	10.2	11.6	0
WHI0167	13	4.00	6.08	7.70	7.96	11.0	11.5	2
WHI0151	16	7.35	8.33	10.1	10.3	12.2	14.7	0
WHI0201	18	6.04	7.20	9.28	9.65	11.9	14.6	0
WHI0166	15	3.81	4.77	8.26	7.74	9.45	12.0	4
WHI0029	68	4.05	8.62	9.89	9.90	11.2	13.1	1

Figure 3.12 shows box and whisker graphs of DO measurements from the primary seasons of 2013-2017. Arkansas water quality regulations define the primary season for DO as when water temperature is 22 deg C or less, usually September to May. In addition, the numeric primary season DO water quality standard that applies in the Middle White River watershed is shown on the graph. For the most part, during the period 2013-2017, DO concentrations measured during the primary season met the primary season DO water quality standard. DO concentrations below the water quality standard were measured during the primary season at two tributary stations, Greenbrier Creek (WHI0167) and Salado Creek at Highway 14 (WHI0166).

Figure 3.13 shows box and whisker graphs of DO measurements from the critical seasons of 2013-2017. Arkansas water quality regulations define the critical season for DO as when water temperature is above 22 deg C, usually May to September. Lines showing the numeric criteria for DO that apply in the Middle White River watershed are shown on Figure 3.13. For the most part, critical season DO measurements from 2013-2017 meet the numeric DO criteria. The three locations where not all DO measurements meet the applicable criterion are Greenbrier Creek (WHI0167), Salado Creek at Highway 14 (WHI0166), and White River at Oil Trough (WHI0029).

### **3.1.4 Current Water Quality Summary**

Two monitored streams, Hicks Creek and Greenbrier Creek, have been classified as impaired by ADEQ. Several of the monitored streams have relatively high concentrations of sediment and/or nutrients. Hicks Creek and Big Creek downstream of the Hicks Creek confluence, have the highest median nutrient concentrations of the monitored locations in the watershed. Greenbrier Creek has measured DO concentrations less than 5 mg/L, and some of the highest median turbidity, TSS, total nitrogen and total phosphorus concentrations in the watershed. Water quality monitoring stations on Roasting Ear Creek, and South Sylamore Creek have relatively high median concentrations of some nutrients. The most downstream Salado Creek station, and White River at Oil Trough also have relatively high median TSS and turbidity concentrations.

Primary Season Surface Water Quality 2013-2017

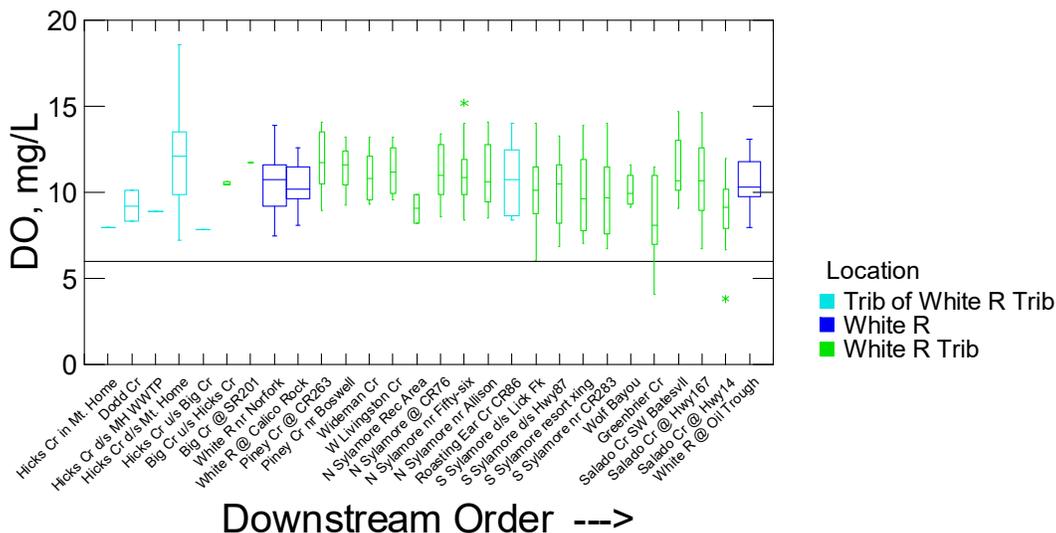


Figure 3.12. Box and whisker graph of primary season DO measurements from Middle White River watershed for the period 2013-2017.

Critical Season Surface Water Quality 2013-2017

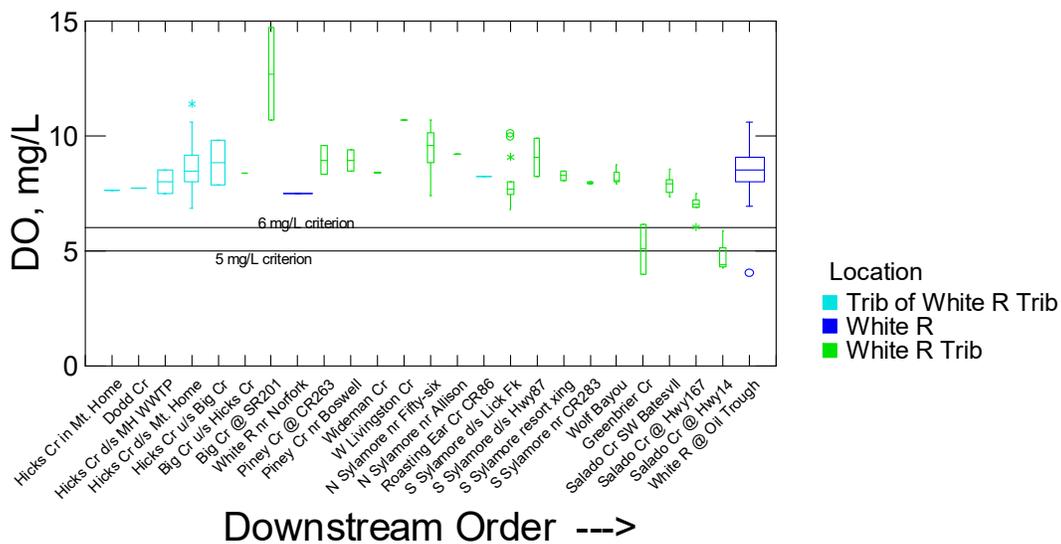


Figure 3.13. Box and whisker graph of critical season DO measurements from Middle White River watershed for the period 2013-2017.

### 3.2 Water Quality Over Time

While it is important to look at current water quality conditions in the watershed, it is also important to determine if water quality is changing over time. Of particular interest for nonpoint source management are locations where water quality still meets water quality standards, but pollutant concentrations are increasing over time, suggesting that water quality standards may not be met in the future if no action is taken. Locations where pollutant concentrations are decreasing over time suggest that water quality is improving and that upstream pollutant management practices are working.

#### 3.2.1 WQ stations with long data records

There are 11 water quality monitoring stations with data records of at least 10 years that appear suitable for evaluation to determine if water quality has changed significantly over time. These stations are listed in Table 3.12. The locations of these monitoring stations are shown on Figure 3.1. There are three stations on South Sylamore Creek, one of which is a continuous record station, WHI0011. The only stations with intermittent data records evaluated for water quality changes are the ADEQ roving stations (WHI0166, WHI0167, and WHI0168). The intermittent data records from the South Sylamore Creek stations WHI0090 and WHI0145B are judged to not be consistent enough to be comparable over time (see Section 3.2.4). Therefore, the data from these stations is not analyzed.

Table 3.12. Active water quality monitoring stations with data records of at least 10 years.

Station	Agency	Stream	Location	Data Period	Type of data record
WHI0011	ADEQ	S. Sylamore Cr	d/s Lick Cr (Mountain View WWTP)	1993-2017	Continuous
WHI0029	ADEQ	White R	Oil Trough	1990-2017	Continuous
WHI0046	ADEQ	White R	Norfolk	1990-2017	Continuous
WHI0065	ADEQ	Hicks Cr	D/S Mt. Home	1990-2017	Continuous
WHI0090*	ADEQ	S. Sylamore Cr	CR283	1991-2015	Intermittent
WHI0145B*	ADEQ	S. Sylamore Cr	d/s Hwy 87	1997-2014	Intermittent
WHI0168	ADEQ	Piney Cr	Near Boswell	2001-2015	Intermittent
WHI0166	ADEQ	Salado Cr	Hwy 167	2001-2016	Intermittent
WHI0167	ADEQ	Greenbrier Cr	Hwy25	2001-2016	Intermittent
07060500	USGS	White R	Calico Rock	1972-2017	Continuous
07060710	USGS	N. Sylamore Cr	Near Fifty-Six	1969-2017	Continuous

\*Excluded from analysis

### 3.2.2 Trend Analysis of Data from Continuous Record Stations

Water quality data collected continuously, or with only short data gaps, can be evaluated mathematically to see if they exhibit trends. Therefore, data for parameters of interest from the six long term data stations with continuous data records (WHI0011, WHI0029, WHI0065, WHI0046, 07060500, and 07060710) were analyzed for trends. The analyses of these data are described in detail in Appendix B. Because of the characteristics of these data sets, non-parametric trend analysis was used. In the majority of the data sets evaluated, no trend was apparent. The stations where parameters of interest did exhibit trends identified by the analyses are listed in Table 3.13. Note that data sets for some of the parameters from some of the stations were not sufficient to be analyzed for trends (see Appendix B for full explanations).

Table 3.13. Water quality stations where parameters of interest exhibit trends.

Station	Stream	Parameter	Trend direction
WHI0011	S. Sylamore Cr	DO (2004-2017)	Decreasing
WHI0065	Hicks Cr	DO	Increasing
		Inorganic nitrogen	Decreasing
		Total nitrogen	Decreasing
07060500	White R	Total nitrogen	Increasing
07060710	N. Sylamore Cr	DO	Increasing

The decreasing trend in DO concentrations in South Sylamore Creek (WHI0011) over the period 2004-2017, may indicate declining water quality, and could be related to the relatively high nutrient concentrations reported in this stream system.

The increasing DO trend in Hicks Creek (WHI0065) could be the result of increased productivity due to relatively high nutrient levels, which could result in algae blooms. Perhaps the declining trends in nitrogen will help improve conditions. However, growth of some nuisance algae in freshwater systems is usually limited by the amount of phosphorus present, and there is no indication that phosphorus concentrations are declining in Hicks Creek. The declining trends in nitrogen concentrations in Hicks Creek at station WHI0065 could be a response to improvements in the Mountain Home WWTP.

The increasing trend in total nitrogen at the White River station at Calico Rock (07060500) may indicate a potential for water quality issues in the future. The increasing trend in DO in North Sylamore Creek may indicate improving water quality. This increasing trend appears to be the result of fewer low DO concentrations, which would seem to indicate better water quality. This is different from the increasing trend in DO concentrations in Hicks Creek, which is primarily the result of increasing high DO concentrations, indicative of increased productivity.

### 3.2.3 Analysis of Data from Intermittent Stations

There are five water quality stations with intermittent data records. To determine if it is a good idea to compare data from the different monitoring periods at these stations, the characteristics of the data sets from these periods were evaluated. Table 3.14 lists sampling periods and numbers of samples from each period for these stations. The number of samples collected and the length of the two sampling periods at stations WHI0090 and WHI0145B appear too different to be used to compare water quality over time. The data records from the two sampling periods at the three ADEQ roving water quality stations (WHI0166, WHI0167, WHI0168) appear similar enough to be used to compare water quality over time.

Table 3.14. Sampling periods and data sets for long term stations with intermittent records.

Station	Stream	Sampling period	Number of samples
WHI0090	S. Sylamore Cr	1991-1993	26-29
		2013-2015	9
WHI0145B	S. Sylamore Cr	1997-2000	18-20
		2013-2014	7
WHI0166	Salado Cr	2001-2003	11-12
		2013-2016	15-16
		2013-2015	13-14
WHI0167	Greenbrier Cr	2001-2003	11-12
		2013-2016	13
WHI0168	Piney Cr	2001-2003	11-12
		2013-2015	9

To evaluate whether concentrations of parameters of interest at the three ADEQ roving water quality stations are different during the two sampling periods, the median values for the data from the two periods were compared using box and whisker graphs. These box and whisker graphs include a notch that indicates the 95% confidence interval around the median value. When the notches of two box graphs overlap, the median values are not statistically significantly different. If the notches do not overlap, the median values are statistically significantly different, indicating a statistically significant difference in water quality for the two sampling periods.

Figures 3.14 through 3.17 show box and whisker graphs comparing inorganic nitrogen, total nitrogen, total phosphorus, and DO from the two roving sampling periods for the three roving stations in the Middle White River watershed. Note that fecal coliform and *E. coli* measurements were collected at these stations only in 2003, so changes cannot be evaluated for these fecal contamination indicators. For these stations, the median values from the 2013-2016 monitoring period are usually lower than the median values from the 2001-2003 monitoring period. However, only for total nitrogen at station WHI0167 (Greenbrier Creek) is the median value for the 2013-2016 data statistically significantly lower than the median value for the 2001-2003 data. A statistically significant decrease in total nitrogen suggests the possibility that water quality has improved between the two periods. The fact that the median dissolved oxygen concentration is higher for the 2013-2016 period than for the 2001-2003 period also suggests improved water quality. Another set of data will need to be collected to confirm that the different in total nitrogen concentrations represents an actual change, rather than natural variation in concentrations. The significant decrease in total nitrogen concentrations at the Greenbrier Creek station appears to be more the result of decreases in organic nitrogen (see total Kjeldahl nitrogen (TKN) graph on Figure 3.18), than decreases in inorganic nitrogen, which are not statistically significant (see inorganic nitrogen graphs on Figure 3.14).

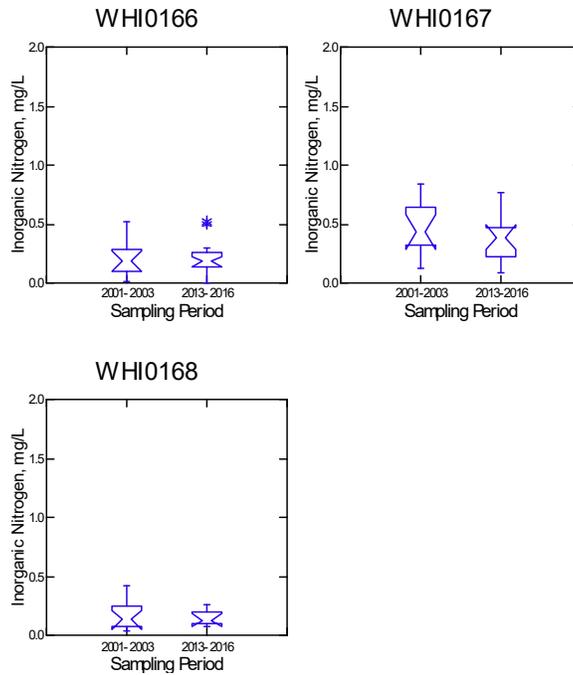


Figure 3.14. Comparison of dissolved inorganic nitrogen data from two sampling periods at ADEQ roving water quality stations.

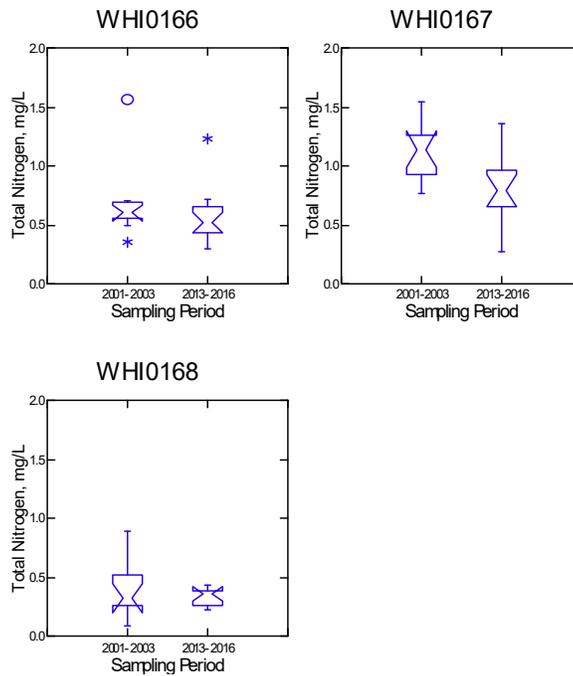


Figure 3.15. Comparison of total nitrogen data from two sampling periods at ADEQ roving water quality stations.

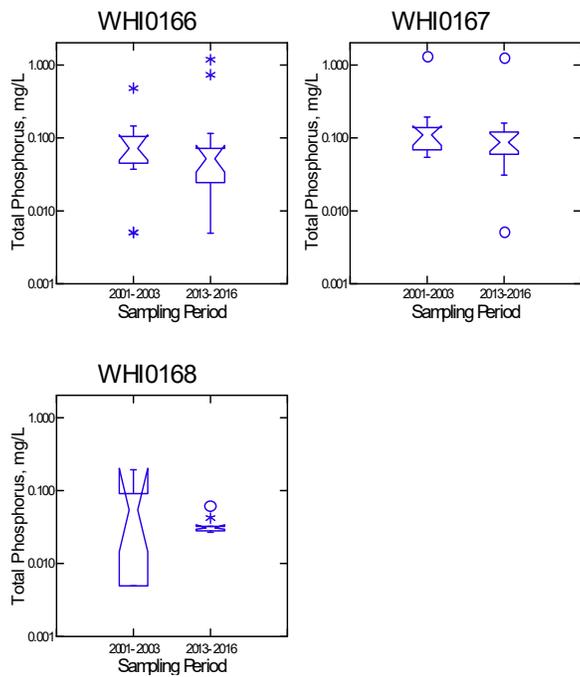


Figure 3.16 Comparison of total phosphorous data from two sampling periods at ADEQ roving water quality stations.

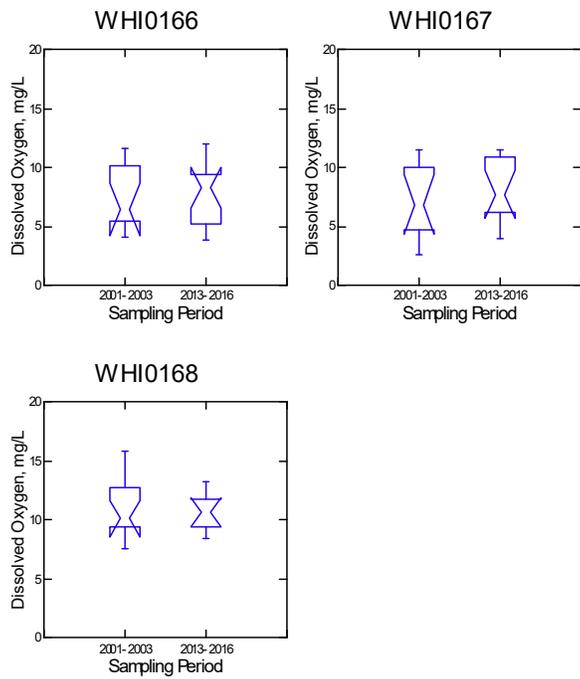


Figure 3.17 Comparison of DO data from two sampling periods at ADEQ roving water quality stations.

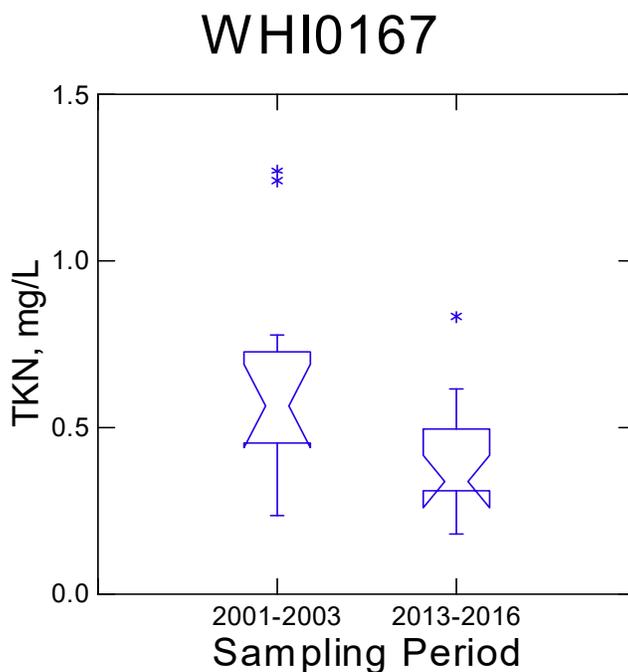


Figure 3.18 Comparison of TKN data from two sampling periods at an ADEQ roving water quality station.

### 3.2.4 Summary of Water Quality Over Time

There are nine water quality stations in the Middle White River watershed with long data records adequate to evaluate changes in water quality over time. Changes in dissolved inorganic nitrogen, total nitrogen, total phosphorus, and dissolved oxygen are evaluated. At stations with continuous data records, i.e., no long periods without measurements, statistical analyses are conducted to determine if there are long term trends in the levels of these parameters. At stations with intermittent data records, i.e., short periods of measurements alternating with long periods without measurements, statistical comparisons of measurements from the different monitoring periods are conducted. These analyses identify trends and possible water quality changes at several water quality stations, summarized below.

At the Hicks Creek water quality station WHI0065, there is a statistically significant increasing trend in DO that appears to indicate increasing primary productivity, and possibly, declining water quality. However, there are also statistically significant decreasing trends in dissolved inorganic nitrogen and total nitrogen, indicating that inputs of these pollutants are declining. Since primary productivity in freshwater systems is often controlled primarily by phosphorus concentrations, the decrease in nitrogen inputs may not have much effect on primary productivity in Hicks Creek.

At the White River water quality station 07060500, at Calico Rock, there is a statistically significant increasing trend in total nitrogen. It is not clear if, or how much, increasing total nitrogen affects water quality in the White River.

At the North Sylamore Creek water quality station 07060710 there is a statistically significant increasing trend in DO. At this station this appears to indicate improving water quality.

At the South Sylamore Creek water quality station WHI0011, there is a statistically significant decreasing trend in DO. There could be a water quality issue in this watershed that needs attention. Note that statistically significant trends are not evident in the nutrient parameters.

At the Greenbrier Creek water quality station WHI0167, total nitrogen and organic nitrogen (TKN) concentrations from the sampling period 2013-2016 are statistically significantly less than those from the 2001-2003 sampling period. Organic nitrogen inputs to this stream may be declining. Additional data are needed to interpret the difference in concentrations from the two available sampling periods with any confidence.

### **3.3 Pollutant Loads**

Pollutant loads are the product of concentration and stream flow. As a result, streams with low concentrations can contribute large loads if they have very large flow. Vice versa, a stream with a high concentration but a low flow, may have a relatively small load. Yield is the load for a stream divided by the drainage area of the stream. This section discusses and compares estimates of loads and yields for several of the tributaries of the White River. The parameters for

which loads are discussed are TSS (as an indicator for erosion), total phosphorus, and total nitrogen.

### **3.3.1 SPARROW Model**

USGS has estimated total nitrogen and total phosphorus exports from subbasins of the Mississippi-Atchafalaya River Basin for 2002 using the SPARROW model (USGS 2011). Maps summarizing the SPARROW 2002 nutrient load estimates for catchments of the Middle White River watershed are shown on Figures 3.19 and 3.20 (all figures for this section are located at the end of the section). SPARROW estimates of 2002 nutrient yields for catchments of the Middle White River watershed are shown on Figures 3.21 and 3.22.

As shown on Figures 3.19 and 3.20, SPARROW estimates that, in 2002, the highest total phosphorus and total nitrogen loads were from South Sylamore Creek, Poke Bayou, and several smaller tributaries of the White River, including Lafferty Creek, Wolf Bayou, and Greenbrier Creek. However, as shown on Figures 3.21 and 3.22, catchments with highest estimated total phosphorus and total nitrogen yields for 2002 are smaller, and in somewhat different locations.

Figures 3.23 and 3.24 show charts of SPARROW estimated catchment loads for 2002 broken into loads from different source categories, including both point and nonpoint sources. In catchments with the highest nutrient loads SPARROW attributes the largest portion of the total phosphorus load to manure, and the largest portion of the total nitrogen load to atmospheric deposition.

It is possible that nutrient loads in the Middle White River watershed have changed between 2002 and the 2013-2017 time period. Therefore, additional load estimate approaches are investigated in the following sections.

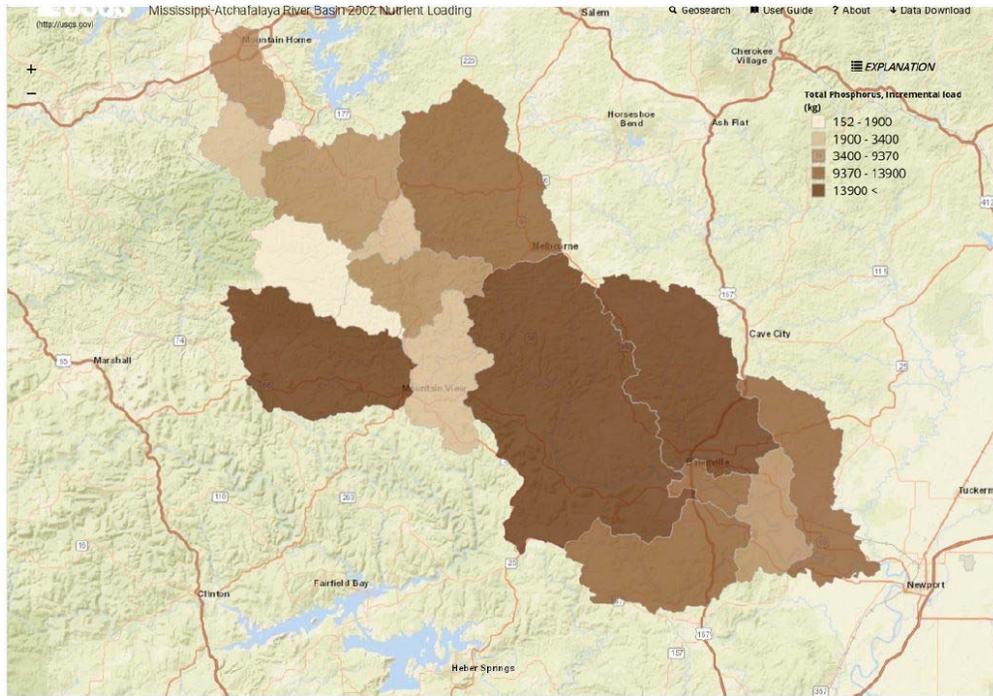


Figure 3.19. Catchment total phosphorus loads for 2002 estimated by SPARROW (USGS 2011).

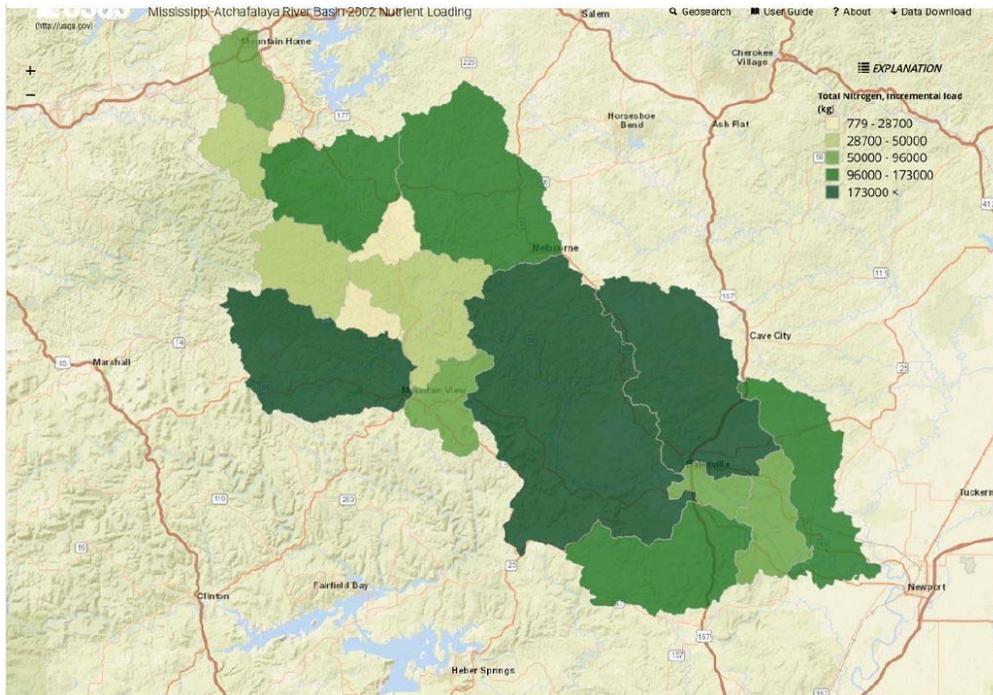


Figure 3.20. Catchment total nitrogen loads for 2002 estimated by SPARROW (USGS 2011).

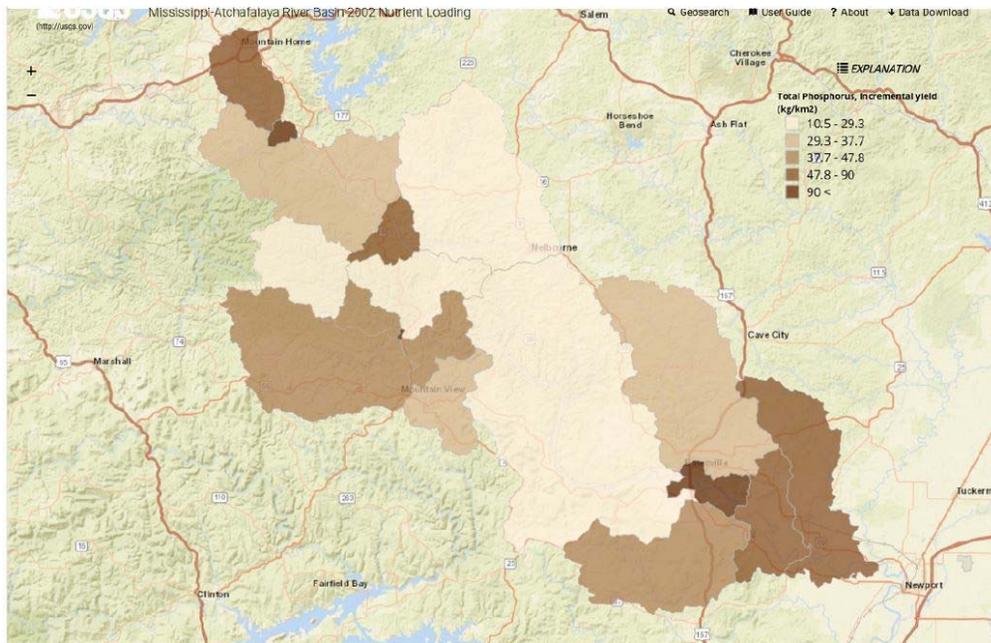


Figure 3.21. Catchment total phosphorus yields for 2002 estimated by SPARROW (USGS 2011).

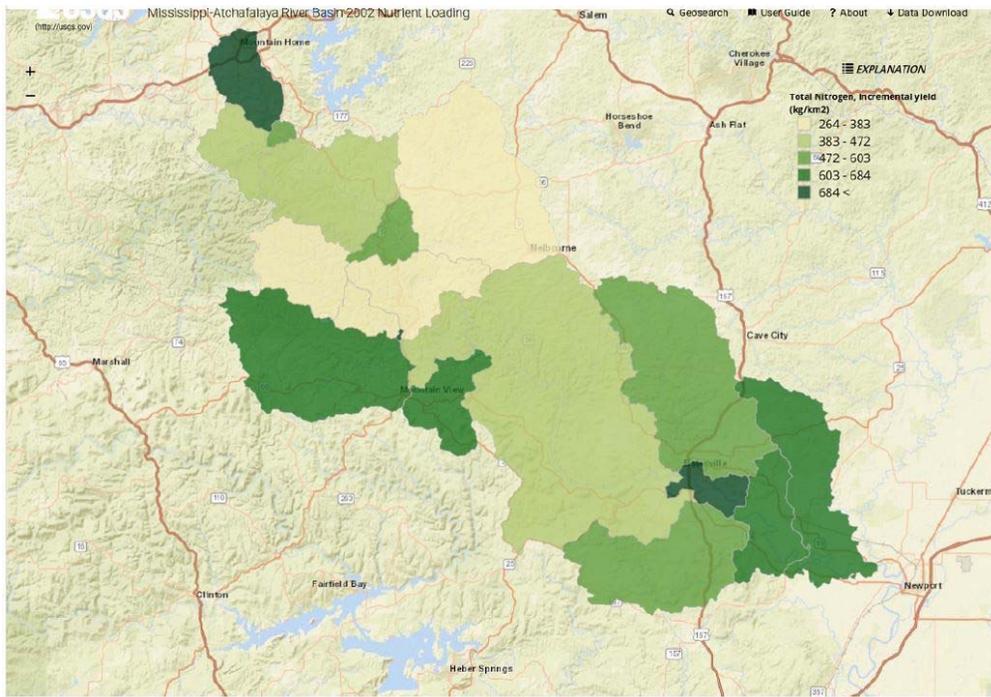


Figure 3.22. Catchment total nitrogen yields for 2002 estimated by SPARROW (USGS 2011).

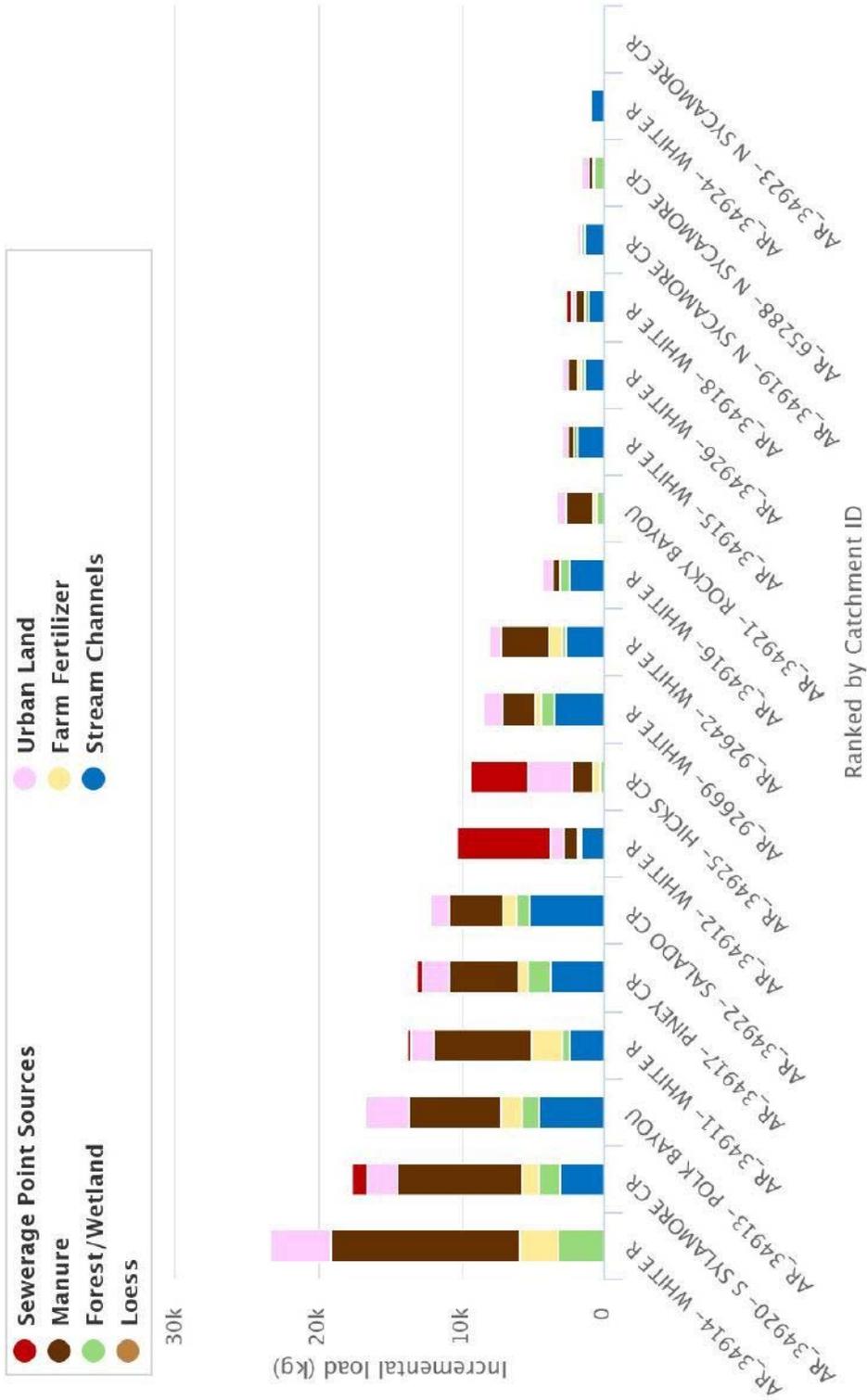


Figure 3.23. Graph of catchment total phosphorus loads for 2002 by source estimated by SPARROW (USGS 2011).

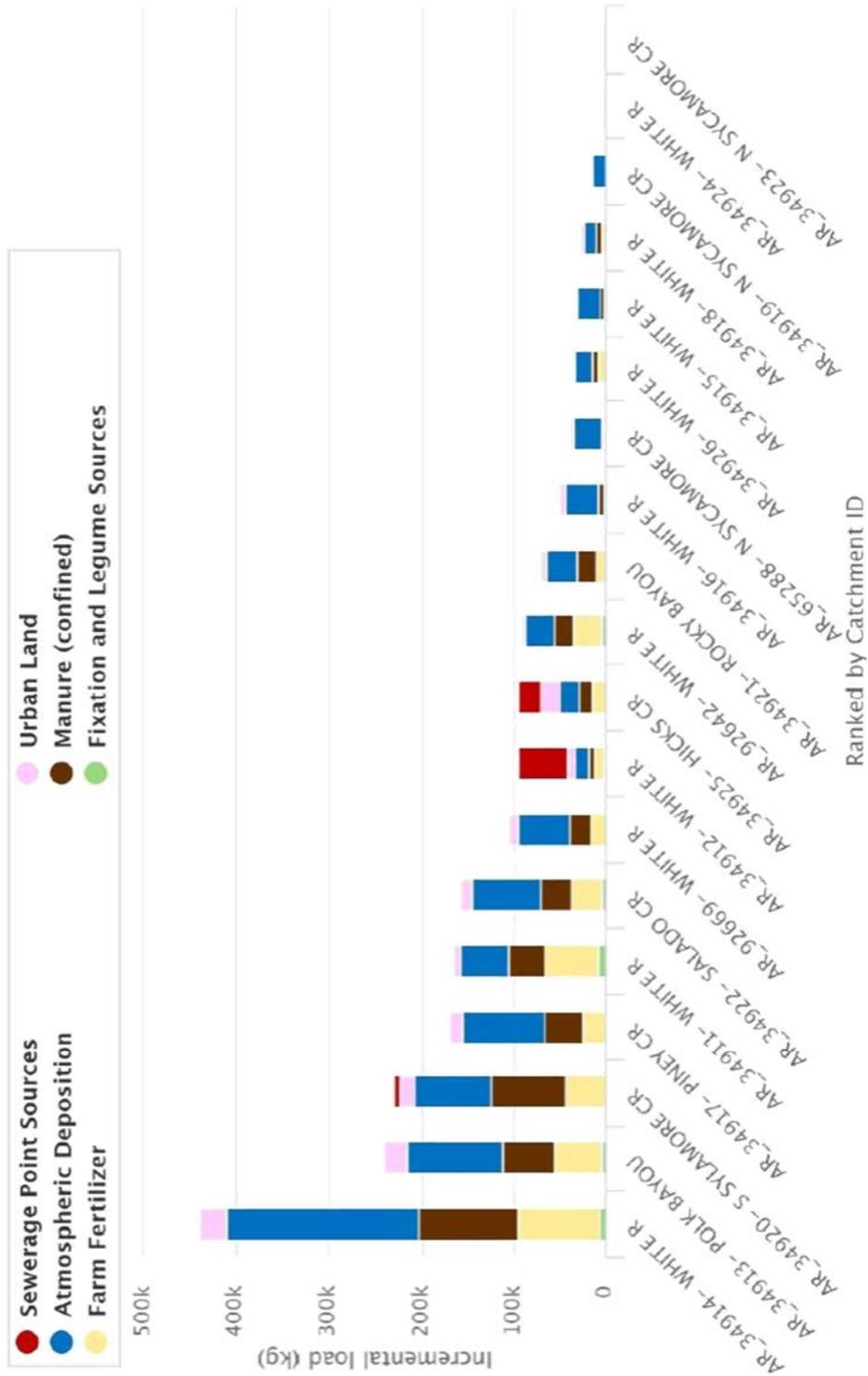


Figure 3.24. Graph of catchment total nitrogen loads for 2002 by source estimated by SPARROW (USGS 2011).

### 3.3.2 Load Estimates using Export Coefficients

A simple, widely used method of estimating loads is the use of export coefficients. An export coefficient is the mass of a pollutant leaving a unit of area over a unit of time. The load from a watershed is estimated by multiplying the export coefficient by the area of the watershed. White et al. (2015) developed export coefficients for sediment, total nitrogen, and total phosphorus (kg/ha/yr) for selected land uses (cultivated cropland, undisturbed forest, grassland, urban) for all of the ecoregions in the US. The Ozark Highlands ecoregion export coefficients (listed in Table 3.15) were used to estimate sediment, total nitrogen, and total phosphorus loads for major tributaries of the Middle White River watershed, based on 2011 land use data (Homer, et al. 2015). For each tributary watershed, the load from each land use was calculated by multiplying the land use area by the appropriate export coefficient, and then summed to get the total load for the subwatershed. These estimated loads and associated yields are summarized by White River tributary in Table 3.16, and Figures 3.25 and 3.26. The calculations are included as Appendix C.

In general, loads estimated for White River tributaries using this method increase as the tributary watershed size increases. However, with regard to yield, smaller tributary watersheds tend to have larger yields. The largest estimated yields are from Big Creek (of which Hicks Creek is a tributary) and Greenbrier Creek, both of which are among the smaller watersheds.

Table 3.15. Ozark Highlands export coefficients from White et al. (2015) used to estimate loads.

Land Use	Sediment export (kg/ha/yr)	Total nitrogen export (kg/ha/yr)	Total phosphorus export (kg/ha/yr)
Developed	1.04	10.5	1.8
Cultivated crops	4.83	23.2	2.21
Forest	0	1.27	0.059
Grassland (pasture/hayland)	0.03	1.36	0.437

Table 3.16. Annual loads and yields estimated for White River tributaries using export coefficients from White et al. 2015.

Tributary	Drainage Area (sq km)	Sediment		Total nitrogen		Total phosphorus	
		Load (kg)	Yield (kg/sq km)	Load (kg)	Yield (kg/sq km)	Load (kg)	Yield (kg/sq km)
Piney Cr	451.1	2,304	5.1	75,636	167.7	9,757	21.6
Poke Bayou	444.4	3,772	8.5	86,497	194.6	13,094	29.5
S Sylamore Cr	369.4	2,232	6.0	64,976	175.9	8,587	23.2
Salado Cr	291.5	2,493	8.6	53,685	184.2	7,348	25.2
N Sylamore Cr	198.6	653.8	3.3	30,894	155.6	2,384	12.0
Lafferty Cr	156.6	680.7	4.3	25,187	160.8	3,219	20.6
Rocky Bayou	110.6	619.0	5.6	19,212	173.6	2,270	20.5
Big Cr-Hicks Cr	105.3	2,580	24.5	35,642	338.5	5,886	55.9
W Rocky Bayou	91.5	450.6	4.9	15,179	165.8	1,877	20.5
Sprint Cr	88.4	1,081	12.2	18,890	213.8	3,269	37.0
Greenbrier Cr	87.6	2,141	24.4	23,556	268.9	3,416	39.0
Wolf Bayou	86.5	287.4	3.3	13,152	152.1	1,652	19.1
Moccasin Cr	62.9	376.2	6.0	10,895	173.2	1,496	23.8
Livingston Cr	55.2	186.5	3.4	8,643	156.7	652.3	11.8
Wideman Cr	34.2	92.3	2.7	1,040	30.4	199.0	5.8

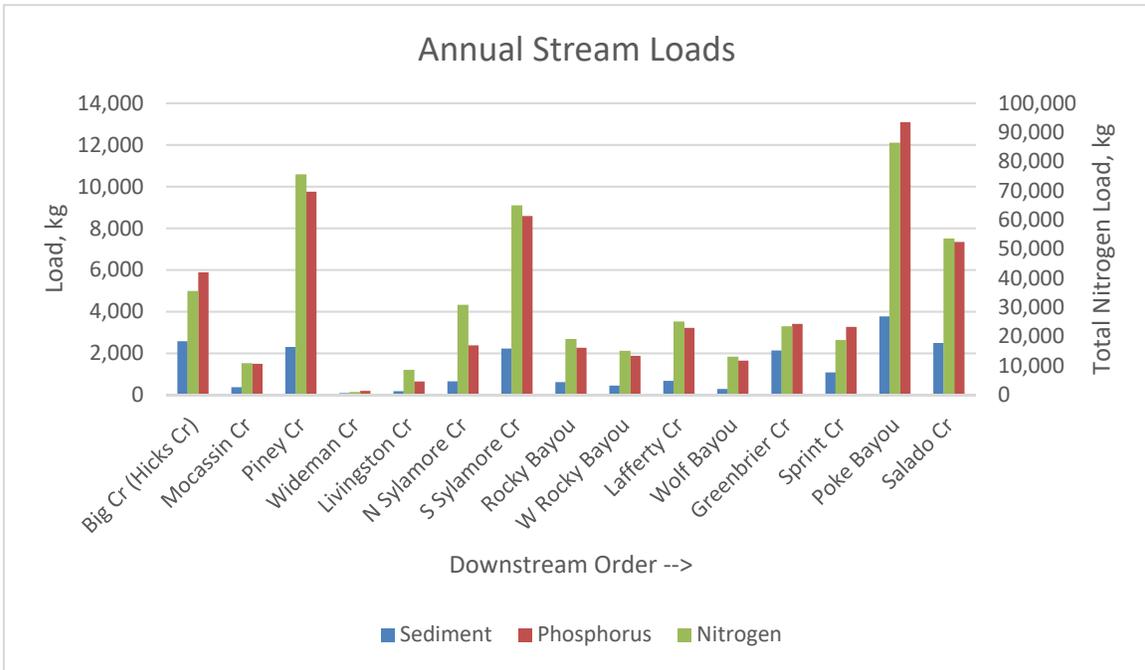


Figure 3.25. Annual loads for White River tributaries estimated using export coefficients from White et al. 2015.

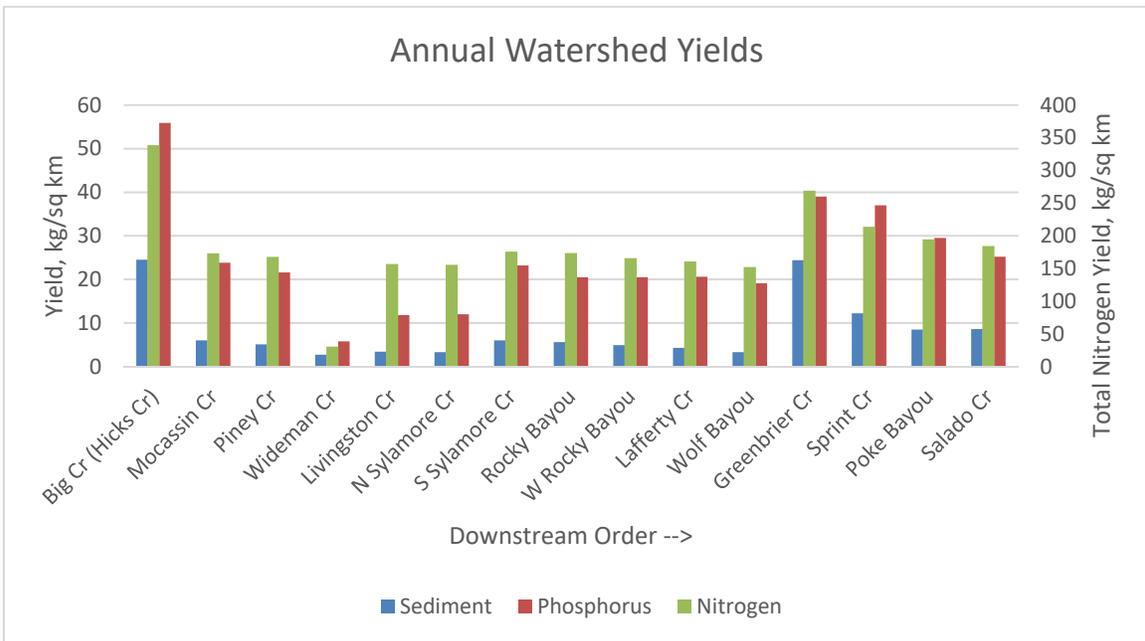


Figure 3.26. Yields for White River tributary watersheds based on loads estimated using export coefficients from White et al. 2015.

### 3.3.3 Current Load Estimates

Estimates of current load for TSS, total nitrogen, and total phosphorus were calculated using data collected during the period 2013-2017. Loads were estimated by multiplying the harmonic mean flow by the harmonic mean concentration for this period<sup>4</sup>. Where water quality is monitored at multiple locations on a stream, or in a subbasin (e.g., Hicks Creek-Big Creek, North Sylamore Creek), a load was estimated only for one monitoring location, usually the farthest downstream. As can be seen in the statistics tables in Section 3.1, for a number of the monitoring stations where data were collected during the period 2013-2017, only three or less data points were collected. These stations were excluded due to the small number of data points. Given these criteria, loads were estimated for seven locations with data from the period 2013-2017; WHI0065 on Hicks Creek, WHI0168 on Piney Creek, WHI0162 on Wideman Creek, WHI0202 on North Sylamore Creek, WHI0090 on South Sylamore Creek, WHI0167 on Greenbrier Creek, and WHI0166 on Salado Creek.

Flow is not measured at the ADEQ water quality monitoring locations where loads are estimated. For those locations, the harmonic mean flow estimated by USGS StreamStats is used to estimate the load (<https://water.usgs.gov/osw/streamstats/>). StreamStats output is included in Appendix D.

There was an approximately two-year period, 2013-2015, when samples were collected at all seven target monitoring locations on the same, or close to the same, dates. At some locations, samples were collected on additional dates. However, to keep the load estimates for all of the sampling locations as comparable as possible, only data from dates sampled at multiple stations were used to calculate the harmonic mean concentration. The data used to calculate the harmonic mean concentrations are listed in Appendix D. The estimated loads are summarized on Figure 3.27. Estimated yields (load/drainage area) are summarized on Figure 3.28.

---

<sup>4</sup> Harmonic mean is the reciprocal of arithmetic mean. It is considered the most appropriate mean for rates, such as flow. It also is less influenced by occasional large values, which occur in some of the water quality records.

---

### Estimated Loads 2013-2015

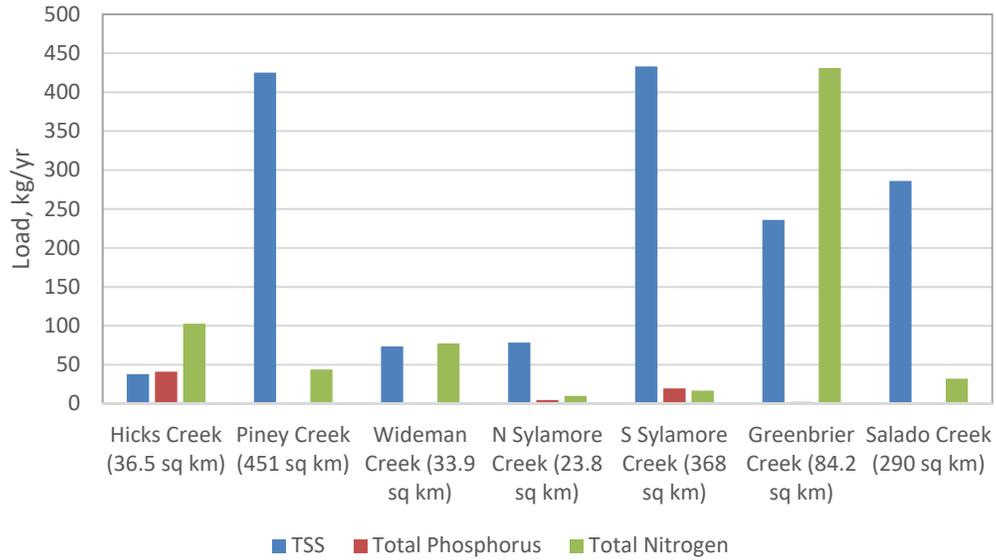


Figure 3.27. Estimated loads based on measurements from 2013-2015.

### Estimated Yields 2013-2015

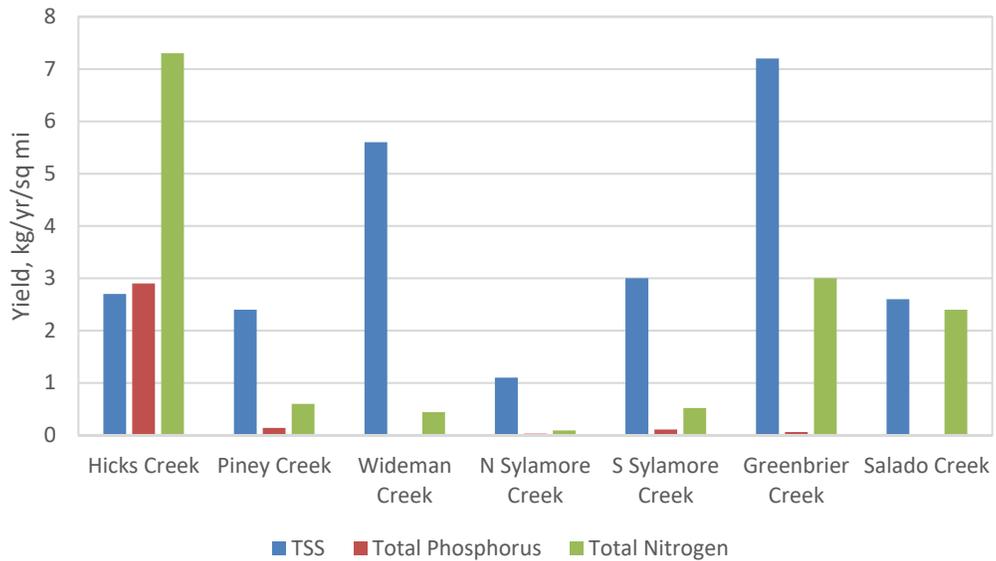


Figure 3.28. Estimated yields based on measurements from 2013-2015.

The ADEQ monitoring program is not designed to collect the type of data needed to calculate realistic estimates of loads. As a result, the loads shown on Figure 3.27 are not expected to accurately represent actual pollutant loads at these locations. These estimates of current load cannot be compared to the 2002 SPARROW estimates to see if loads have changed over time. However, they can be compared to each other, to get a relative idea of how the monitored streams compare in terms of the load they are contributing to the White River.

Relative size of TSS loads shown on Figure 3.27 appear to be strongly related to watershed size. The two monitoring locations with the largest contributing drainage areas (shown in parentheses with the stream name) have the largest TSS loads. This is not the case with the nutrients. The Hicks Creek monitoring location has the largest total phosphorus load, but a relatively small drainage area. The South Sylamore Creek monitoring station has the second largest total phosphorus load, and a drainage area approximately ten times larger than the Hicks Creek station. The Greenbrier Creek station has the largest total nitrogen load, while the drainage area is in the middle range.

Examining pollutant yields provides another perspective on water quality in the monitored streams. TSS yields are greatest for the Greenbrier Creek and Wideman Creek monitoring stations (Figure 3.28). No cause for these high TSS yields is readily apparent. Nutrient yields are greatest for the Hicks Creek monitoring station. This is not surprising since this monitoring station is located just downstream of the outfall of the Mountain Home WWTP. Relatively high total nitrogen yields at the Greenbrier and Salado Creek stations are not as easily explained. As expected, yields for the North Sylamore Creek monitoring station are the lowest of the monitored locations.

### **3.3.4 Data gaps**

The monitoring programs active in the Middle White River watershed are not designed to collect the data needed to calculate realistic estimates of loads for the White River tributaries. The most recent model of loads in the watershed estimates total nitrogen and total phosphorus loads for 2002. To get more current realistic estimates of pollutant loads to the White River, a

new or updated model would need to be developed, or a study specifically designed to collect data for load estimates would need to be implemented.

### **3.3.5 Load Summary**

USGS has modeled total phosphorus and total nitrogen loads for catchments of the Middle White River watershed for the year 2002. Loads were estimated for subwatersheds for the Middle White River watershed using export coefficients recently developed using a regional SWAT model (White, et al. 2015). Recent (i.e., from the period 2013-2017) available water quality data were also used to calculate estimates of load. While the available recent data are not from a monitoring program designed to facilitate accurate load estimates, the estimates calculated using these data can provide insight into the relationships among loads in tributaries of the White River in this watershed.

There are differences in loads and yields of TSS, sediment, total phosphorus, and total nitrogen estimated for monitored locations on White River tributaries in the Middle White River watershed. The size of TSS loads appears to be most strongly influenced by the size of the drainage area, although TSS yields for the monitored locations range from 1 kg/yr/sq mi to just over 7 kg/yr/sq mi. Relatively high nutrient loads and yields for the Hicks Creek monitoring station may be at least partly the result of the influence of the Mountain Home WWTP, which discharges upstream of the monitoring station. The high total nitrogen load and yield for the Greenbrier Creek station can only be the result of nonpoint sources.

## **3.4 Geomorphology and Channel Stability**

Stream geomorphology addresses the relationships between characteristics of a stream watershed (i.e., topography, geology, and land use) and the shape of the stream channel (i.e., width, depth, and slope). A “stable” stream channel experiences only small changes in shape or location over time.

Measurements of geomorphologic characteristics have been collected by USGS from North Sylamore Creek as part of the National Water Quality Assessment (NAWQA) program

and associated studies (e.g., Panfil and Jacobson 2001). However, no geomorphological studies were found for areas within the Middle White River watershed.

In general, streams in the Ozark Highlands, such as White River tributaries located within the Middle White River watershed, are considered to be somewhat unstable. These streams are responding to the changes in land use and land cover that have occurred in this region since settlement. Specific land use/land cover changes believed to affect stream stability in the Ozark Highlands include large-scale commercial timber harvest that occurred in the region between the 1880s and 1920s, and removal of riparian forest. Symptoms of stream instability in Ozark Highlands streams include large gravel bars and bank erosion (Jacobson and Primm 1997). Researchers have noted morphologic changes in Ozark streams in northern Arkansas that include decreased pool depths, increased stream widths, and increase in gravel in the substrate (Adams, Adams and Connolly 2017).

### **3.5 Hydrology**

There were four active USGS flow gages in the Middle White River watershed in 2018 (Figure 3.29). Table 3.17 lists summary statistics for flow measurements from these gages. The farthest downstream USGS flow gage on the White River in this watershed is at Batesville. Only one of the White River tributaries in the Middle White River watershed has a USGS flow gage. Only USGS measures flow when collecting water quality samples or conducting biological surveys.

The USGS analyzed flow data from 1951-2011 for 38 stream gages across the state to identify long term trends. One of the stream gages analyzed was on the White River at Calico Rock (07060500). No statistically significant long-term trends were identified in annual, seasonal, or peak White River flows at this location. A statistically significant decreasing trend in minimum flows was identified (Wagner, Krieger, and Merriman 2014).

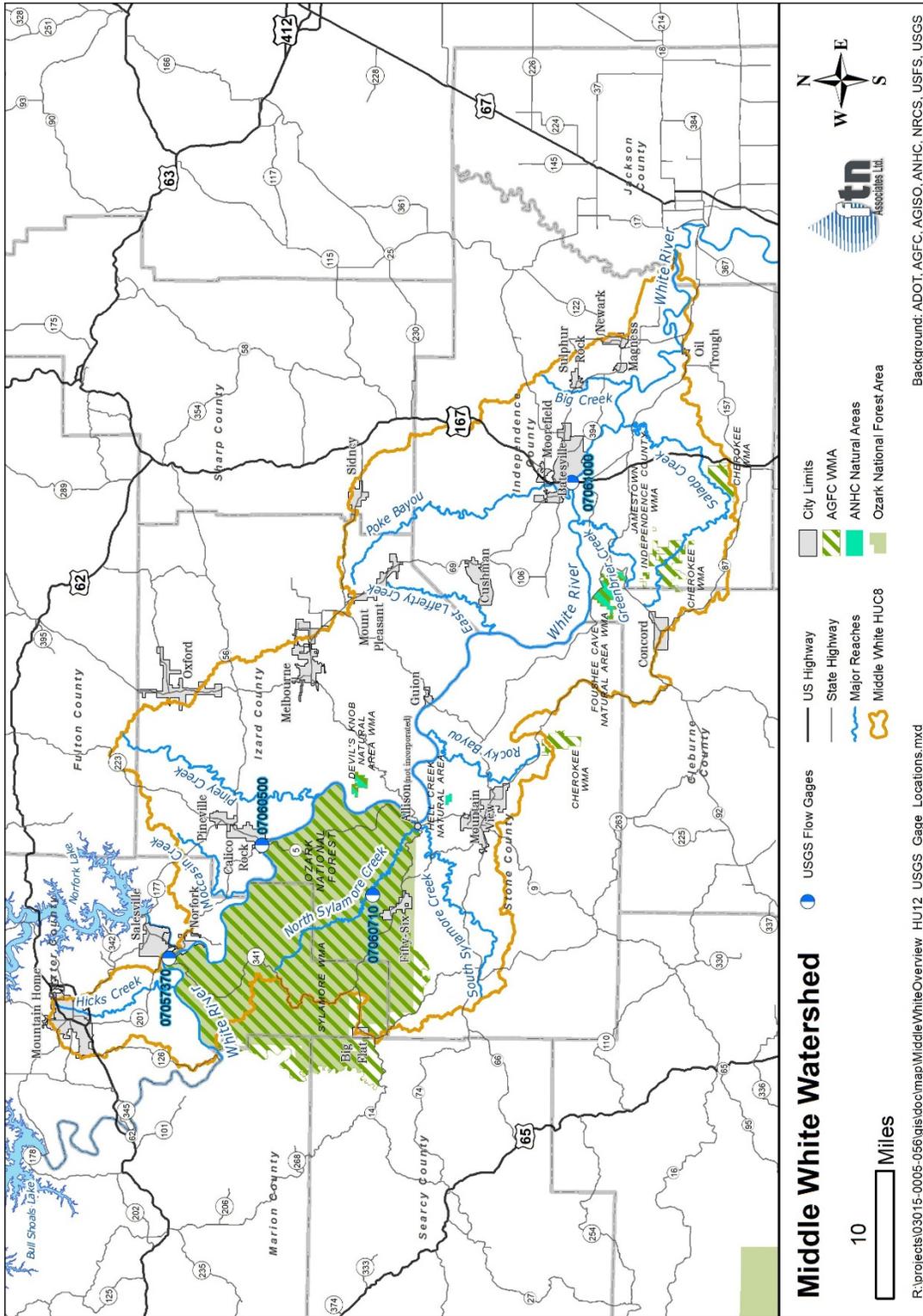


Figure 3.29. Active USGS flow gages in the Middle White River watershed, 2017.

As part of this same study, pool elevations and releases from selected USACE reservoirs were also evaluated for long term trends. The Middle White River watershed receives releases from the USACE reservoirs Bull Shoals Lake and Norfolk Lake. Statistically significant increasing trends were identified in pool elevations for both Bull Shoals Lake and Norfolk Lake. Additionally, statistically significant increasing trends were identified in annual mean and maximum daily releases from Bull Shoals Lake, and in the number of low flow days in releases from Bull Shoals Lake. No trend was apparent in releases from Norfolk Lake (Wagner, Krieger and Merriman 2014). Minimum flow releases have recently been set for both of these reservoirs; 800 cfs for Bull Shoals Lake and 300 cfs for Norfolk Lake (USACE Little Rock District 2016).

Table 3.17. Statistics for discharge data from USGS gages active in 2018 (USGS 2018a).

Site Number	Year Established	Site Name	Annual Average Discharge (cfs*)	Lowest Mean Monthly Discharge, (cfs*)	Highest Mean Monthly Discharge (cfs*)	7Q10 Flow, (cfs*)	90% Exceeds Flow, (cfs*)	Peak Flow, (cfs*)
07057370	1996	White River near Norfolk, AR	8,727	1,060	44,940	649	1,850	196,000
07060500	1939	White River at Calico Rock, AR	10,795	1,905	37,470	950	2,710	202,000
07060710	1965	North Sylamore Creek near Fifty-Six, AR	54.4	2.31	471	1.8	4.1	28,200
07061000	1937	White River at Batesville, AR	12,604	2,160	45,210	1,104	3,360	208,000

\* calculated for period 2004-2016, longest period when all stations have data. Annual average calculated for calendar year.

Flows in the White River are largely controlled by releases from Bull Shoals and Norfolk reservoirs. Some elements of White River flows appear to be changing over time. Minimum releases have been set for Bull Shoals and Norfolk reservoirs. No information was found on evaluation of flows in White River tributaries within this watershed.

### 3.6 Aquatic Habitat

Physical habitat in streams is a combination of factors that support aquatic organisms, including water depth, water velocity, water temperature, channel substrate (i.e., what kind of material makes up the stream bottom), and cover. Physical habitat in streams, and the condition of that habitat, varies naturally, but can also be affected by human activities.

ADEQ collects habitat information during fish surveys and uses this information to develop an index of fish habitat integrity score. Fish Habitat integrity scores for fish survey locations in the Middle White River watershed are summarized in Table 3.18. Higher scores indicate better fish habitat. Locations surveyed are shown on Figure 3.30.

Table 3.18. ADEQ fish habitat integrity scores from fish survey locations in Middle White River watershed (ADEQ 2018b).

ADEQ Station ID	ADEQ Sample ID	Stream Name	Date	Habitat integrity scores		
				Pool	Riffle	Run
WHI0147	4F007	South Sylamore Cr	7/30/1997	153.1	21.7	152.4
WHI0146	4F008	South Sylamore Cr	7/30/1997	67.8	47.4	90.4
WHI0145	4F009	South Sylamore Cr	7/30/1997	96.3	27.1	143.8
WHI0151	4F010	Salado Cr	6/16/1998	211.5	8.2	4.4
WHI0161	4F011	Piney Cr	9/16/1999	95.2	4.9	NA*
WHI0162	4F012	Wideman Cr	6/14/1999	71.2	55.7	25.6
WHI0159	4F013	West Livingston Cr	6/14/1999	166.3	19.2	27.2
WHI0147	4F014	South Sylamore Cr	9/14/1999	233.6	53.8	98.5
WHI0146	4F015	South Sylamore Cr	9/14/1999	31.7	24.2	50.6
WHI0145	4F016	South Sylamore Cr	9/14/1999	202.9	34.8	62.3
WHI0144A	4F017	North Sylamore Cr	9/19/2013	61.2	19.4	13.2
WHI0147	4F018	South Sylamore Cr	9/20/2013	83	11.2	41.9
WHI0202	4F019	North Sylamore Cr	9/19/2013	92.7	17.2	21.1
WHI0168	4F020	Piney Cr	9/16/2011	95.2	4.9	NA*

\*This habitat is not present at this location.

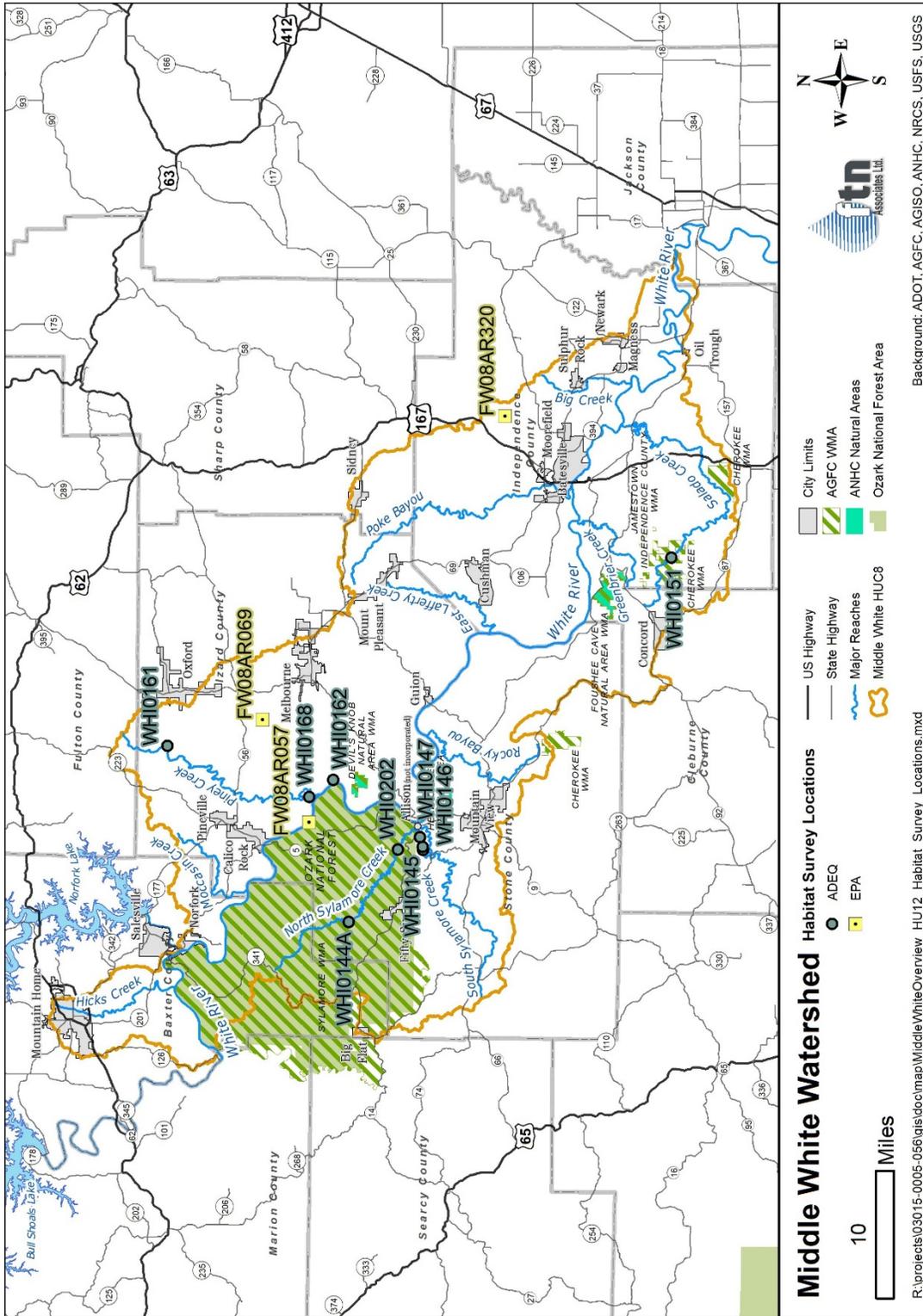


Figure 3.30. Locations of habitat surveys in Middle White River watershed.

There are three sites on South Sylamore Creek that were surveyed more than once, WHI0145, WHI0146, and WHI0147. These sites are associated with an instream gravel mining operation. The 1997 surveys (Sample IDs 4F007, 4F008, and 4F009) were conducted prior to initiation of mining. The 1999 surveys (Sample IDs 4F014, 4F015, and 4F016) were conducted after mining was initiated. In the mined area (WHI0146), habitat scores for all three habitats (pool, riffle, and run) were lower after mining started. At the upstream (WHI0145) and downstream locations (WHI0147) pool and riffle habitat scores were higher after mining started, and run habitat scores were lower. The downstream location (WHI0147) was surveyed again in 2013 (sample 4F018). In 2013, integrity scores for all three habitats were lower than in 1997 (sample 4F007), and 1999 (sample 4F014).

EPA also collected habitat information from the watershed during the 2004 National Aquatic Resources Survey and the 2009 National Rivers and Streams Assessment (EPA 2013). Table 3.19 summarizes the habitat condition results from the EPA work in the Middle White River watershed. In the 2009 National Rivers and Streams Assessment, habitat condition is classified as good, fair, or poor.

Table 3.19. EPA habitat condition results for locations in Middle White River watershed.

EPA Station ID	Stream Name	Year	Substrate	In-stream cover	Riparian vegetation
FW08AR057	White River	2008	Good	Good	Fair
FW08AR069	Band Mill Cr	2008	Good	Good	Poor
FW08AR320	Gravel Cr	2008	Good	Good	Poor

There are a few locations in the watershed where aquatic habitat has been evaluated. Condition categories were not found for the locations evaluated by ADEQ. EPA evaluations categorized instream habitat as good, but riparian areas as being in poor condition.

### 3.7 Surveys of Aquatic Communities

Aquatic communities respond to changes in habitat, including water quality, and are useful indicators of stream health. The condition of aquatic communities is characterized based

on information such as the abundance of animals, the number of different species present, the water quality and habitat requirements of the species that are present, and how sensitive the species that are present are to changes in water quality or physical habitat. In many cases, selected information about the aquatic communities present are used to develop a score or grade that reflects the health of streams, such as an Index of Biotic Integrity (IBI) for fishes or for aquatic invertebrates. Much of the biological monitoring in the watershed is being used to characterize best possible ecoregion reference conditions. Figure 5.3 shows locations in the Middle White River watershed where biological surveys have been conducted since 2000.

### **3.7.1 Fish Communities**

During the period 2013-2017 ADEQ, and USGS conducted fish community surveys in the Middle White River watershed (ADEQ 2018b, National Water Quality Monitoring Council 2018). The locations of these surveys are shown on Figure 3.31. Researchers from the University of Central Arkansas are currently surveying fish communities in the Middle White River watershed for a project to assess distribution and status of fish species (University of Central Arkansas 2018). EPA conducted fish surveys in the watershed during the 2009 National Rivers and Streams Assessment (EPA 2013). In addition, the USFS conducted fish surveys in the watershed during 2007 (USFS 2016).

In 2014 ADEQ conducted fish surveys on Salado Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waters in the Boston Mountains ecoregion. In 2011 and 2013, ADEQ conducted fish surveys on Ecoregion Reference Streams, including North and South Sylamore Creeks, West Livingston Creek, and Piney Creek in the Middle White River watershed. Fish surveys were also conducted on most of these streams in the late 1990s (ADEQ 2018b). ADEQ has developed a series of fish IBIs for each of the ecoregions in the State. IBIs are used to classify the health of streams based on selected characteristics of the fish community. IBI values for ADEQ fish surveys conducted since 2005 are listed in Table 3.20.

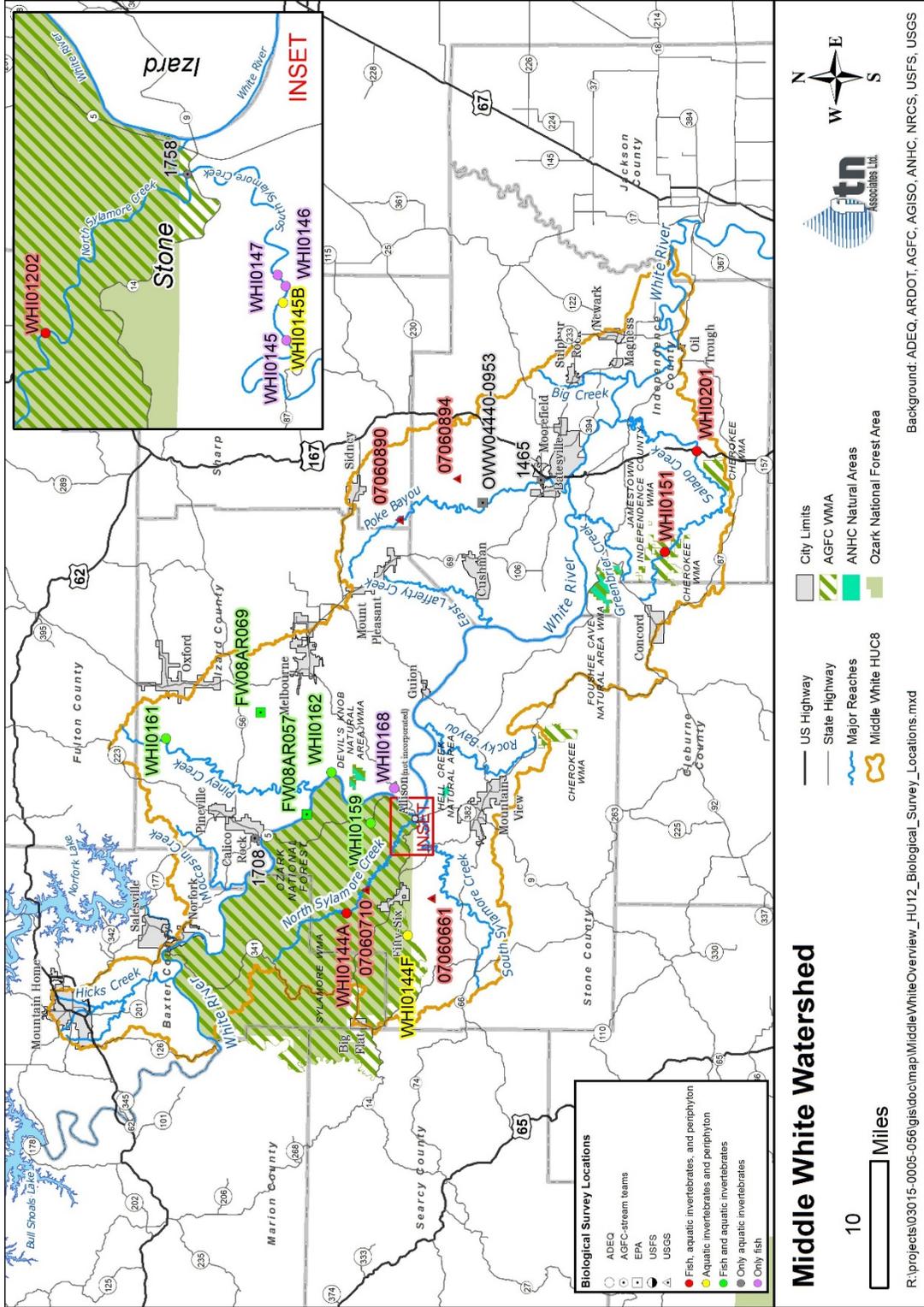


Figure 3.3.1. Locations of aquatic community surveys in the Middle White River watershed.

Table 3.20. IBI scores and associated stream health ratings based on recent fish surveys.

Stream (Station ID)	Agency	Year	Index Score	Rating
Tributary of W. Livingston Cr	USFS	2007	18	Fair
Tributary of E. Livingston Cr	USFS	2007	24	Fair
Spring Tributary of W. Livingston Cr	USFS	2007	13	Fair
E. Livingston Cr	USFS	2007	37	Excellent
Livingston Cr	USFS	2007	33	Good
Bearhead Br	USFS	2007	16	Fair
Coldwater Cr	USFS	2007	28	Good
Farris Cr	USFS	2007	22	Fair
Goose Cr	USFS	2007	13	Fair
Sycamore Cr	USFS	2007	27	Good
Twin Cr	USFS	2007	16	Fair
Walker Cr	USFS	2007	25	Good
Sneeds Cr	USFS	2007	23	Fair
Sugarloaf Cr	USFS	2007	11	Poor
Perry Cr	USFS	2007	39	Excellent
White R. (FW08AR057)	EPA	2009	73.81	Good
Band Mill Cr (FW08AR069)	EPA	2009	60.42	Fair
Gravel Cr (FW08AR320)	EPA	2009	60.11	Fair
Salado Cr (WHI0201)	ADEQ	2014	19	Good
Salado Cr (WHI0151)	ADEQ	2014	24	Good
South Sylamore Cr (WHI0147)	ADEQ	2013	39	Excellent
North Sylamore Cr (WHI0202)	ADEQ	2013	41	Excellent
North Sylamore Cr (WHI0144A)	ADEQ	2013	39	Excellent
West Livingston Cr (WHI0159)	ADEQ	2011	25	Good
Piney Cr (WHI0168)	ADEQ	2011	33	Good

In 2006, USGS conducted fish surveys at four locations in the Middle White River watershed; North Sylamore Creek near Fifty-Six (07060710), Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010). USGS used fish survey data from the North Sylamore Creek in 2001 and 2002 to calculate an IBI developed by Dauwalter et al. (2003). The resulting IBI value placed North Sylamore Creek in the Reference category, indicating a healthy fish community (Petersen 2004).

The USFS has conducted fish surveys on streams in the Middle White River watershed as part of implementing the 2005 Revised Land and Resource Management Plan for the Ozark-St. Francis National Forests. In 2007, fish surveys were conducted at 14 stream sites and one spring located within the watershed in the Sylamore District of the Ozark National Forest (USFS 2008). No new fish survey results have been reported by USFS as of the most recent monitoring and evaluation report, from 2015 (USFS 2016). The USFS used the ADEQ fish IBI to classify the condition of the fisheries based on their surveys (USFS 2008). This information is listed in Table 3.20. Only one fish community surveyed by USFS was classified as poor, in Sugarloaf Creek.

The USGS conducts fish surveys at the North Sylamore Creek gaging station (07060710), as part of the NAWQA program (National Water Quality Monitoring Council 2018). USGS has conducted fish surveys at this location routinely since 1993. Fish counts from this series of surveys are graphed on Figure 3.32. The number of fish collected has ranged from 23 to 543, but most years between 200 and 400 fish were collected. With the exception of 2004, the number of species identified is fairly consistent among years, with between 15 and 18 species identified most years. The graph on Figure 3.32 shows variation in the make-up of the fish community over time.

Matthews et al. (2016) analyzed fish surveys conducted at 12 locations in the Piney Creek subwatershed over a 40-year period. Matthews et al. (2016) concluded that the fish community in Piney Creek is relatively stable. Variability evident in the surveys apparently is the result of natural events, with the limited human activities in the watershed not significantly affecting the fish community over the long term.

N. Sylamore Cr. near Fifty Six

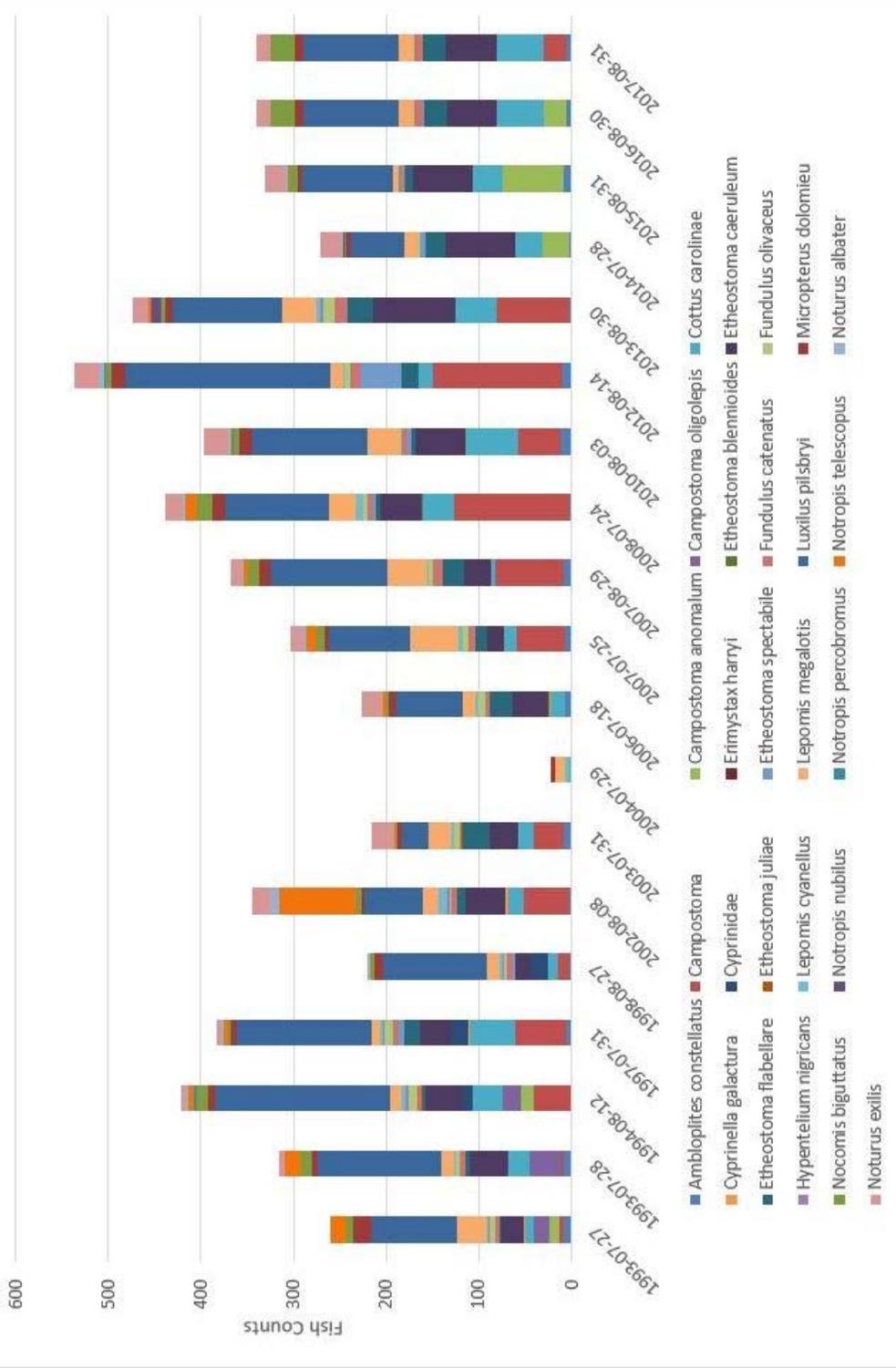


Figure 3.32. USGS fish counts over time at North Sylamore Creek near Fifty-Six (Station 07060710).

### 3.7.2 Aquatic Invertebrates

During the period 2013-2017 ADEQ and local Stream Teams have conducted aquatic invertebrate surveys in the Middle White River watershed (ADEQ 2018c)(W. Posey, AGFC, personal communication 6/13/18). The locations of these surveys are shown on Figure 3.31. EPA conducted aquatic invertebrate surveys in the watershed as part of the 2004 National Aquatic Resource Survey and the 2009 National Rivers and Streams Assessment (EPA 2013).

In 2013, ADEQ conducted aquatic invertebrate surveys on North and South Sylamore Creeks, and Roasting Ear Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Ozark Highlands ecoregion. During the period 2014-2015, ADEQ conducted aquatic invertebrate surveys on Salado Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Boston Mountain ecoregion (ADEQ 2016). Results from these surveys were not found in the ADEQ online aquatic invertebrate database (ADEQ 2018c). ADEQ also conducted aquatic invertebrate surveys in Salado Creek during 1998, and in Piney Creek, West Livingston Creek, and Wideman Creek during 1999.

As part of the National Rivers and Streams Assessment, EPA conducted aquatic invertebrate surveys at two sites in the Middle White River watershed (Figure 3.31). As part of this assessment, aquatic invertebrate community condition was characterized using a multimetric index (EPA 2013). The reported aquatic invertebrate community condition at these sites are listed in Table 3.21.

Stream Teams conduct aquatic invertebrate surveys at three locations in the Middle White River watershed (Figure 3.31).

Table 3.21. Condition of aquatic invertebrate communities surveyed by EPA in the National Rivers and Streams Assessment, 2009 (EPA 2013).

Station	Stream	Year	Condition
FW08AR057	White R	2009	Poor
FW08AR069	Band Mill Cr	2009	Poor

In 2006, USGS conducted aquatic invertebrate surveys at three locations in the Middle White River watershed; Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010).

### **3.7.3 Periphyton**

Periphyton communities have been surveyed in the Middle White River watershed by ADEQ and USGS. The locations where periphyton surveys have been conducted are shown on Figure 3.31.

ADEQ has collected periphyton from several streams in the Middle White River watershed as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Ozark Highlands and Boston Mountain ecoregions (ADEQ 2016).

The USGS has studied periphyton within the Middle White River watershed as part of the NAWQA Program. The USGS collected data on the amount of periphyton present at one reach of North Sylamore Creek as part of this program. These data were collected in 1993-1995 (Petersen and Femmer 2003). In 2006, USGS conducted periphyton surveys at three locations in the Middle White River watershed; Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010).

Justus et al. (2010) found that periphyton metrics were most sensitive to changes in nutrient concentrations in small Ozark streams. Petersen and Femmer (2003), evaluating periphyton data from the USGS NAWQA Program, found that, in Ozark streams, the amount of blue-green species of periphyton tended to increase as the percentage of the stream watershed in agricultural land use increased. They also found that the amount of diatom algae increased as stream alkalinity increased, and stream orthophosphate, total phosphorus, and dissolved organic carbon decreased. Therefore, the presence of large amounts of blue-green species is considered

indicative of poorer water quality, while the presence of large amounts of diatom algae is considered indicative of better water quality.

#### **3.7.4 Aquatic Communities Data Gaps**

Most biological surveys in the Middle White River watershed appear to have been targeted at streams expected to have healthy aquatic communities. The only two locations in the watershed with long-term fish community monitoring are mostly undeveloped, North Sylamore Creek and Piney Creek. No records were found to indicate that biological communities of the impaired Greenbrier Creek have been surveyed. The most recent ADEQ biological survey on the impaired Hicks Creek indicated on the ADEQ website is a 2001 aquatic invertebrate survey on Hicks Creek. There is an active Stream Team that regularly surveys aquatic invertebrates in Hicks Creek.

#### **3.7.5 Aquatic Communities Summary**

Information on surveys of fish, aquatic invertebrates, and periphyton communities was found for the Middle White River watershed. The majority of surveys have been conducted on streams with little or no human development in their watersheds. Condition categories were not found for the locations surveyed by ADEQ. USGS, USFS, and EPA categorized the fish communities at the locations they surveyed mostly as fair to excellent. Sugarloaf Creek was the only stream where the fish community was categorized as poor. EPA categorized the aquatic invertebrate communities at the two locations they surveyed (White River and Band Mill Creek) as poor. Periphyton community surveys were not used to categorize the health of the streams, so community condition categories were not found.

### **3.8 Cave Aquatic Habitat and Species of Greatest Conservation Need**

The Nature Conservancy has conducted a literature-based survey of the occurrence of state Species of Greatest Conservation Need associated with cave habitats in the Ozarks region of Arkansas (Inlander, Gallipeau and Slay 2011). In addition, Inlander, Gallipeau and Slay (2011) evaluated threats to these species. This study included 30 cave habitat sites within the

Middle White River watershed where aquatic Species of Greatest Conservation Need have been identified. The majority of these sites were classified as having medium-low or low overall threat scores for aquatic Species of Greatest Conservation Need (Figure 3.33). Three sites in the watershed are classified as having medium-high vulnerability to groundwater contamination, which could impact the species. Thirteen other sites in the watershed were classified as having a medium risk of groundwater contamination. All of the remaining sites with aquatic Species of Greatest Conservation Need had medium-low to low risk of groundwater contamination (Inlander, Gallipeau, and Slay 2011).

There are at least 30 cave or karst sites in the Middle White River watershed where aquatic Species of Greatest Conservation Need for Arkansas are present. Of these, eight have been classified as experiencing a medium-high threat to community health due to a combination of potential for water contamination and human access. All other sites have lower risk of being negatively impacted by water contamination and/or human access (Inlander, Gallipeau and Slay 2011).

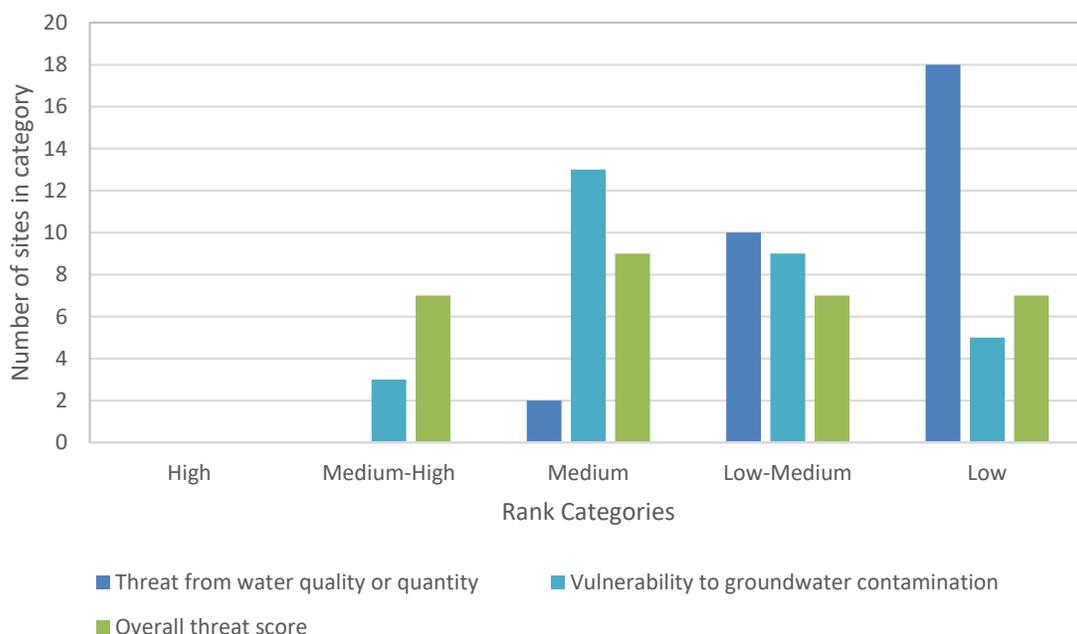


Figure 3.33. Inlander, Gallipeau, and Slay 2011 ranking of threats to Species of Greatest Conservation Need in selected cave habitat sites in the Middle White River.

### **3.9 Subwatersheds Recommended for Initial Management**

The Middle White River watershed is large, covering 1,476.2 sq mi. This section describes the approach used to identify areas in the watershed where nonpoint source pollution management appears to be most needed at this time.

For this watershed management plan, 12-digit hydrologic cataloging unit (HUC12) subwatersheds delineated by the USGS are utilized as focus areas for nonpoint source management. There are 44 HUC12 subwatersheds within the Middle White River watershed. Figure 3.34 shows the HUC12 subwatersheds with the numeric codes used to identify them. Three to five HUC12 subwatersheds is a reasonable number to recommend for initiating management of nonpoint source pollution sources under this watershed management plan.

#### **3.9.1 Approach for Identifying Recommended HUC12 Subwatersheds**

To identify HUC12 subwatersheds to recommend for management under this plan, available information was used to rank all of the HUC12 subwatersheds of the Middle White River in terms of water quality concerns. HUC12 subwatersheds with the most information suggesting water quality concerns were ranked the highest. The following information was used to rank the HUC12 subwatersheds:

1. Condition of aquatic communities, including fish, aquatic invertebrates, and periphyton;
2. Water quality data, including concentrations, loads, trends, and natural resource concerns;
3. Condition of aquatic habitat, including substrate, streambanks, and riparian areas;
4. The presence of aquatic habitats designated for protection; and
5. Groundwater quality vulnerability.

To rank the HUC12 subwatersheds, each subwatershed was assigned a score of 1 or 0 for each type of information. A score of 1 was assigned if the information indicated water quality concerns. A score of 0 was assigned if the information did not indicate water quality concerns. Where a type of data was not available, no score was assigned. These scores were then summed.

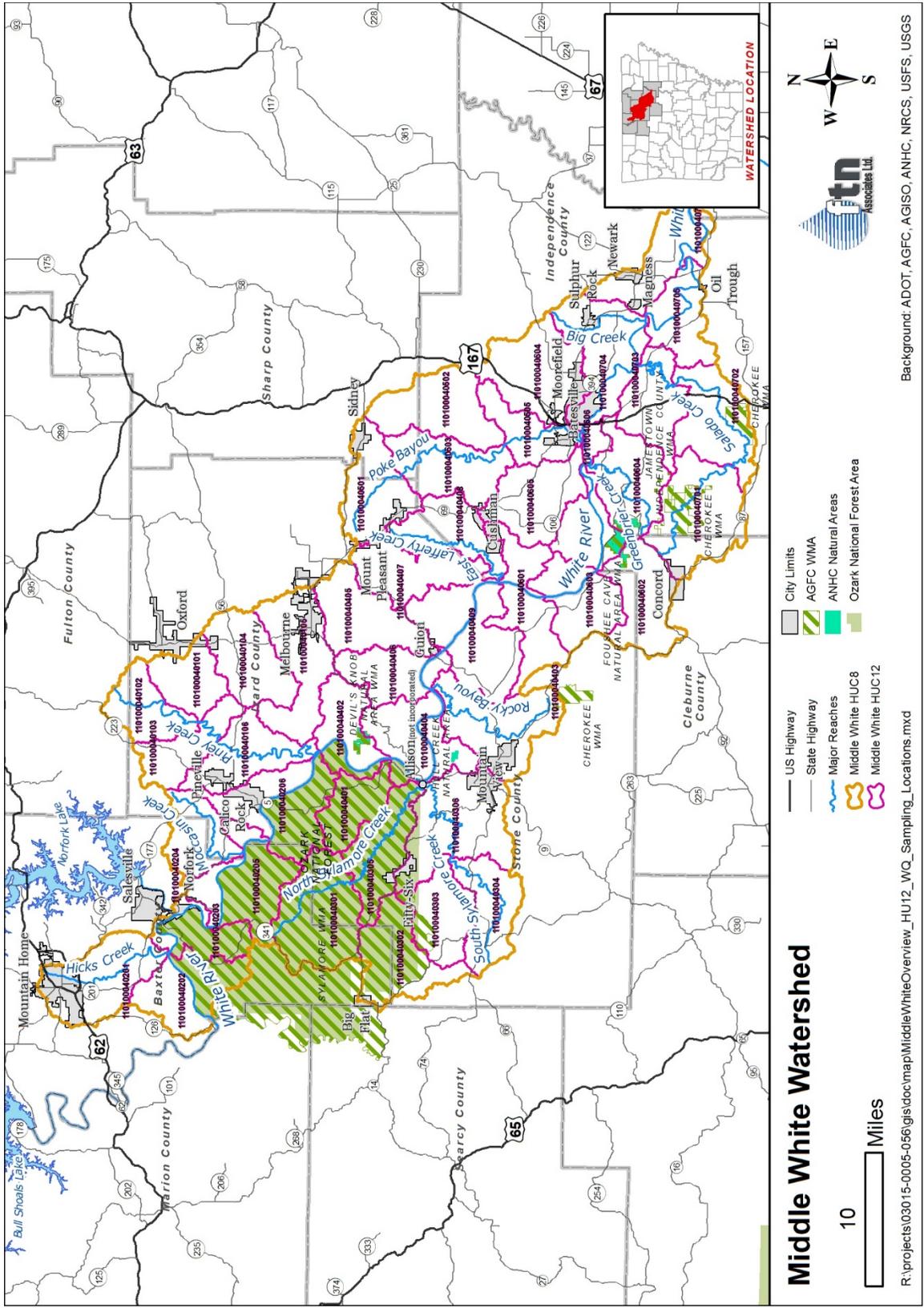


Figure 3.34. HUC12 subwatersheds of the Middle White River watershed.

Scores were assigned as follows. For information on condition of aquatic communities and habitat, HUC12 subwatersheds where condition was classified as poor based on surveys were assigned a score of 1, all others where condition was classified based on surveys received a score of 0. Biological and/or habitat surveys have been conducted in only 19 of the 44 HUC12 subwatersheds (see Section 3.7).

Scores were assigned to HUC12 subwatersheds based on the median concentrations of turbidity, TSS, total phosphorus, inorganic nitrogen, total nitrogen, and dissolved oxygen from the period 2013-2017. For each water quality parameter, all of the water quality stations in the Middle White River watershed were ranked from highest to lowest median concentration. For dissolved oxygen concentrations, HUC12 subwatersheds with at least one water quality station with a median concentration in the lowest 25th percentile were assigned a score of 1. Low dissolved oxygen typically indicates water quality issues. All other HUC12 subwatersheds where data were available, were assigned a score of 0 for dissolved oxygen. For all other water quality parameters, HUC12 subwatersheds with at least one station where the median concentration was in the highest 25th percentile were assigned a score of 1, and all others were assigned a score of 0. Note that there are active water quality monitoring stations in only 17 of the 44 HUC12 subwatersheds (see Section 3.1).

There was data available from three HUC12 subwatersheds sufficient to evaluate water quality trends. Measurements of dissolved oxygen, inorganic nitrogen, total nitrogen, total phosphorus, and fecal coliforms were evaluated for trends (see Section 3.2). A score of 1 was assigned if a trend indicative of declining water quality was found. At least one trend indicative of declining water quality was identified in all three HUC12 subwatersheds with water quality data evaluated for trends.

Scores were assigned to the HUC12 subwatersheds based on sediment, total phosphorus, and total nitrogen yields calculated using export coefficients (see Section 3.3.2). The HUC12 subwatersheds of the Middle White River watershed were ranked from highest to lowest yields (i.e., load/area). The HUC12 subwatersheds with estimated yields in the upper 25<sup>th</sup> percentile were assigned a score of 1, and the rest were assigned a score of 0.

US Department of Agriculture Natural Resource Conservation Service (NRCS) Natural Resource Concern Assessment Scores were also used to rank the HUC12 subwatersheds. Every 5 years the NRCS conducts state and national resource assessments to assess major concerns related to impacts of land use practices on the environment. There are nine major resource concerns, addressing such issues as soil erosion and soil quality degradation, water quality degradation, inadequate habitat for fish and wildlife, and air quality degradation. Most of the major resource concerns are partitioned to account for specific factors contributing to the resource concern. For example, the soil erosion major resource concern is partitioned into sheet, rill, and wind erosion; concentrated flow erosion, or gully formation; and streambank erosion. The latest resource assessment for Arkansas was conducted in 2016. The state resource assessments are conducted at the HUC12 subwatershed scale, with a mean score for each resource concern assigned to the HUC12 subwatersheds. For our scoring, the HUC12 subwatersheds of the Middle White River watershed were ranked from highest to lowest mean natural resource concern score. Eight resource concern categories were ranked for each HUC12 subwatershed: sheet, rill, and wind erosion; concentrated flow erosion; streambank erosion; excess sediment; excess nutrients; heavy metals and petroleum; pathogens; and pesticides and herbicides. Those subwatersheds with mean natural resource concern scores in the upper 25th percentile for the Middle White River watershed were assigned a ranking score of 1, while all others were assigned a ranking score of 0.

There are a number of stream reaches and some springs in the Middle White River watershed that have been designated by state or federal agencies as having habitats that should be specifically protected. HUC12 subwatersheds with designated trout fishery, Extraordinary Resource Water, Ecologically Sensitive Water, or critical habitat for a threatened or endangered species, were assigned a score of 1. All other HUC12 subwatersheds were assigned a score of 0 for this ranking information.

The Nature Conservancy has prepared a map of groundwater quality vulnerability in northern Arkansas based on the results of the model DRASTIK. A copy of this map was presented in Inlander, Gallipeau and Slay (2011). Ranking scores were assigned to the HUC12 subwatersheds based on the groundwater vulnerability map in Inlander, Gallipeau and Slay

(2011). GIS mapping was used to overlay the HUC12 subwatershed boundaries on the groundwater vulnerability map. Those HUC12 subwatersheds where DRASTIK model results indicated medium-high or greater vulnerability in 50% or more of the subwatershed (based on professional judgement) were assigned a score of 1, and all others were assigned a score of 0.

As noted above, not all of the data types used in ranking the HUC12 subwatersheds of the Middle White River watershed, are available for all of the HUC12 subwatersheds. The data types used for ranking that covered the entire Middle White River watershed were: 1) the NRCS Natural Resource Concerns assessment; 2) estimated yields of sediment, total nitrogen, and total phosphorus (based on land use); and 3) modeling of groundwater quality vulnerability. Ranking scores for just these data are shown on Figure 3.35. The HUC12 subwatersheds with the six highest total scores from just these data include Hicks Creek and Greenbrier Creek, as well as Miller Creek, Lower Salado Creek, Spring Creek, and Big Creek-White River. These HUC12 subwatersheds had the most Natural Resource Concern scores and estimated yields in the upper 25<sup>th</sup> percentile. In addition, for all of these HUC12 subwatersheds except Spring Creek, 50% or more of the subwatershed area was classified with medium-high or greater vulnerability to groundwater contamination.

Among the HUC12 subwatersheds with water quality monitoring locations, and aquatic community and aquatic habitat survey locations, the ones with the highest total ranking scores, based on just these data, are Hicks Creek and Greenbrier Creek. The Outlet of South Sylamore Creek subwatershed has the third highest total score (Figure 3.36).

### **3.9.2 Recommended HUC12 Subwatersheds**

Table 3.21 shows a summary of the scores for each type of information used to rank the HUC12 subwatersheds of the Middle White River watershed, and the totals of the scores for each HUC12 subwatershed. When all of the ranking scores for each HUC12 subwatershed are added together, Hicks Creek has the highest total score, followed by Greenbrier Creek, Lower Salado Creek and Miller Creek, and Spring Creek. There are also nine HUC12 subwatersheds where the total score is zero. Because not all HUC12 subwatersheds have scores (i.e., data) for all of the information categories, the percentage of scores equal to 1 is also shown in Table 3.22.

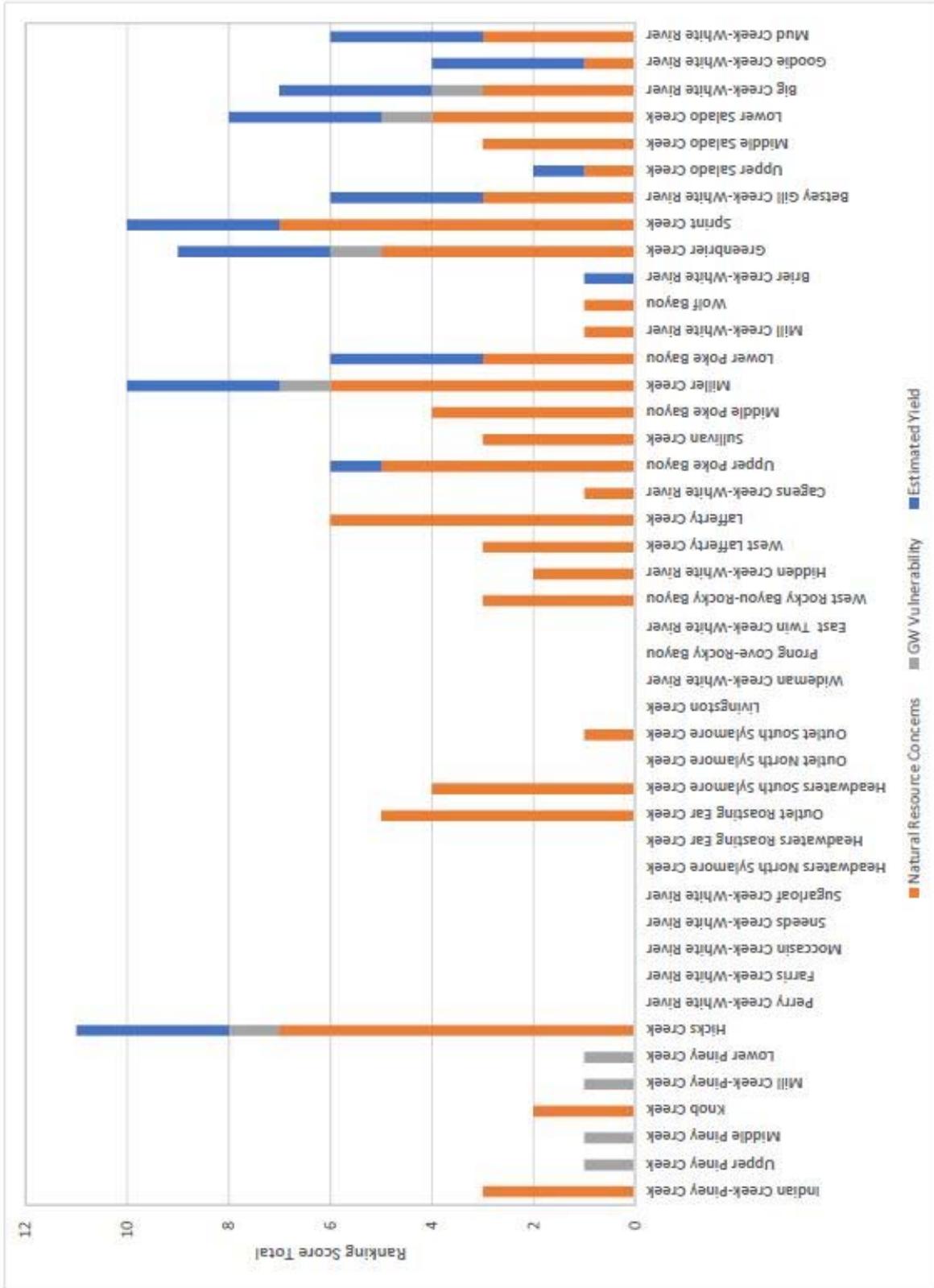


Figure 3.35. Graph of HUC12 subwatershed ranking scores for data types available for entire Middle White River watershed.

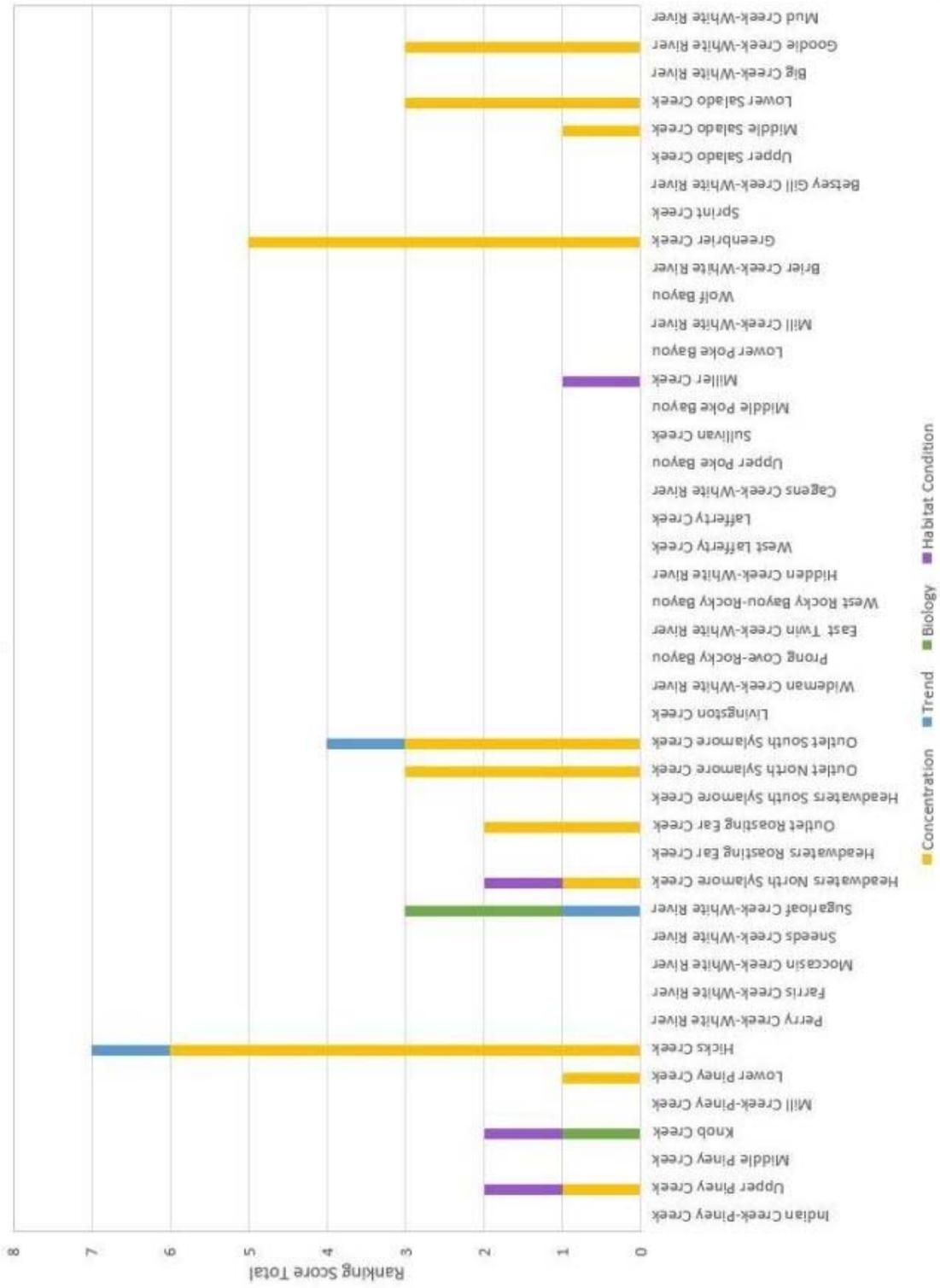


Figure 3.36 Graph of HUC12 subwatershed ranking scores for data types not available for entire Middle White River watershed.

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed.

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040101	Indian Creek-Piney Creek	3	ND	ND	0	ND	ND	0	0	3	21%
110100040102	Upper Piney Creek	0	1	ND	0	1	0	1	0	3	14%
110100040103	Middle Piney Creek	0	ND	ND	0	ND	ND	1	0	1	7%
110100040104	Knob Creek	2	ND	ND	0	1	1	0	0	4	24%
110100040105	Mill Creek-Piney Creek	0	ND	ND	0	ND	ND	1	0	1	7%
110100040106	Lower Piney Creek	0	1	ND	0	0	0	1	0	2	10%
110100040201	Hicks Creek	7	6	1	3	ND	ND	1	0	18	86%
110100040202	Perry Creek-White River	0	ND	ND	0	ND	0	0	1	1	7%
110100040203	Farris Creek-White River	0	0	ND	0	ND	0	0	1	1	5%
110100040204	Moccasin Creek-White River	0	ND	ND	0	ND	ND	0	0	0	0%
110100040205	Sneeds Creek-White River	0	ND	ND	0	ND	0	0	1	1	7%
110100040206	Sugarloaf Creek-White River	0	0	1	0	0	2	0	1	4	18%
110100040301	Headwaters North Sylamore Creek	0	1	ND	0	1	0	0	1	3	14%
110100040302	Headwaters Roasting Ear Creek	0	ND	ND	0	ND	ND	0	1	1	7%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040303	Outlet Roasting Ear Creek	5	2	ND	0	ND	0	0	1	8	38%
110100040304	Headwaters South Sylamore Creek	4	ND	ND	0	ND	ND	0	0	4	29%
110100040305	Outlet North Sylamore Creek	0	3	ND	0	0	0	0	1	4	18%
110100040306	Outlet South Sylamore Creek	1	3	1	0	0	0	0	0	5	22%
110100040401	Livingston Creek	0	0	ND	0	ND	ND	0	0	0	0%
110100040402	Wideman Creek-White River	0	0	ND	0	0	ND	0	1	1	5%
110100040403	Prong Cove-Rocky Bayou	0	ND	ND	0	ND	ND	0	0	0	0%
110100040404	East Twin Creek-White River	0	ND	ND	0	ND	ND	0	1	1	7%
110100040405	West Rocky Bayou-Rocky Bayou	3	ND	ND	0	ND	ND	0	0	3	21%
110100040406	Hidden Creek-White River	2	ND	ND	0	ND	0	0	1	3	20%
110100040407	West Lafferty Creek	3	ND	ND	0	ND	0	0	0	3	20%
110100040408	Lafferty Creek	6	ND	ND	0	ND	ND	0	0	6	43%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
1110100040409	Cagens Creek-White River	1	ND	ND	0	ND	ND	0	1	2	14%
1110100040501	Upper Poke Bayou	5	ND	ND	1	ND	ND	0	0	6	43%
1110100040502	Sullivan Creek	3	ND	ND	0	ND	0	0	0	3	21%
1110100040503	Middle Poke Bayou	4	ND	ND	0	ND	0	0	0	4	27%
1110100040504	Miller Creek	6	ND	ND	3	1	0	1	0	11	69%
1110100040505	Lower Poke Bayou	3	ND	ND	3	ND	0	0	0	6	43%
1110100040601	Mill Creek-White River	1	ND	ND	0	ND	0	0	0	1	7%
1110100040602	Wolf Bayou	1	0	ND	0	ND	0	0	0	1	5%
1110100040603	Brier Creek-White River	0	ND	ND	2	ND	0	0	0	1	7%
1110100040604	Greenbrier Creek	5	5	ND	3	ND	ND	1	0	14	70%
1110100040605	Spring Creek	7	ND	ND	3	ND	ND	0	0	10	71%
1110100040606	Betsy Gill Creek-White River	3	ND	ND	3	ND	ND	0	1	7	50%
1110100040701	Upper Salado Creek	1	0	ND	0	0	0	0	1	3	14%
1110100040702	Middle Salado Creek	3	1	ND	0	ND	ND	0	1	5	25%
1110100040703	Lower Salado Creek	4	3	ND	3	ND	0	1	1	12	57%
1110100040704	Big Creek-White River	3	ND	ND	3	ND	ND	1	1	8	57%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040705	Goodie Creek-White River	1	3	ND	3	ND	ND	0	1	8	40%
110100040706	Mud Creek-White River	3	ND	ND	3	ND	ND	0	1	7	50%

ND = no data available for this HUC12 subwatershed

The Hicks Creek HUC12 subwatershed also has the highest percentage of scores that are 1, followed by Spring Creek, Greenbrier Creek, Miller Creek, and then Lower Salado Creek. The same HUC12 subwatersheds are the top five in both total scores and percentage of scores equal to 1, although there is some variation in the order of the top five spots. The fact that the HUC12 subwatersheds with streams on the state list of impaired waterbodies have the highest-ranking scores, indicates that the ranking approach used is appropriate for identifying subwatersheds with water quality issues.

The five HUC12 subwatersheds recommended for nonpoint source pollution management through this current watershed are listed below and mapped on Figure 3.37:

- Hicks Creek (HUC ID number 110100040201);
- Greenbrier Creek (HUC ID number 110100040604);
- Miller Creek (HUC ID number 110100040504);
- Spring Creek (HUC ID number 110100040605); and
- Lower Salado Creek (HUC ID number 110100040703).

### **3.9.3 Management of Other HUC12 Subwatersheds**

There are five HUC12 subwatersheds specifically recommended for management through this watershed management plan. As can be seen in Table 3.22, these are not the only subwatersheds with potential water quality or biological issues. This plan is not intended to restrict management activities in areas outside of the recommended subwatersheds. There is value in management of water quality issues anywhere in the Middle White River watershed.

### **3.10 Stakeholder Concerns**

On May 31, 2018, ANRC sponsored a stakeholder meeting as part of development of this watershed management plan. At this meeting, stakeholders were asked to identify issues and concerns about activities occurring in the Middle White River watershed. The emphasis was on water quality issues, but stakeholders were free to identify other issues. Table 3.23 is a list of the water quality issues identified by stakeholders for this watershed management plan.

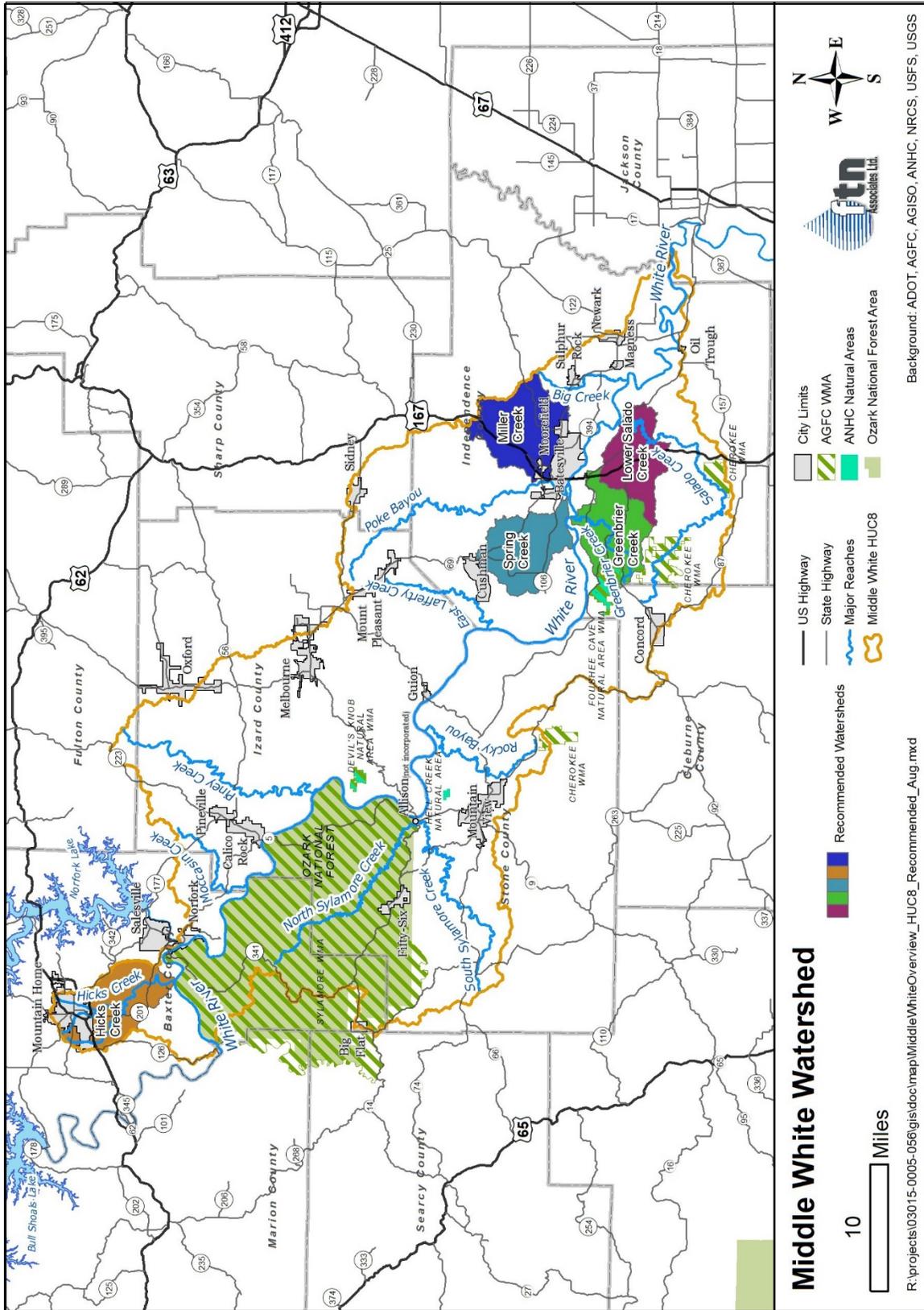


Figure 3.37. Middle White River HUC12 subwatersheds recommended for initial nonpoint source pollution management.

Table 3.23. Water quality issues in the Middle White River watershed identified at stakeholder meeting.

Legal/illegal gravel mining	Cattle in streams
Protecting public water supply and source water areas	Need to upgrade wastewater facilities throughout the watershed
Destruction of riparian areas	Pesticide spraying in ditches by county
Protecting karst areas from nutrients, bacteria leaching from soils above	Tourism and recreation major part of the economy and dependent on good water quality
Failed septic systems	Erosion from croplands
Overgrazing of pastures and erosion	Erosion from dirt and gravel roads
Clear cutting and other forest management practices affect stream water quality	

In 2005, a Watershed Restoration Action Strategy was prepared for the watershed of the White River from Bull Shoals Dam to the Independence County line (Friends of the North Fork and White Rivers, Inc. 2007). Issues and concerns identified during public meetings associated with the Watershed Restoration Action Strategy are listed in Table 3.24.

Table 3.24. Issues identified in Watershed Restoration Action Strategy (Friends of the North Fork and White Rivers, Inc. 2007).

Water Quality	Habitat Quality	Recreation, aesthetics, general	Regulatory Issues
<ul style="list-style-type: none"> <li>• Elevated nutrients in rivers</li> <li>• Septic systems</li> <li>• Livestock and poultry waste</li> <li>• Poor water well placement</li> <li>• Contamination of fish, wildlife, and humans</li> <li>• Toxic spills</li> <li>• Wastewater discharges</li> <li>• Overuse of fertilizers, pesticides, and other chemicals</li> <li>• Instream flow, stream minimum flow</li> <li>• Sediment and erosion</li> <li>• Unregulated development with substandard road and drainage</li> <li>• Instream gravel mining</li> <li>• Mining of sod, dirt or stone near rivers</li> </ul>	<ul style="list-style-type: none"> <li>• Destruction of riparian buffers</li> <li>• Loss of undeveloped area</li> <li>• Reduction of habitat due to development</li> <li>• Forest health and maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Need for walk-in fishing access</li> <li>• Lack of watercraft horsepower limits</li> <li>• Lack of watercraft speed limits</li> <li>• Public apathy</li> <li>• Loss of aesthetics, need to preserve natural beauty</li> <li>• Trash dumping</li> </ul>	<ul style="list-style-type: none"> <li>• Perceived lack of enforcement of existing regulations</li> </ul>

## 4.0 MANAGEMENT PLAN

### 4.1 Management Concerns for Recommended Subwatersheds

#### 4.1.1 Hicks Creek HUC12 Subwatershed

Natural Resource Concern scores for this subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, excess sediment, streambank erosion, concentrated flow erosion, and sheet, rill, and wind erosion. Hicks Creek is on the state list of impaired waterbodies due to high measurements of *E. coli* (ADEQ 2017, 2018a), which is expected to be addressed through management of regulated point and nonpoint sources. Median concentrations of turbidity, TSS, and nutrients for 2013-2017 at Hicks Creek water quality stations are in the upper 25th percentile, and the median concentration of DO for 2013-2017 at one Hicks Creek water quality station is in the lowest 25th percentile. Median nutrient concentrations for 2013-2017 at the water quality station closest to the subwatershed outlet on Big Creek are also in the upper 25th percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed. In addition, water quality trends that suggest declining water quality were identified at a monitoring station on Hicks Creek. Groundwater quality is also considered to be vulnerable in areas of this subwatershed.

Based on available water quality data, and ADEQ water quality assessments, the high *E. coli* levels that have resulted in Hicks Creek being on the state list of impaired waters, are from the Mountain Home WWTP and runoff from developed areas in and around Mountain Home. It is expected that this impairment will be addressed by regulation of the point and nonpoint sources through the state National Pollutant Discharge Elimination System (NPDES) program. It is possible that storm runoff from Mountain Home will be regulated under the NPDES stormwater program starting in 2019. Because Mountain Home is classified by the US Census Bureau as an “urbanized cluster”, and stormwater runoff from Mountain Home enters an impaired waterbody (Hicks Creek), Mountain Home may be required by ADEQ to obtain an NPDES municipal stormwater discharge permit. If this occurs, nonpoint sources in the Hicks Creek subwatershed within the delineated permit area will become regulated nonpoint sources. Therefore, nonpoint sources of *E. coli* in the Hicks Creek subwatershed will not be addressed in

this plan. High nutrient and sediment concentrations in Hicks Creek can be reduced along with *E. coli* levels through management of regulated point and nonpoint sources.

The relatively high nutrient concentrations in lower Big Creek are likely at least partly the result of the influence of the Mountain Home WWTP, a regulated point source. However, there are unregulated nonpoint sources of nutrients in the areas of the Hicks Creek subwatershed that do not drain to Hicks Creek. Therefore, the suggested focus for nonpoint source pollution management in this subwatershed includes maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams and groundwater.

#### **4.1.2 Greenbrier Creek HUC12 Subwatershed**

Natural Resource Concern scores for the Greenbrier Creek subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, heavy metals, and pesticides. Median concentrations of turbidity, TSS, total phosphorus, and total nitrogen for the period 2013-2017 are in the upper 25th percentile for the watershed, and the median concentration of DO for 2013-2017 is in the lowest 25th percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed.

Greenbrier Creek is on the state list of impaired waterbodies because it was assessed in 2004 using the DO criteria for Boston Mountain perennial streams with watersheds larger than 10 sq mi, 6 mg/L. Since then, ADEQ has determined that DO criteria for Delta least-altered streams with watersheds 10 to 100 sq mi (5 mg/L for primary season and 3 mg/L for critical season) are more appropriate for Greenbrier Creek at the ADEQ water quality monitoring location (station WHI0167). The DO measurements that have been collected appear to indicate Greenbrier Creek is meeting the Delta least-altered stream DO criteria. However, ADEQ has not been able to collect enough critical season DO measurements to officially assess it since the change in evaluation method (J Wise, ADEQ, personal communication 12/10/18).

A comparison of nutrient concentrations collected since 2001 at station WHI0167 indicated that nitrogen inputs to Greenbrier Creek have declined. In addition, DO concentrations may have increased (see Section 3.2). This suggests that there may be a relationship between

nitrogen concentrations and DO. Linear regression analysis of DO to nutrient concentrations found a statistically significant negative correlation between TKN and DO concentrations (Appendix E).

The recommended focus for the Greenbrier Creek subwatershed is delisting Greenbrier Creek as an impaired waterbody, while maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to the stream and groundwater.

#### **4.1.3 Miller Creek HUC12 Subwatershed**

Natural Resource Concern scores for the Miller Creek subwatershed in the upper 25<sup>th</sup> percentile for the Middle White River watershed were excess nutrients, excess sediment, pathogens, pesticides, streambank erosion, and rill, sheet, and wind erosion. Estimated yields of sediment, total phosphorus, and total nitrogen were all in the upper 25<sup>th</sup> percentile for the watershed. A 2008 EPA habitat survey of Gravel Creek in this subwatershed classified riparian vegetation as poor. Groundwater quality is also vulnerable in this subwatershed. No water quality data were found from the Miller Creek subwatershed.

The recommended focus in the Miller Creek subwatershed is water quality monitoring to determine if water quality is meeting standards, and maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams and groundwater.

#### **4.1.4 Spring Creek HUC12 Subwatershed**

Natural Resource Concern scores for the Spring Creek subwatershed in the upper 25<sup>th</sup> percentile for the Middle White River watershed were excess nutrients, excess sediment, pathogens, pesticides, concentrated flow erosion, streambank erosion, and rill, sheet, and wind erosion. Estimated yields of sediment, total phosphorus, and total nitrogen were all in the upper 25<sup>th</sup> percentile for the watershed. No water quality data were found from the Spring Creek subwatershed.

The recommended focus in the Spring Creek subwatershed is water quality monitoring to determine if water quality is meeting standards, and maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams.

#### **4.1.5 Lower Salado Creek HUC12 Subwatershed**

Natural Resource Concern scores for the Lower Salado Creek subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, petroleum and heavy metals, and pesticides. Median concentrations of turbidity and TSS for the period 2013-2017 are in the upper 25<sup>th</sup> percentile for the watershed, and the median concentration of DO for 2013-2017 is in the lowest 25<sup>th</sup> percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed. Salado Creek is designated an Extraordinary Resource Water[body] of the Boston Mountains ecoregion (Arkansas Pollution Control and Ecology Commission 2014). The Salado Creek fish community in this subwatershed has been characterized as being good, i.e., generally similar to communities in Boston Mountain ecoregion reference streams.

The majority of the Lower Salado Creek subwatershed is relatively flat, and much of the stream has a low gradient, more like streams of the Delta region than the reaches of Salado Creek in the Upper and Middle Salado Creek HUC12 subwatersheds. Therefore, ADEQ has changed the DO evaluation criteria for Salado Creek station WHI0166 to those for Least-altered Delta streams with watersheds greater than 100 sq mi (5 mg/L for both primary and critical season). A number of DO measurements from station WHI0166 on Salado Creek are below the applicable Least-altered Delta Stream DO water quality criterion of 5 mg/L. However, there are not enough measurements for ADEQ to assess whether this reach of Salado Creek meets the DO criterion.

DO saturation percentages were calculated for the samples from station WHI0166. If the DO levels were not influenced by decomposing organic matter, DO percent saturation values for the sample would be close to 100%. DO percent saturation values ranged from 101% to 41%. When DO concentrations were less than 5 mg/L, DO percent saturation values ranged from 72% to 41%. This suggests that the low DO levels are not solely the result of natural conditions, and

that decomposing organic matter, which could include die-off from algal blooms, is affecting DO levels in Salado Creek at station WHI0166.

A comparison of nutrient concentrations collected since 2001 at station WHI0166 indicated that total phosphorus inputs to lower Salado Creek may have declined, and DO concentrations may have increased (see Section 3.2). This suggests that there may be a relationship between phosphorus concentrations and DO. However, linear regression analysis of DO to nutrient concentrations did not find a statistically significant relationship with total phosphorus. This analysis did find a statistically significant negative correlation between total nitrogen and DO (Appendix E).

The recommended focus for nonpoint source pollution management in the Lower Salado Creek subwatershed is maintaining, improving, or increasing practices that reduce nonpoint source inputs of nitrogen, pathogens, and sediment to the stream and groundwater.

#### **4.2 Management Targets for Recommended Subwatersheds**

Water quality pollutants and parameters targeted for management in this watershed management plan were selected based on water quality impairments in the watershed. The water quality pollutants and parameters targeted for management in this watershed management plan are DO and Nutrients.

DO was selected because the DO concentrations at station WHI0166 on Salado Creek appear to be low relative to other water quality monitoring station in the Middle White River watershed. Nutrients were selected because they were identified as a concern by stakeholders (see Section 3.10), and they may be contributing to the low DO levels in Salado Creek at station WHI0166. Reducing *E. coli* levels in the Hicks Creek subwatershed will be addressed through management of regulated sources, and thus is not being addressed in this watershed management plan.

For this watershed management plan, management targets are developed for only three of the five recommended subwatersheds, Hicks Creek (110100040201), Greenbrier Creek (110100040604), and Lower Salado Creek (110100040703). Because there are no water quality measurements available from the Spring Creek (110100040605) or Miller Creek

(110100040504) subwatersheds, it is not possible to develop reduction targets, or determine if reduction targets are needed. If water quality measurements are collected from these subwatersheds, it will be possible, in the future, to determine if reductions in nonpoint source pollution loads are needed, and develop reduction targets.

#### 4.2.1 Dissolved Oxygen Management Targets

The DO numeric criterion for lower Salado Creek is 5 mg/L during both primary and critical seasons (J. Wise, ADEQ, personal communication, 12/10/18). DO concentrations below this criterion have been measured at the lower Salado Creek water quality monitoring station (WHI0166) during both the critical and the primary season. To be assessed as achieving the DO criterion, ADEQ requires that 90% or more of the DO measurements from primary and critical seasons of the assessment period must be equal to or greater than the criterion. The watershed management plan DO target for lower Salado Creek is that 90% or more of DO measurements at station WHI0166, over a five-year period, data from both seasons combined, are 5 mg/L or greater.

All DO measurements from water quality monitoring stations in the Hicks Creek and Greenbrier Creek subwatersheds during the period 2013-2017 meet the applicable numeric criteria (listed in Table 4.1). The focus for the Hicks Creek and Greenbrier Creek subwatersheds, therefore, is to prevent worsening of water quality. Thus, the management target for DO for Hicks Creek and Greenbrier Creek is that there be zero DO measurements less than the criteria.

Table 4.1. Numeric criteria for DO in recommended subwatersheds (J. Wise, ADEQ, personal communication, 12/10/18; Arkansas Pollution Control and Ecology Commission 2014).

Subwatershed	DO criteria, mg/L	
	Primary season	Critical season
Hicks Creek	6	6
Greenbrier Creek	5	3
Lower Salado Creek	5	5

#### **4.2.2 Nutrient Management Targets**

There are no numeric criteria for nutrients that apply to the Middle White River watershed. Therefore, no management targets are set for nutrients in the recommended subwatersheds for this plan.

For informational purposes, total nitrogen and total phosphorus measurements collected in the Middle White River watershed during the period 2013-2017 were examined. Data from water quality monitoring stations in those subwatersheds not recommended for initial management, but with percentages of pasture and forest land use similar to that in the recommended subwatersheds (i.e., pasture > 20% and/or forest < 75%), were combined and compared to data from water quality stations in the recommended subwatersheds. Box and whisker graphs comparing these data sets are shown on Figures 4.1 and 4.2.

#### **4.3 Load Reduction Targets**

Given the existing levels of pollutants in the recommended HUC12 subwatersheds, and the target levels or loads, we can determine the reduction needed to achieve the target levels. For Hicks Creek and Greenbrier Creek subwatersheds, management targets are already being met, so no reductions are needed.

In the Lower Salado Creek subwatershed, however, it appears that the DO management target is not being met in Salado Creek at station WHI0166. As noted in Section 4.1.5, linear regression analysis identified a statistically significant relationship between DO levels and nitrogen concentrations at Salado Creek water quality station WHI0166. Therefore, it may be possible to improve DO levels in this stream reach by reducing nitrogen inputs. The linear regression relationship is used below to set a nitrogen reduction target associated with DO concentrations that meet water quality standards.

Data from 2013-2017

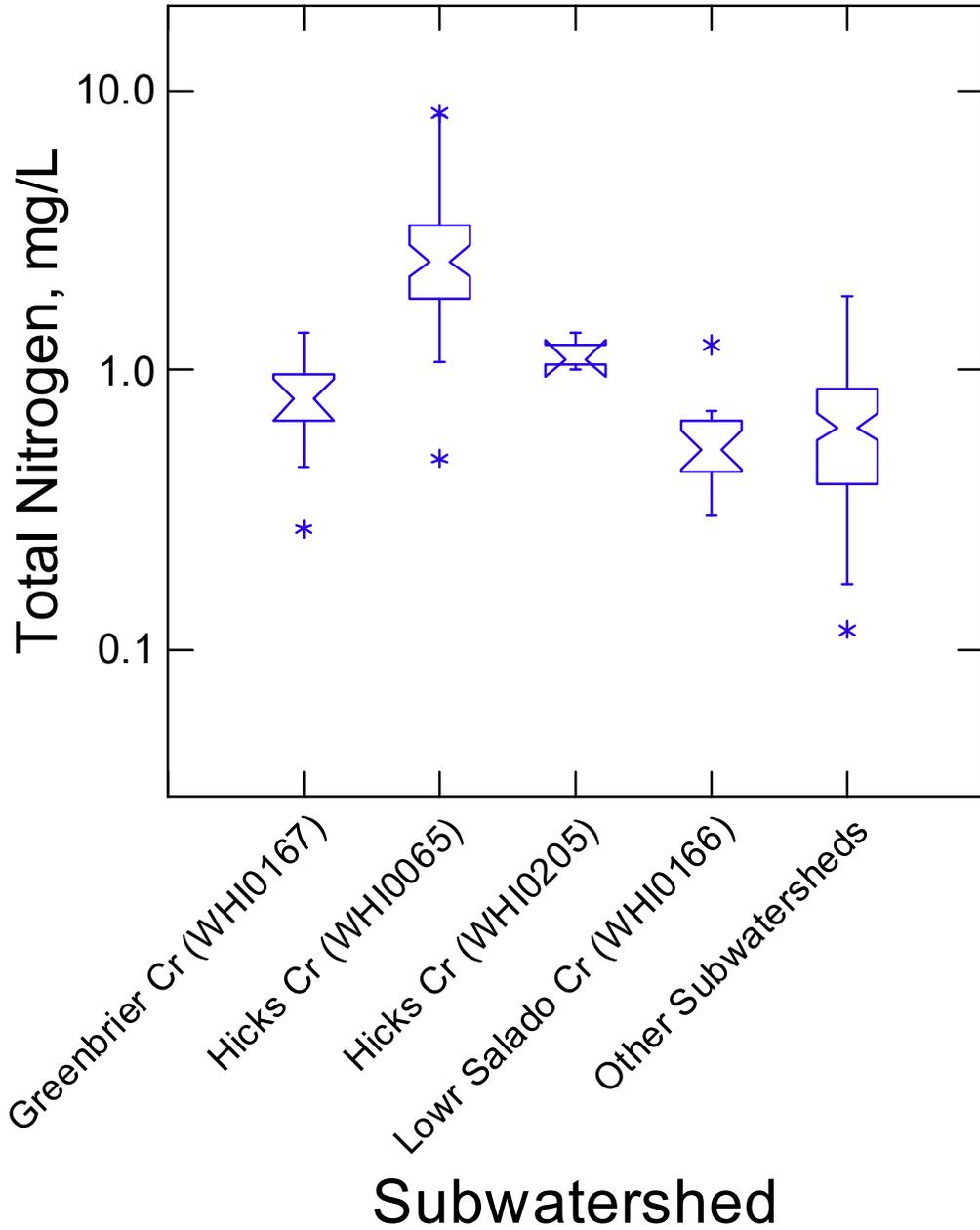


Figure 4.1. Box and whisker graph comparing total nitrogen measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.

## Data from 2013-2017

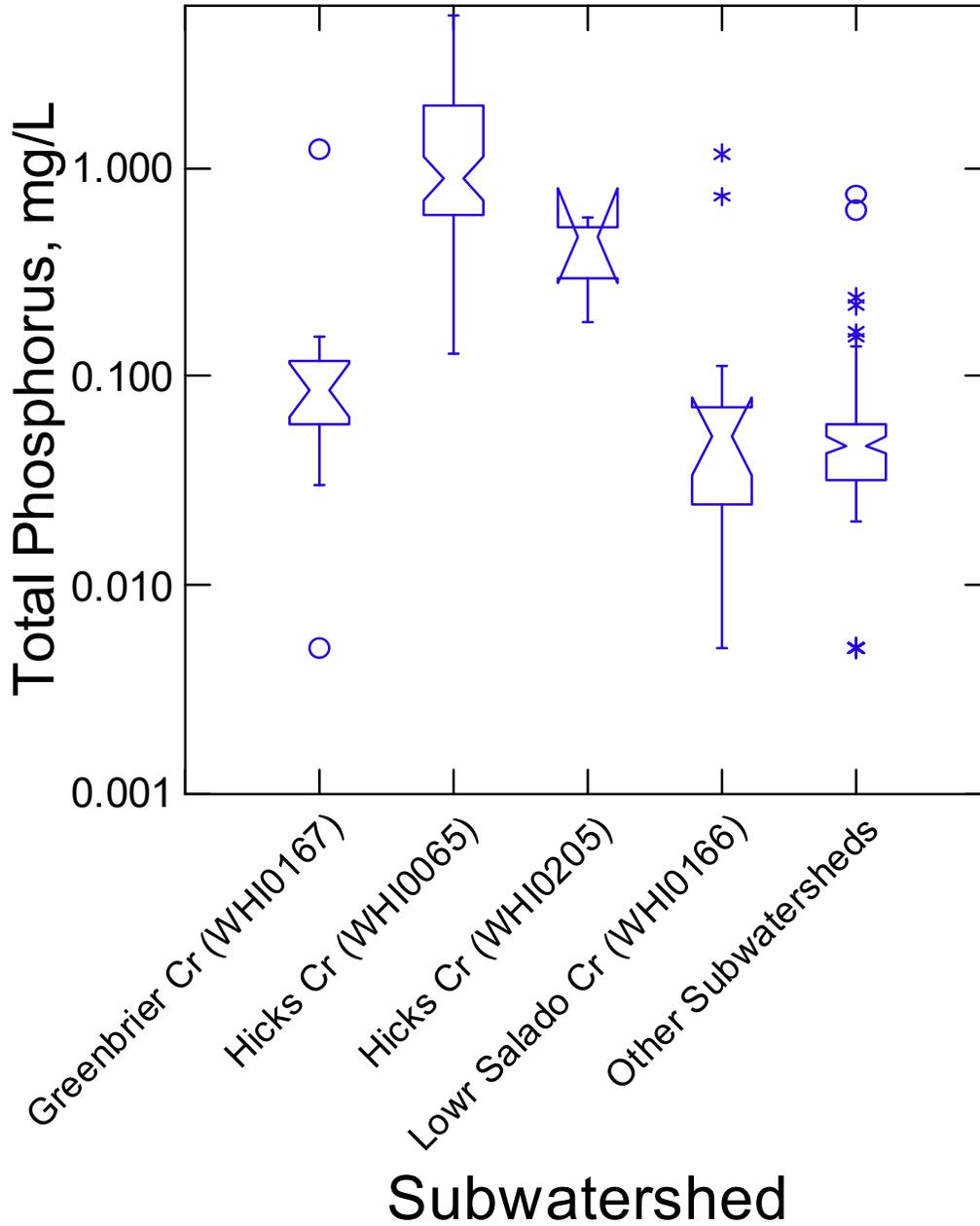


Figure 4.2. Box and whisker graph comparing total phosphorus measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.

At the Lower Salado Creek water quality station, WHI0166, there are 15 DO measurements collected during the period 2013-2017 (Table 4.2). Five of these measurements, i.e., 33%, were less than 5 mg/L. For no more than 10% of the DO measurements from this five-year period to be less than 5 mg/L, only one of the measurements can be less than 5 mg/L, i.e., 6%.

Linear regression analysis identified a statistically significant linear relationship between DO and TKN concentrations at station WHI0166. The equation for this relationship is:  $DO = 4.22 - 3.23 * \ln(TKN)$ . The  $R^2$  value associated with this relationship indicates that variations in TKN concentration account for around 36% of the variation in DO. Note that the linear regression analysis indicates that variation in water temperature accounts for around 62% of the variation in DO.

Table 4.2. DO measurements from station WHI0166 2013-2017.

Date	DO, mg/L
5/14/2013	8.27
8/20/2013	4.40
1/27/2014	12.0
4/8/2014	9.23
6/24/2014	4.26
10/14/2014	3.81
11/18/2014	9.16
2/9/2015	11.9
4/27/2015	7.51
6/29/2015	4.38
8/17/2015	5.89
9/21/2015	8.26
12/28/2015	10.8
3/7/2016	9.53
4/25/2016	6.66

The target reduction for nitrogen is the change in TKN needed to make less than 10% of the 2013-2017 seasonal DO measurements meet the 5 mg/L criterion. Thus, the DO concentration of 4.26 mg/L from 2013-2017 needs to increase to 5.0 mg/L. The linear regression equation for DO and TKN given above was used to calculate TKN concentrations associated with DO concentrations of 4.26 mg/L and 5.0 mg/L. The target reduction for nitrogen was calculated by taking the percent difference of these two calculated TKN values. These calculations are summarized in Table 4.3.

Table 4.3. Calculation of reduction target for nitrogen in lower Salado Creek.

DO mg/L	Estimated TKN mg/L	Percent Difference TKN
4.26	0.99	21%
5.00	0.78	

Note that the data used in the analysis above do not meet ADEQ requirements for evaluation of water quality standards (ADEQ 2018d). As a result, the lower Salado Creek stream reach is not currently included on the Arkansas list of impaired waterbodies (ADEQ 2017, 2018a).

#### 4.4 Nonpoint Pollution Sources to be Targeted for Management

The focus of nonpoint source pollution management in the recommended subwatersheds of the Middle White River watershed is nutrients (total nitrogen and total phosphorus) from developed areas, pasture, and hayland. Table 4.4 lists the recommended subwatersheds and nonpoint pollution sources of the target pollutants known or expected to be present. Focus areas for management include developed areas, and pasture and haylands along streams and on ridge tops. Of particular interest are areas within 50 feet of streams, and areas where karst features are present. Note that this watershed management plan is intended to address only unregulated nonpoint sources. Some nonpoint sources, such as stormwater runoff from urban areas or industrial sites, may be regulated and/or permitted by ADEQ.

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds.

<b>Hicks Creek (110100040201)</b>			
<b>Target Land Use</b>	<b>% of Area</b>	<b>Nonpoint Pollutant Sources</b>	<b>Land Use Map</b>
Developed	23%	Onsite wastewater treatment systems, leaking sewer lines, illicit discharges, pets and wildlife	
Pasture and hayland	28%	Livestock, feral hogs, other wildlife	
Forest	49%	Feral hogs, other wildlife	

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds (continued).

<b>Greenbrier Creek (110100040604)</b>			
<b>Target Land Use</b>	<b>% of Area</b>	<b>Nonpoint Pollutant Sources</b>	<b>Land Use Map</b>
Developed	7%	Fertilizer runoff or seepage, illicit discharges, onsite wastewater treatment systems, pets, wildlife	
Pasture and Hayland	35%	Livestock, feral hogs and other wildlife, manure and fertilizer runoff	
Forest	54%	Feral hogs and other wildlife	

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds (continued).

<b>Lower Salado Creek (110100040703)</b>			
<b>Target Land Use</b>	<b>% of Area</b>	<b>Nonpoint Pollutant Sources</b>	<b>Land Use Map</b>
Developed	8%	Fertilizer runoff or seepage, illicit discharges, onsite wastewater treatment systems, pets, wildlife	
Hay and pasture	38%	Livestock, feral hogs and other wildlife, manure and fertilizer runoff	
Forest	51%	Feral hogs and other wildlife	

#### 4.4.1 On-site Wastewater Treatment Systems

Areas within the three HUC12 subwatersheds recommended for initial management are located within incorporated areas of Mountain Home or Southside, which are served by centralized sewer collection and treatment systems. However, there are residences, subdivisions, campgrounds, and businesses within these subwatersheds that are known or suspected of treating sewage using on-site wastewater treatment systems (e.g., septic systems, small package treatment plants). Some on-site wastewater treatment systems are subject to discharge permitting and monitoring by ADEQ. Most on-site wastewater treatment systems are regulated by the Arkansas Department of Health. In some situations, monitoring of these systems is required (Arkansas State Board of Health 2014). Information on the number of systems permitted by the Arkansas Department of Health present in the recommended subwatersheds is not readily available.

The majority of the land within the recommended HUC12 subwatersheds is classified as being of “very limited suitability” for septic systems (see Table 4.5). Given the karst geology underlying these subwatersheds, it is possible that pollutants discharged to the subsurface, as with septic systems, could find their way into groundwater and surface water.

Table 4.5. Suitability of soils in recommended subwatersheds for septic systems (Center for Advanced Spatial Technologies 2006).

Soils Septic System Suitability	Hicks Creek Subwatershed	Greenbrier Creek Subwatershed	Lower Salado Creek Subwatershed
Slightly limited	22.8%	<1%	2.0%
Moderately limited	<1%	0	0
Limited	23.0%	26.6%	13.4%
Very limited	52.2%	72.5%	83.7%
Not rated	1.5%	<1%	<1%

#### **4.4.2 Illicit Wastewater or Sewage Discharges**

Discharge of untreated wastewater to stormwater collection systems can occur as the result of leaks in wastewater collection pipes, or accidental or purposeful connection of wastewater pipe to storm drains, ditches, or streams. If untreated sewage is entering the storm drains and/or streams within Mountain Home, Southside, or other developments in the Hicks Creek, Greenbrier Creek and Lower Salado Creek subwatersheds, it could be a source of nutrients.

Identification and elimination of illicit discharges is a required part of stormwater pollution prevention plans associated with NPDES municipal storm runoff permits. No active storm runoff NPDES permits were found for municipalities or developments in the recommended subwatersheds (ADEQ 2018e). However, it is possible that runoff from Mountain Home that goes into Hicks Creek, which is listed as impaired, could be regulated under the state municipal storm runoff NPDES general permit in the future.

#### **4.4.3 Pets and Wildlife**

In cities, the waste from pets, if not properly disposed of, can be a significant source of nutrients and pathogens (e.g., *E. coli*) to surface waters (Hobbie, et al. 2017, Northern Virginia Regional Commission 2004). Wildlife associated with developed areas, such as racoons and Canada geese, also contribute nutrients and pathogens to surface waters (Northern Virginia Regional Commission 2004, Pieper 2013). In less developed areas of the recommended subwatersheds, feral hogs may contribute to erosion, nutrient, or pathogen issues. Feral hogs have been reported in Baxter and Independence Counties (Rushing 2012). It was not confirmed if feral hogs have been reported in the recommended subwatersheds.

#### **4.4.4 Fertilizer**

Commercial fertilizer applied to lawns in developed areas can be a significant source of nutrients to surface waters (Hobbie, et al. 2017). The same is true for commercial fertilizers applied to pastures and croplands. Focus areas for management are primarily areas within 50 feet of streams and where karst features are present.

Records from the US Department of Agriculture (USDA) National Agricultural Statistical Service online CropScape application were reviewed to determine the types of crops planted in the two subwatersheds recommended for initial nonpoint source management where crops are grown, Greenbrier Creek and Lower Salado Creek (<https://nassgeodata.gmu.edu/CropScape/>). These records indicate that, in the Greenbrier Creek subwatershed, cropland upstream of the water quality monitoring station (WHI0167) has primarily been planted with soybeans. Since soybeans are not usually fertilized with nitrogen, cropland in the Greenbrier Creek subwatershed is assumed to not be contributing to the nitrogen load. These records indicate that the majority of the cropland in the Lower Salado Creek subwatershed is also planted in soybeans each year. Other crops planted in this subwatershed appear to be planted in rotation with soybeans, so we assume that fertilizer use on these crops is low, and not a significant contribution to nitrogen load.

#### **4.4.5 Livestock and Manure**

Livestock using pastures are sources of nutrients that can enter surface water and groundwater in the recommended subwatersheds (Justus, et al. 2010). Focus areas for management include pasture and haylands along streams and on ridge tops, particularly areas within 50 feet of streams and where karst features are present.

Cattle production has been increasing in Independence County (including Greenbrier Creek and Lower Salado Creek subwatersheds) since 1982, while remaining fairly steady in Baxter County (Hicks Creek subwatershed) (see Figure 4.3). Cattle wastes deposited in or beside streams can provide nutrients and pathogens to streams (e.g., cows loitering in streams). James et al. (2007) found that pastured cattle deposited significantly more manure in and near streams than in other areas of the pasture. Studies have shown that, unless access to streams is restricted, cattle generally spend much of the day in the riparian area, no matter the season, or the availability of other water sources (Zuo and Miller-Goodman 2004, Bagshaw, et al. 2008).

Manure from animal production facilities is a potential source of nutrients in the recommended subwatersheds. Based on 2017 aerial imagery, it appears there may be active confined animal production facilities operating in the recommended subwatersheds (ADEQ

2018f). Poultry production has been increasing in Independence County since 1982, while declining and remaining steady since 2002 in Baxter County (see Figure 4.4). The most common method of disposing of manure from confined animal operations in northern Arkansas is spreading it on pastures. Stockpiles of manure from poultry houses and other confined animal operations are another potential source of nutrients to surface water and groundwater.

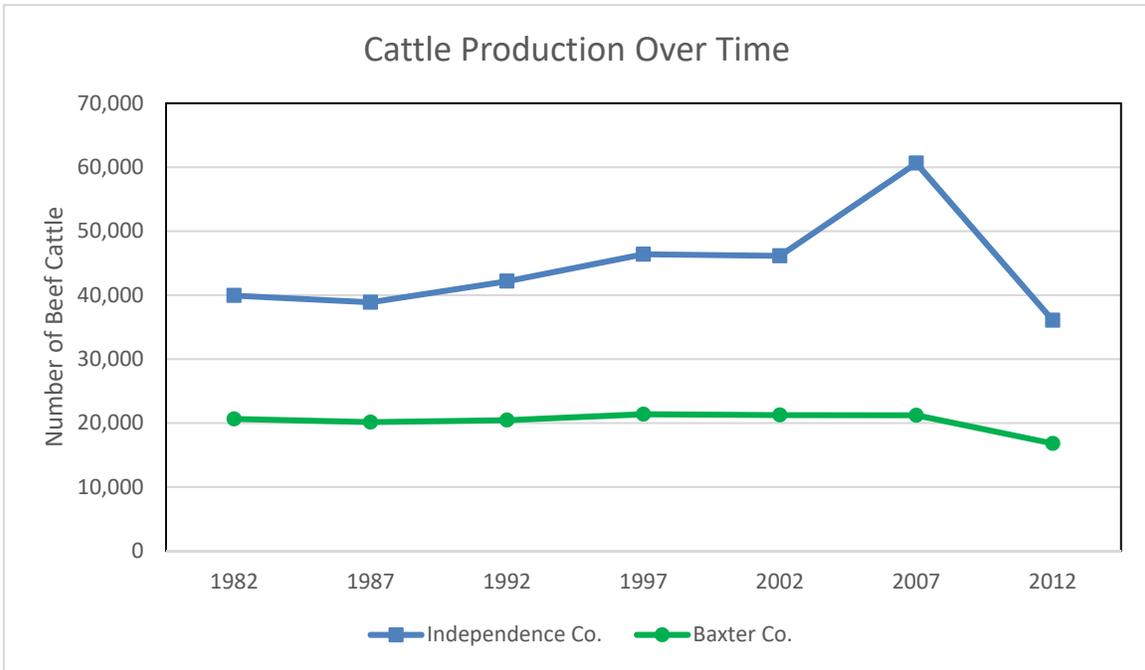


Figure 4.3. Beef cattle reported in Baxter and Independence Counties since 1982 (USDA National Agricultural Statistics Service 2018). The lower cattle production numbers reported for 2012 are likely a result of severe drought conditions in Arkansas that year (Kemper, et al. 2012).

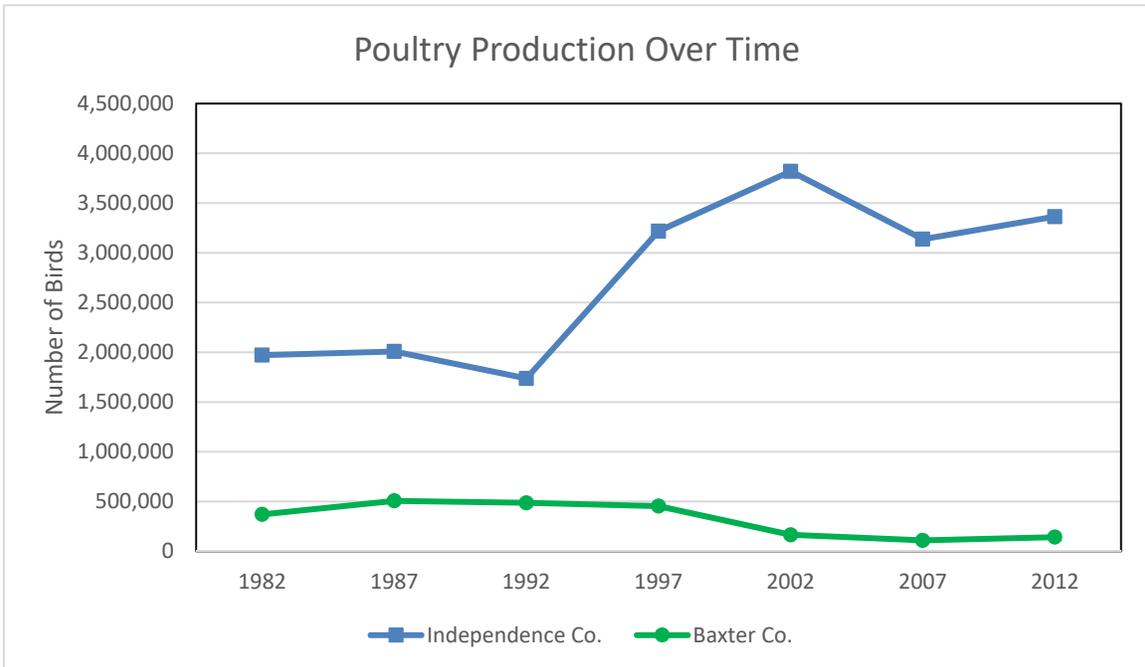


Figure 4.4. Poultry numbers reported for Baxter and Independence Counties since 1982 (USDA National Agricultural Statistics Service 2018).

#### 4.5 Management Practices

At the second public meeting for this watershed management plan, stakeholders were asked to identify management practices to address issues in the Middle White River watershed. Table 4.6 lists the practices identified at the meeting. Those practices identified by stakeholders that are applicable to the target pollutant and nonpoint sources in the recommended subwatersheds are highlighted in yellow.

Table 4.6. Management practices for the Middle White River watershed recommended by stakeholders (yellow highlighted practices are applicable to plan target pollutant and sources).

Nutrient Management Plans	Integrated Pest Management plans
Restrict development along White River	Rotational grazing, flash grazing, pasture management
Stream fencing	Voluntary septic system inspections & repair
Arkansas Unpaved Roads Program	Streambank restoration
Livestock exclusion/restricted access to streams	Arkansas Forestry Commission Forestry recommended practices
Rosgen channel training and low water crossings recommendations	Pasture improvement
Erosion control practices	Woodland restoration with prescribed burning
Greenbelt buffers	Unpaved road management practices & training

ANRC and its partners have implemented nonpoint source pollution management projects in the past that included the recommended subwatersheds. Table 4.7 summarizes the projects in the Middle White River watershed since 2000. Project 16-200 is on-going. In addition to the projects listed in Table 4.7, the Arkansas NRCS annual reports show that farmers in all of the counties of the Middle White River watershed have been implementing management practices through the NRCS Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), e.g., (NRCS 2017a).

There are two approaches for managing nonpoint source pollution inputs. One is to reduce the sources of the pollutant that end up in runoff. The second is to treat runoff to reduce pollutant load.

Table 4.7. Examples of nonpoint source management practices implemented in the recommended Middle White River watershed since 2000.

Project ID & Name (Lead)	Location	Practice	Extent	Status	Pollutant Reduction
02-162	Stone County	Pasture Aerator	NA	Completed 2003	No information
04-106 Marion County 2004 Mini Grant Project (Crooked Creek Conservation District)	Marion County	No-till Drill	NA	Completed 2005	1,339 lb/yr N 699 lb/yr P 873 lb/yr sediment <sup>1</sup>
		Farm Plans	100		
		Brush Management Fence	5,100 ac 42,892 ft		
05-500 Middle White River – South Izard County (Izard County Conservation District)	MWR watershed south Izard County	Pasture & Hay Planting	250 ac	Completed 2008	13,072 lb/yr N 6,531 lb/yr P 7,876 lb/yr sediment <sup>1</sup> 32,084 tons soil <sup>2</sup>
		Pest Management	7,042 ac		
		Prescribed Grazing	7,065 ac		
		Nutrient Management	7,065 ac		
		Cross Fence	129,007 ft		
06-800 Middle White River Watershed (Stone County Conservation District)	MWR watershed Stone County	Pasture & Hay Planting	762 ac	Completed 2008	449 lb/yr N 224 lb/yr P 236 lb/yr sediment <sup>3</sup>
		Water Facilities	10		
		Pipeline	12,665 ft		
		Brush Management	552 ac		
		Spring Development	5		
		Critical Area Planting	6 ac		
		Brush Management			
16-200 Hicks Creek – White River Watershed Project (Baxter County Conservation District)	Hicks Cr, Perry Cr-White R, Farris Cr-White R, Moccasin Cr-White R, Sneeds Cr-White R, and Sugarloaf Cr-White R in Baxter County	Fence		In progress, expect completion 2020	19,225 lb/yr N 9,609 lb/yr P 7,440 ton/yr sediment <sup>4</sup>
		Pasture Establishment			
		Livestock Pipeline			
		Heavy Use Areas			
		Watering Facilities			
		Spring Development			
		Pond			
		Equipment to Rent	NA		
		Farm Plans	60		

<sup>1</sup> (ANRC, 2007)  
<sup>2</sup> (Izard County Conservation District, 2008)  
<sup>3</sup> (ANRC, 2010)  
<sup>4</sup> (ANRC, 2017)

Developed, residential, and agricultural land uses are present in the recommended subwatersheds and have potential nonpoint sources of nutrients associated with them. Below, management practices appropriate to the unregulated nonpoint sources of nitrogen associated with these land uses in the recommended subwatersheds are discussed separately

#### **4.5.1 Developed and Residential Areas**

In this watershed management plan, nonpoint sources of nutrients associated with developed and residential areas in within the incorporated areas of Mountain Home in the Hicks Creek subwatershed are assumed to be regulated, as it is likely that Mountain Home stormwater runoff will be regulated under an NPDES permit in the near future.

Possible nutrient sources associated with developed and residential areas in the Greenbrier Creek and Lower Salado Creek subwatersheds that could be reduced include commercial fertilizer, leaking septic systems or sewage collection systems, and pet waste. Homeowners and lawn care companies can reduce the amount of fertilizer that gets into runoff from lawns by applying fertilizers only during the growing season, not over-applying fertilizer, and not applying fertilizer immediately before or after heavy rainfall (Patton 2008). Pet waste can be picked up and disposed of so that it does not get into runoff.

Much of the developed area in the Greenbrier Creek and Lower Salado Creek subwatersheds is served by a “low pressure” sewage collection system installed around 2008 (Southside Public Water Authority 2018, ADEQ 2018e). New construction within the service area for this system is required to connect to the system (Southside Public Water Authority 2018). Being relatively new, leakage from this system is less likely to be a source of nutrients in these subwatersheds. Conversion from on-site wastewater treatment to the centralized wastewater treatment system may be at least part of the reason behind the declines in median TKN and total nitrogen concentrations at the Greenbrier Creek and lower Salado Creek water quality monitoring stations between the periods 2001-2003 and 2013-2016 (see Section 3.2).

There are stormwater management practices for residential and urban areas that can passively treat storm runoff to reduce nutrients. A recent review of stormwater best management practices (BMPs) commonly used and studied in urban areas found that the following practices

often resulted in statistically significant reductions in nitrogen concentrations in runoff; grass strip, media filter, porous pavement, retention pond, and wetland basin or channel (Clary, et al. 2017). Riparian buffers (i.e., greenbelt buffers suggested by stakeholders) are also a recommended practice to improve water quality in residential areas (Barry n.d.). Riparian buffers have been shown to reduce total nitrogen inputs to streams (Klapproth and Johnson 2009, Merriman, Gitau and Chaubey 2009).

#### **4.5.2 Pasture and Hayland**

Through its Conservation Practice Physical Effects program (CPPE), the NRCS determined that the following management practices not already identified by stakeholders (Table 4.6) are also effective for reducing nutrient inputs to both surface water and groundwater from pasture: silvopasture establishment, karst sinkhole treatment, conservation cover, vegetated treatment area, agrichemical handling facility, manure storage, feral hog management, filter strip, and livestock shelter structure (NRCS 2017b).

Possible agricultural nutrient sources associated with pasture and haylands in the recommended subwatersheds that could be reduced include commercial fertilizer, use of manure from confined animal operations as fertilizer, feral hogs, and livestock in streams. Agricultural users of commercial fertilizers often have a nutrient management plan, and usually have a monetary incentive to apply commercial fertilizer when it is least likely to runoff, because of the cost of the fertilizer. Nutrient management plans (recommended by stakeholders) and associated practices can help farmers apply commercial fertilizer so the amount in runoff and groundwater is minimized. Agrichemical handling facilities reduce the exposure of stored fertilizers to rain and keep it out of runoff and groundwater.

There are practices that can reduce animal manure sources of nutrients in runoff. Feral hogs are present in forest and on agricultural lands throughout Arkansas, and are the focus of active efforts to control their population, including large-scale eradication efforts (Arkansas Cooperative Extension Service 2018, Arkansas Agriculture Department 2018). Reducing feral hogs reduces their manure as a nutrient source.

Eliminating or reducing livestock access to streams associated with pastures (recommended by stakeholders) can reduce inputs of livestock waste directly into the streams. Practices such as alternative water sources, livestock shelter structures, and flash grazing of riparian areas (recommended by stakeholders) can reduce the time livestock spend in pasture streams and reduce inputs of livestock waste into the streams. Rotational and prescribed grazing (recommended by stakeholders) reduces runoff of nutrients from livestock waste on pastures. Waste storage facilities reduce exposure of waste from confined animal production operations to rainfall to keep it out of runoff. Nutrient management plans (recommended by stakeholders) and associated practices can help farmers apply manure from confined animal operations to pastures so the amount that gets into runoff and groundwater is minimized.

Management practices that can reduce nutrients in runoff from pasture and haylands include riparian buffer – forested or herbaceous (suggested by stakeholders), pasture improvement or establishment (recommended by stakeholders), silvopasture establishment, conservation cover, and vegetated treatment area. When these practices are used around sinkholes, they can reduce nutrient inputs to groundwater. In state aerial imagery from 2017 (available on ADEQ EnviroView and AquaView), it appears that trees are present along many of the bigger streams through pastures in the Greenbrier Creek and Lower Salado Creek subwatersheds (ADEQ 2018f). Where forested riparian buffers are not present, they can be added.

#### **4.6 Meeting Reduction Goals**

This section explores whether it is possible to achieve the 21% nitrogen reduction goal for the Lower Salado Creek subwatershed, using the management practices identified in Section 4.5. Information on the effectiveness in reducing selected pollutants in surface waters has been published for a number of the management practices identified in the previous section. This information is summarized in Table 4.8. Table 4.8 shows reported reduction percentages for TKN, total nitrogen, total phosphorus, sediment, fecal coliforms, and *E. coli*. This shows that, while the focus of management in this plan is nitrogen, practices that reduce this pollutant also reduce other pollutants that are a concern in the recommended subwatersheds.

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice.

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	<i>E. coli</i> reduction
Repair of failing on-site wastewater treatment systems and/or leaking wastewater collection systems, and removal of illicit discharges to stormwater systems	100% from this source	100% from this source	100% from this source	Not applicable	100% from this source	100% from this source
Pick up and properly dispose of pet waste	100% from this source	100% from this source	100% from this source	Not applicable	100% from this source	100% from this source
Media filters for stormwater	-4,900% to 95%, median 39% <sup>a</sup>	17-71%, median 32% <sup>m</sup> -312% to 94%, median 19% <sup>a</sup>	-79% to 88%, median 59% <sup>m</sup> -621% to 99%, median 47% <sup>a</sup>	8-98% TSS, median 86% <sup>m</sup> -2,300% to 100%, TSS, median 81% <sup>a</sup>	-85% to 83%, median 37% <sup>m</sup> -43,233% to 100%, median 45% <sup>a</sup>	No information
Constructed wetland	-800% to 92%, median 11% <sup>a</sup> -416% to 79%, median 9% <sup>a</sup>	-49% to 76%, median 24% <sup>m</sup> -10,570% to 98%, median 2% <sup>a</sup> -5,929% to 78%, median 21% <sup>a</sup>	71% <sup>a</sup> -55% to 100%, median 48% <sup>m</sup> -1,679% to 99%, median 27% <sup>a</sup> -5,500% to 93%, median 12% <sup>a</sup>	-100% to 100%, median 72% <sup>m</sup> -3,294% to 100% TSS, median 58% <sup>a</sup> -17,900% to 100%, median 34% <sup>a</sup>	55-97%, median 78% <sup>m</sup> -1,150% to 100%, median 55% <sup>a</sup> -6,900% to 94%, median 0% <sup>a</sup>	-17,005% to 100%, median 69% <sup>a</sup>
Stormwater detention pond	-619% to 92%, median 11% <sup>a</sup>	-19% to 43%, median 24% <sup>m</sup> -418% to 86%, median 8% <sup>a</sup>	0-48%, median 20% <sup>m</sup> -1,072% to 92%, median 19% <sup>a</sup>	-1% to 90% TSS, median 49% <sup>m</sup> -5,378% to 100% TSS, median 57% <sup>a</sup>	78-97%, median 88% <sup>m</sup> -574,900% to 100%, median 31% <sup>a</sup>	-3,053% to 100%, median 52% <sup>a</sup>
Stormwater retention pond	-1,383% to 97%, median 24% <sup>a</sup>	-12% to 76%, median 31% <sup>m</sup> -662% to 91%, median 27% <sup>a</sup>	12% to 91%, median 52% <sup>m</sup> -10,300% to 99%, median 49% <sup>a</sup>	-33% to 99% TSS, median 80% <sup>m</sup> -8,600% to 100% TSS, median 75% <sup>a</sup>	-6% to 99%, median 70% <sup>m</sup> -7,900% to 100%, median 67% <sup>a</sup>	-7,900% to 100%, median 68% <sup>a</sup>
Porous pavement	-182% to 99%, median 42% <sup>a</sup>	0-85%, median 42% <sup>m</sup>	0-100%, median 65% <sup>m</sup> -733% to 95%, median 26% <sup>a</sup>	0-97% TSS, median 89% <sup>m</sup> -1,500% to 99% TSS, median 53% <sup>a</sup>	No information	No information

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice (continued).

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	<i>E. coli</i> reduction
Correct application of commercial fertilizer	No information	No information	No information	No information	Not applicable	Not applicable
Stream exclusion (Fencing + alternative water supply)/Access control	No information	32% <sup>a</sup> , 60% <sup>e</sup> , 18-25% <sup>h</sup>	76% <sup>a</sup> , 60% <sup>e</sup> , 18-25% <sup>h</sup>	83% <sup>a</sup> , 75% <sup>e</sup> 18-25% TSS <sup>h</sup>	30% - 95% <sup>f</sup> 44-52% <sup>g</sup>	46% <sup>h</sup>
Alternative water supply	No information	41% <sup>a</sup> , 13-77% <sup>e</sup> , 30% <sup>e</sup>	74-97% <sup>e</sup> , 30% <sup>e</sup>	38% <sup>a</sup> , 38-96% <sup>e</sup> , 30% <sup>e</sup>	57% <sup>b</sup> , 51-94% <sup>d</sup>	85% <sup>l</sup>
Livestock shelter structure	No information	No information	No information	No information	No Information	85% <sup>h</sup>
Heavy use area treatment	No information	86% <sup>i</sup>	50% <sup>i</sup>	98% <sup>i</sup>	92-99% <sup>i</sup>	No information
Prescribed/rotational grazing	No information	20% <sup>e</sup>	20% <sup>e</sup>	60% <sup>b</sup> , 20% <sup>e</sup>	90-96% <sup>e</sup>	60% - 72% <sup>e</sup>
Forested riparian buffer	No information	47-59% <sup>a</sup> , 37-57% <sup>e</sup> , 44-70% <sup>e</sup> , 68-89% <sup>o</sup>	53-63% <sup>a</sup> , 45-70% <sup>e</sup> , 30-80% <sup>o</sup>	76% <sup>a</sup> , 55-95% <sup>e</sup> , 45-70% <sup>e</sup> , 60-90% <sup>o</sup>	30% <sup>b</sup>	No information
Pasture planting	No information	66% <sup>a</sup>	67% <sup>a</sup>	59% <sup>a</sup>	No information	No information
Filter strips	-1.536% to 80%, median 4% <sup>k</sup>	1-93% <sup>c</sup> -586% to 70%, median 17% <sup>k</sup>	2-93% <sup>c</sup> 27-96% <sup>j</sup> -25,400% to 99%, median -46% <sup>k</sup>	53% - 91% <sup>a</sup> , 18-99% <sup>c</sup> 41-100% <sup>d</sup> -34,881% to 99% TSS, median 50% <sup>k</sup>	30-100% <sup>j</sup> -5,970% to 100%, median -5% <sup>k</sup>	58-99% <sup>j</sup>
Conservation cover	No information	No information	No information	70-76% <sup>a</sup>	No information	No information
Vegetated treatment area	>85% <sup>q</sup>	>85%, average 70% <sup>q</sup>	12-97%, average 70% <sup>q</sup>	70-90% of solids <sup>s</sup>	64-87% <sup>q</sup>	No information

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice (continued).

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	<i>E. coli</i> reduction
Waste storage facility	No information	52% <sup>a</sup> , 29-75% <sup>c</sup> , 35% <sup>gk</sup>	58% <sup>a</sup> , 26-90% <sup>c</sup> , 54% <sup>gk</sup>	Not applicable	44-99% <sup>gk</sup>	97-99% <sup>gk</sup>
Agrichemical storage facility	No information	No information	No information	No information	Not applicable	Not applicable
Nutrient management plans	No information	0-84% <sup>c</sup>	8-91% <sup>c</sup>	72-92% <sup>c</sup>	No information	No information
Herbaceous riparian buffer	No information	68% <sup>d</sup> , 31-48% <sup>g</sup> , 50-76% <sup>gp</sup>	67% <sup>d</sup> , 50-70% <sup>g</sup> , 50-89% <sup>gp</sup>	23% <sup>d</sup> , 50-70% <sup>g</sup> , 66-84% <sup>gp</sup>	21-100% <sup>g</sup> , 70-95% <sup>gq</sup>	No information
Pond	See stormwater retention pond	82% <sup>a</sup>	72-80% <sup>a</sup>	77% <sup>gq</sup>	See stormwater retention pond	See stormwater retention pond
Feral hog management	No information	No information	No information	No information	No information	No information
Silvopasture establishment	No information	No information	No information	No information	No information	No information

<sup>a</sup> (Merriman, et al., 2009)  
<sup>b</sup> VT database  
<sup>c</sup> BMP Tool II  
<sup>d</sup> (Garrett, 2011)  
<sup>e</sup> (Peterson, et al., 2011a)  
<sup>f</sup> (Peterson, et al., 2011b)  
<sup>g</sup> [https://www.hrpdcva.gov/Documents/Phys%20Planning/2011/ChesBayTMDL/AdditMaterials/CB\\_Model\\_BMP\\_Doc.pdf](https://www.hrpdcva.gov/Documents/Phys%20Planning/2011/ChesBayTMDL/AdditMaterials/CB_Model_BMP_Doc.pdf)  
<sup>h</sup> (Peterson, et al., 2011c)  
<sup>i</sup> with use of mulch, straw, and seed on high use areas from (Peterson, et al., 2011d)  
<sup>j</sup> (Peterson, et al., 2011e)  
<sup>k</sup> Stream crossing combined with other practices from (Peterson, et al., 2011f)  
<sup>l</sup> (Peterson, et al., 2011g)  
<sup>m</sup> (Center for Watershed Protection, 2007)  
<sup>n</sup> (Geosyntec Consultants, 2018)  
<sup>o</sup> (North Carolina Department of Environment and Natural Resources, n.d.)  
<sup>p</sup> (Klaproth & Johnson, 2009)  
<sup>q</sup> (Koelsch, et al., 2006)

It is useful to consider that, typically, suites of management practices are implemented together. Pollutant reductions from implementing suites of practices are likely to be greater than those indicated for individual practices in Table 4.8. For example, stream access control, alternative water supply, and rotational grazing can be implemented together as a suite of practices. Given the large number of potential combinations of practices, it is only practical at this point to consider the impacts of practices individually.

In addition, it is good to keep in mind that studies in the Ozarks suggest that land management on karst terrain can affect groundwater quality, which can in turn affect surface water quality (Mott, Hudson and Aley 2000). NRCS states that several of the management practices recommended in this plan can also protect groundwater quality (NRCS 2017b). However, information on effectiveness of these practices in reducing target pollutants in groundwater was not found. In addition, no data was found that would indicate if there are problems with groundwater quality in the Middle White River watershed.

The target reductions for nitrogen loads from hayland and pasture, and residential and developed areas in the Lower Salado Creek subwatershed, are 21%. With no data available to indicate otherwise, we assume that the loads from developed areas and pastures are equal, so the reduction target is the same for both sources.

#### **4.6.1 Developed and Residential Areas**

Practices that appear appropriate for reducing nitrogen inputs from developed and residential nonpoint sources in the Lower Salado Creek subwatershed are listed in Table 4.9. Based on state imagery from 2017, it appears that forested riparian buffers of some kind are already present along the majority of the stream reaches in developed areas within this subwatershed. Therefore, riparian buffers are excluded from Table 4.9. Although those stormwater management practices that have been studied have been shown to reduce nitrogen concentrations by over 90% in some cases, the median removal efficiencies reported for several of these practices are less than 21%. However, since multiple practices are usually implemented together, it should be possible to achieve the target 21% nitrogen load reduction. A water quality survey could be useful in characterizing nitrogen loads from different locations within the subwatershed. This knowledge would help with siting practices to effectively reduce nitrogen load.

Table 4.9. Management practices for reducing nitrogen from developed and residential areas.

<b>Practices</b>	<b>Range of reported TKN reductions<sup>a</sup></b>	<b>Median of reported change in TKN<sup>b</sup></b>	<b>Range of reported total nitrogen reductions<sup>a</sup></b>	<b>Reported medians of total nitrogen reductions<sup>b</sup></b>	<b>Reduction assumed for estimates<sup>c</sup></b>
Pet waste management program	-	-	-	-	-
Inspect and repair on-site wastewater systems	-	-	-	-	-
Fertilizer management program	-	-	-	-	-
Media filter	0-95%	39%	0-94%	19%, 32%	25%
Constructed wetland	0-92%	10%	0-98%	2%, 21%, 24%	20%
Detention pond	0-92%	11%	0-86%	8%, 24%	15%
Retention pond	0-97%	24%	0-91%	27%, 31%	30%
Porous pavement	0-99%	42%	0-85%	42%	40%
Filter strips	0-80%	4%	0-93%	17%	20%

<sup>a</sup> Note that all of these practices also increased nitrogen in some cases.

<sup>b</sup> These median values are based on including cases where nitrogen increased as well as those where nitrogen was reduced.

<sup>c</sup> Based on reported median values.

#### 4.6.2 Pasture and Hayland

Practices that appear appropriate for reducing nitrogen inputs from pasture and hayland in the Lower Salado Creek subwatershed are listed in Table 4.10. Based on state imagery from 2017, it appears that trees, which may be forested riparian buffers, are present along many of the stream reaches adjacent to pasture and hayland in this subwatershed. A water quality survey could help with siting practices where they would do the most good.

Table 4.10. Management practices for reducing total nitrogen from pasture and hayland.

Practices	Range of reported reductions	Reduction assumed for estimates
Nutrient Management Plan	8-84%	40%
Waste storage facility	29-75%	30%
Agrichemical storage facility	-	30%
Stream access control	18-60%	40%
Alternative water supply	13-77%	40%
Livestock shelter structure	-	-
Prescribed grazing	20%	20%
Pasture improvement	66%	50%
Silvopasture establishment	-	-
Forested riparian buffer	37-89%	50%
Herbaceous riparian buffer	31-76%	40%
Filter strip	0-93%	10%
Heavy use area treatment	86%	70%
Vegetated treatment area	>85%	50%
Feral hog management	-	-

## 5.0 IMPLEMENTATION STRATEGY

The implementation strategy for the Middle White River watershed management plan includes several elements. These elements are described in this section. In addition to implementing practices to manage unregulated nonpoint pollution sources, the program includes:

- Information and education activities aimed at watershed stakeholders,
- Teams to guide and coordinate voluntary activities in recommended subwatersheds,
- Water quality and biological monitoring to document any changes resulting from voluntary nonpoint source pollution management activities,
- Milestones for implementation,
- Criteria for evaluation of progress,
- Regular evaluation of progress toward plan goals,
- Updating the plan to accommodate changes in the watershed, and/or in understanding of the watershed, and
- Proposed implementation schedule.

### 5.1 Information and Education

Watershed management is fundamentally a social activity (Thornton and Laurin 2005). While technical solutions to problems are necessary for effective watershed management, they are not sufficient. Decisions on how to protect and improve water quality, and implement management practices, are ultimately based on the socioeconomic perceptions, beliefs, and values of landowners and stakeholders on how these technical solutions will affect them. The Information and Education objectives of this watershed plan, therefore, include the following:

- Increase local landowner and public awareness of the need for, and the benefits of, watershed restoration and protection practices;
- Increase stakeholder support and participation in watershed management activities for water quality protection and improvement; and

- Improve the understanding of how water quality and environmental improvements contribute to increased economic and social capital in the community.

### 5.1.1 Existing Outreach and Education in the Middle White River Watershed

There are a number of organizations active in the Middle White River watershed that have outreach and education programs in place that could be used as vehicles to accomplish the Information and Education objectives of this watershed management plan. Examples are listed in Table 5.1. Outreach and education activities of some of these organizations are described below. Most, but not all, of these organizations are active throughout the Middle White River watershed.

Table 5.1. Middle White River watershed stakeholder groups and outreach programs.

Stakeholder Groups	Organizations with Information and Education Programs for the Stakeholders
Agriculture producers	Natural Resources Conservation Service, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Grazing Lands Coalition, The Nature Conservancy, Arkansas Cattlemen’s Association, Arkansas Farm Bureau, Arkansas Pork Producers Association, Poultry Federation
Recreationists	USFS, US Fish and Wildlife Service, USACE, AGFC, Arkansas Canoe Club, Audubon Arkansas, Friends of the North Fork and White Rivers, Ozark Off-road Cyclists, Ozark Society, Ozark Highlands Trail Association, The Nature Conservancy, Federation of Fly Fishers, Trout Unlimited, Lyon College Education and Adventure Program
Landowners and residents	USFS, US Army Corps of Engineers, Rural Water Associations, NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Forestry Commission, AGFC, Arkansas Natural Heritage Commission, The Nature Conservancy, Arkansas Master Naturalists, Trout Unlimited, Friends of the North Fork and White Rivers
Local and county governments	Arkansas Economic Development Commission, The Nature Conservancy, Arkansas Natural Resources Commission, Friends of the North Fork and White Rivers, Arkansas Department of Parks and Tourism
Concessioners, vendors, hostellers, restaurants	USACE, Friends of the North Fork and White Rivers, Arkansas Economic Development Commission

#### **5.1.1.1 US Forest Service**

Information and education activities of the USFS include interpretive programs at Blanchard Springs Caverns; Ozark-St. Francis National Forest website (<https://www.fs.usda.gov/osfnf>) and Facebook page (<https://www.facebook.com/ozarkstfrancis>); publications; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events. Given the location of the Sylamore District of the Ozark National Forest, information and education activities are focused primarily in Stone County, however, visitors from all over the Middle White River watershed can be exposed to USFS interpretive programs in person and online.

#### **5.1.1.2 Natural Resources Conservation Service**

Information and education activities of the NRCS include participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices, in addition to information posted on their website (<https://www.nrcs.usda.gov/wps/portal/nrcs/ar/home/>), Twitter (<https://twitter.com/arkansasnrcs>), and YouTube (<https://www.youtube.com/channel/UCWPRIlokkCy1DTROIEoW5OA/featured>). Through these activities, NRCS provides information and education on a wide range of topics related to agriculture in the state, including benefits of, implementation, and maintenance of agricultural practices to protect or improve water quality so water quality standards are met.

#### **5.1.1.3 University of Arkansas Division of Agriculture**

The UofA Division of Agriculture is a research and information support agency for the agricultural sector in Arkansas. The Division of Agriculture provides information and education through the Cooperative Extension Service. Information and education activities of the Cooperative Extension Service include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, informational and training programs at county offices, newsletters, publications on a variety of topics including feral hog management, and short and long-term agricultural methods that protect water quality so water quality standards are met. A website (<https://www.uaex.edu/>), and Facebook

(<https://www.facebook.com/uaex.edu/>), Twitter ([https://twitter.com/UAEX\\_edu](https://twitter.com/UAEX_edu)), Instagram ([https://www.instagram.com/uaex\\_edu/](https://www.instagram.com/uaex_edu/)), and YouTube (<https://www.youtube.com/user/ARextension>) accounts provide access to information about programs and resources, and copies of informational publications and videos.

The Arkansas Cooperative Extension Service also provides information on protecting water quality for non-agricultural landowners and residents in developed areas, through their website and social media. In addition, they work with communities in Northwest and Southeast Arkansas to provide public urban stormwater education and participation programs to fulfill requirements of NPDES municipal stormwater permits. These programs include printed materials; videos; commercials; storm drain markers; demonstrations and presentations to children, adults, and local companies; stream and lake clean-up events; and social media that include slogans or catch phrases like “slow it down, spread it out and soak it in”, “Know the Flow – storms on streets drain to creeks”, “If it rains, it drains”, and an animated spokesperson Wayne the raindrop. This information could be useful to the Middle White River watershed municipalities even if they don’t come under NPDES municipal stormwater permits. Information on this topic is available to the public on the Cooperative Extension Service website, <https://www.uaex.edu/environment-nature/water/stormwater/default.aspx>.

#### **5.1.1.4 County Conservation Districts**

Information and education activities of the County Conservation Districts include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices, in addition to websites (e.g., <http://www.stonecountyconservationdistrict.com/>, <http://www.baxtercountycd.com/>, <http://www.independececcd.com/>) and social media like Facebook (e.g., <https://www.facebook.com/izardcountyconservationdistrict/>, <https://www.facebook.com/stonecountyconservationdistrict/>, <https://www.facebook.com/independececcd/>). Through these activities, County Conservation Districts provide information and education on a wide range of topics related to agriculture and rural life, including benefits, implementation, and maintenance of agricultural practices to protect

water quality so water quality standards are met. The Baxter County Conservation District is also conducting education and outreach activities as part of the active 319 Project in the Hicks Creek subwatershed.

#### **5.1.1.5 Arkansas Natural Resource Agencies**

Arkansas natural resource agencies, including Arkansas Forestry Commission, AGFC, Arkansas Natural Heritage Commission, and the ANRC all have information and education programs aimed at increasing public interest, understanding, and stewardship of the natural resources of our state, including protecting water quality to achieve water quality standards. These agencies use a variety of methods to reach Arkansans, including websites (<https://www.agfc.com/en/>, <http://www.naturalheritage.com/>, <https://www.anrc.arkansas.gov/>); social media (e.g., <https://www.youtube.com/user/ArkansasGameandFish>, <https://www.facebook.com/arnaturalheritage/>, <https://www.facebook.com/Arkansas-Natural-Resources-Commission-127788010626999/>); newsletters; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events.

#### **5.1.1.6 Arkansas Grazing Lands Coalition**

One of the goals of the Arkansas Grazing Lands Coalition is education of landowners and operators on implementation and maintenance of “grazing practices that promote environmental, financial, and social stability.” Protecting and improving water quality to meet standards is part of this goal. This goal is accomplished in part through sponsorship of field days, and an annual conference (Arkansas Grazing Lands Coalition 2017).

#### **5.1.1.7 Friends of the North Fork and White Rivers**

The Friends of the North Fork and White River conducts and is active in a number of activities to educate local stakeholders about water quality in Bull Shoals Lake, Norfork Lake, White River (from Bull Shoals Lake to Independence County line), North Fork of the White River, and their tributaries, and what can be done to protect and improve that water quality. These activities include resources and a program to educate students about aquatic food webs, an

Enviroscape physical model to demonstrate nonpoint source pollution, video on nonpoint source pollution, presentations at meetings of their own and other local groups, trash clean up events at local streams and rivers, newspaper stories, website (<http://friendsoftherivers.org/>), and social media posts (<https://www.facebook.com/Friends-of-the-North-Fork-of-the-White-River-and-Bryant-Creek-242047022547296/>). They also offer scholarships, lead stream teams in Mountain Home and surrounding area (including Dodd Creek and Hicks Creek) with children and adults, are supporting a Paint the Drain project by Mountain Home High School, and collaborate with Trout Unlimited White River Chapter on a youth mentoring program based on trout fishing on Dry Run Creek (a tributary of North Fork of the White River) (Friends of the North Fork and White Rivers 2018).

#### **5.1.1.8 The Nature Conservancy**

The Nature Conservancy uses their Strawberry River Preserve and Demonstration Ranch in Sharp County as an outreach and education project. This preserve showcases economically feasible specialized grazing techniques that protect streambanks and stream ecology, including water quality that meets state standards. Training workshops in these techniques have been offered for local ranchers by The Nature Conservancy (The Nature Conservancy 2015).

Through its Ozark Highlands Karst program, The Nature Conservancy educates local governments, developers, and farmers about the sensitivity of karst areas to groundwater pollution from surface activities. They also provide information about how to reduce impacts of surface activities on groundwater and cave biota in karst areas (The Nature Conservancy 2017). Because groundwater influences many of the surface waters in this area of the state, including the Middle White River watershed, this program helps surface waters meet state water quality standards.

#### **5.1.1.9 Other Nonprofit Interest Groups**

There are a number of nonprofit groups with interests in the Middle White River watershed. These include the Arkansas Backcountry Horsemen of America, Arkansas Cattlemen's Association, Arkansas Farm Bureau, Arkansas Master Naturalists, Arkansas Pork

---

Producers Association, Audubon Arkansas, Federation of Fly Fishers, Ozark Off-road Cyclists, Ozark Society, The Poultry Federation, Trout Unlimited, and White River Waterkeeper. These organizations provide information and education to their members and the public through a variety of methods including, websites; social media; newsletters; presentations and displays at schools, meetings, conferences, fairs, and festivals; news media stories; and hosting events like day camps, contests, and river clean ups. Many of these organizations already provide information and education about how to protect and improve water quality so that state water quality standards are met. Several of these organizations, e.g., Friends of the North Fork and White Rivers, Trout Unlimited, Ozark Off-road Cyclists, Arkansas Backcountry Horsemen of America, primarily focus their efforts only in select areas of the Middle White River watershed.

### **5.1.2 Proposed Information and Education Programs for Middle White River Watershed**

There are a number of information and education programs active in the Middle White River watershed that target agricultural producers. However, all of the subwatersheds recommended for initial management in this plan have significant residential and developed areas that can contribute nutrients and other pollutants to surface waters. Therefore, to further assist in protection and improvement of water quality in the recommended subwatersheds to meet water quality standards, some additional information and education programs that target stakeholders in developed and residential areas are proposed. These programs are described below.

#### **5.1.2.1 Hicks Creek Impairment**

Hicks Creek is included on the state list of impaired waterbodies due to high levels of *E. coli* in the creek just downstream of Mountain Home and its wastewater treatment plant. The Mountain Home WWTP has not reported fecal coliform levels exceeding its permit limits in at least 12 years (EPA 2018a). ADEQ conducted water quality sampling in Hicks Creek and its tributary Dodd Creek during the summer of 2015. The results of this water quality sampling indicate that, occasionally, discharge from the WWTP may exceed water quality standards. However, high *E. coli* levels are coming from other sources in addition to the WWTP. Whether

---

or not Mountain Home stormwater runoff ends up being regulated under an NPDES permit, it is important to continue to make Mountain Home residents aware that the stream running through their city is not meeting water quality standards for primary body contact use, and encourage officials and residents to take actions to improve water quality in Hicks Creek. The Friends of the North Fork and White Rivers have several projects going that help bring attention to this issue, including sponsoring painting storm drains and Stream Teams monitoring Dodd Creek and Hicks Creek. These activities need to continue.

#### **5.1.2.2 Onsite Wastewater System Maintenance Outreach**

Information and education about proper maintenance of onsite wastewater systems could improve water quality in the recommended subwatersheds and ensure water quality standards are achieved. The Arkansas Department of Health offers training for operators of regulated onsite wastewater systems that serve camps, trailer parks, or multiple households. The EPA SepticSmart information and education program has a variety of materials that can be used to inform and educate homeowners with individual onsite wastewater systems, e.g., septic systems (<https://www.epa.gov/septic>). SepticSmart is endorsed by the Arkansas Rural Water Association. White River Waterkeeper has expressed interest in education outreach to homeowners with individual onsite wastewater systems in the region (J. Green, personal communication, September 11, 2018, White River Waterkeeper).

#### **5.1.2.3 Social Media Platform for the Middle White River**

Social media platforms are one of the primary sources of information on almost any topic within any age demographic. Within the Middle White River watershed, the average age of landowners is in the 50+ category (see Section 2.2.1). The two social media platforms used most extensively by this age group are Facebook and YouTube (Figure 5.1). Using these two social media platforms in the Middle White River watershed, then, can be one of the more effective approaches for outreach and education. Most of the organizations active in the Middle White River watershed already utilize social media platforms to interact with their constituents. For example, ANRC and the UofA Cooperative Extension currently have Facebook pages

(<https://www.facebook.com/Arkansas-Natural-Resources-Commission-127788010626999/>, <https://www.facebook.com/uaex.edu/>). NRCS Arkansas uses Twitter extensively (<https://twitter.com/arkansasnracs>), and all three agencies host and refer users to YouTube (<https://www.youtube.com/channel/UCWPRIlokkCy1DTROIEoW5OA/featured>, <https://www.youtube.com/user/ARextension>). These three agencies also interact regularly with landowners in the watershed as well as nonprofit organizations such as Friends of the North Fork and White Rivers, the White River Waterkeeper, municipalities, conservation districts, county agencies, and other entities. As importantly, these three agencies also have individuals who routinely monitor traffic and post information on their platforms.

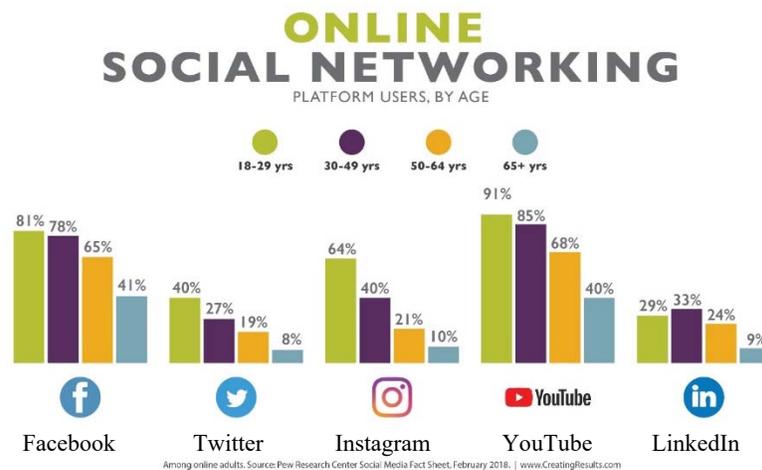


Figure 5.1. Social media platforms use by age group (Mickey 2018).

To enhance the effectiveness of social media in attaining the Middle White River watershed management plan goals, several questions, including the following, need to be addressed:

- What are the social media goals?
- What social media platforms are proposed?
- Who is the target audience?
- What are the core demographics?

- What are the core metrics for tracking effectiveness?
- How often will these metrics be assessed?
- What type of content will be hosted?
- What are the best times to post on the platforms?
- Who will monitor and maintain the social media platforms?

A social media marketing checklist is included in Appendix F (York 2018).

The social media goals for the Middle White River watershed include the following:

- Provide landowners with technical information, opportunities for cost-share programs, and testimonials of landowners who have cost-effectively implemented management practices;
- Increase community engagement, volunteerism, and educational activities in furthering the WMP goals;
- Encourage behavioral actions that protect and sustain existing water quality throughout the Middle White River watershed; and
- Highlight the economic benefits to landowners from protecting, sustaining, and improving water quality within the watershed.

Facebook and Twitter platforms already exist within ANRC, NRCS, and UofA Cooperative Extension as well as county conservation districts (see information above and in Section 5.1.1). The platforms not only currently have followers, but followers who are landowners within the watershed and represent the target audience for information (i.e., 50+ age demographic).

The following core metrics are suggested for these social media platforms:

- Number of clicks or hits;
- Number of likes;
- Retweets; and
- Reach (e.g., how broadly information is being discussed among residents and visitors in the watershed).

Both Facebook and Twitter have free analytics tools (e.g., Facebook Insights) that track the metrics listed above, including analytics on days and times of day with the greatest traffic on

---

the site. This information can be used to decide when it is most effective to post new information on these social media platforms.

Weekly assessment (e.g., Monday morning) of the platform metrics can be used to determine the effectiveness and reach of the platform in supporting the watershed management goals.

There currently is extensive content on watershed management practices, outreach and education efforts and information, meeting, workshop, and field day announcements, and YouTube and other videos on technical assistance on the ANRC, NRCS, and UofA Cooperative Extension platforms, but these sites are not always linked to each other or linked to the Middle White River watershed activities, university and nonprofit organizations social media platforms and websites. ANRC initially will develop these links and ensure that its platform is linked to any institutions or organizations interested in implementing this watershed management plan.

#### **5.1.2.4 Quantify Ecosystem Services**

Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005) and the direct and indirect contributions of ecosystems to human well-being (Kumar 2010). As categorized by the Ecosystem Millennium Assessment, these include *provisioning* services such as food, water, timber and fiber; *regulating* services that affect climate, floods, disease, wastes, and water quality; *cultural* services that provide recreational, aesthetic, and spiritual benefits; and *supporting* services such as soil formation, nutrient cycling, and photosynthesis (Millennium Ecosystem Assessment 2005). Typically, only provisioning services have market value, with the monetary benefits determined within the market place where goods and services are bought and sold. However, there are significantly more benefits or values that are provided by ecosystem services other than provisioning services.

A taxonomy of economic values for ecosystem services has been developed based on whether there is a physical relationship between the ecosystem and human use (National Research Council 2004). Use values can be consumptive, non-consumptive, or indirect use. Consumptive uses, for example, include commercial fishing and water withdrawals for drinking (i.e., market-based provisioning services). Non-consumptive uses include boating, swimming, or

health impacts. Indirect use includes habitat for birds and bird-watching or spawning habitat for fish. There are also non-use values, which are not tied directly or indirectly to human use. For example, there are option values, where there currently is no desire to use the ecosystem, but there may be in the future and people value having that future option. Bequest and altruistic values relate to wanting the resource or service available for future generations (bequest) or available for others now (altruistic).

Economists have developed methods for quantifying the value of many of the non-consumptive, indirect, and non-use ecosystem services (Table 5.2). Many of these methods are applicable for estimating the value of ecosystem services that contribute to sustaining and improving water quality within the Middle White River watershed and its tributaries.

Table 5.2. Monetary valuation methods for ecosystem goods and services.

<b>Market Place Method</b> – value based on ecosystem goods and services bought and sold in commercial markets	<b>Productivity Method</b> – value-based products or services that contribute to the production of commercially marketed goods
<b>Hedonic Pricing Method</b> – value based on services that directly affect market price of another good (e.g., streamside vs non-streamside property)	<b>Travel Cost Method</b> – value associated with ecosystem used for recreation and willingness of people to pay to travel to the site
<b>Damage Cost Avoided/Replacement Cost Method</b> – value based on cost of avoiding damages from lost services or cost of replacing services (e.g., drinking water treatment costs)	<b>Contingent Valuation Method</b> – value based on asking people their willingness to pay (WTP) for specific ecosystem services based on scenario (most widely used method for estimating nonuse values)
<b>Contingent Choice Method</b> – value based on asking people to make trade-offs among choices of services or characteristics. Does not ask for WTP, but infers value from trade-offs	<b>Benefit Transfer Method</b> – value based on transferring existing benefit estimates to similar location, issue or use.

The value of ecosystem services is generally unknown and rarely considered by society because the services are “free”. Because most people are risk averse and fear loss significantly more than gain (Kahneman and Tversky 1979, Thaler, et al. 1997), the ecosystem services will be quantified so the differential loss of valued services (e.g., monetary value) can be estimated. For example, manure decomposition (supporting service) makes nutrients available for grass/hay production that offsets the cost of fertilizer application. Soil health, in addition to water quality,

represents a category of ecosystem services with significant value to cattle ranchers and hay producers that can also contribute to improved water quality.

The initial quantification of ecosystem services is proposed for Hicks Creek. Hicks Creek receives both point and nonpoint source pollutant contributions, which diminish water quality, including wastewater effluent, septic tank leakage, sediment loading from erosion, and runoff from developed areas and pastures. These, and similar drivers and pressures can all impact aquatic ecosystems and their services. A DPSIR model framework (Bradley and Yee 2015) is proposed to illustrate the linkages among drivers (D), pressures (P), status (S), impacts (I), and responses (R – DPSIR) and their relationship with ecosystem service changes and well-being in Hicks Creek. The voluntary set of practices and activities proposed in this watershed management plan represent one set of responses to the impacts on these ecosystem services.

Ecosystem services will be quantified following the frameworks proposed by Grizzetti et al. (2016), Ready (in preparation), and using the tools assessed by Bagstad et al., (2013) and InVEST ([www.naturalcapitalproject.org/invest/](http://www.naturalcapitalproject.org/invest/)). InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of open source ecosystem service models developed by the Natural Capital Project. The Natural Capital Project is a joint initiative of the University of Minnesota, The Nature Conservancy, Stanford University and World Wildlife Fund ([www.naturalcapitalproject.org](http://www.naturalcapitalproject.org)). The set of ecosystem services considered for initial valuation, along with the proposed valuation method, is shown in Table 5.3.

Table 5.3. Freshwater Ecosystem services, type of value and applied valuation methods. The classification of ecosystem services has been developed for fresh and transitional water (Reynaud and Lanzanova, 2015).

Ecosystem services	Category <sup>a</sup>	Value type	Valuation method <sup>b</sup>	Examples of economic good provided
1-Water for Drinking	Provisioning	Direct	MP, CV	Water for domestic uses
2-Raw (biotic) materials	Provisioning	Direct	MP, RC	Algae as fertilizers
3-Water for no-drinking purposes	Provisioning	Direct	MP, PF	Water for industrial or agricultural uses
4-Raw materials for energy	Provisioning	Direct	RC	Wood from riparian zones
5-Water purification	Regulation	Indirect	RC, CV	Excess nitrogen removal by microorganisms
6-Erosion prevention	Regulation	Indirect	RC	Vegetation controlling soil erosion
7-Flood protection	Regulation	Indirect	RC, CV	Vegetation acting as barrier for the water flow
8-Maintaining populations and habitats	Regulation	Indirect	RC	Habitats use as a nursery
9-Pest and disease control	Regulation	Indirect	RC, CV	Natural predation of diseases and parasites
10-Soil formation	Regulation	Indirect	RC	Rich soil formation in flood plains
11-Carbon sequestration	Regulation	Indirect	RC, MP	Carbon accumulation in sediments
12-Location climate regulation	Regulation	Indirect	RC, MP	Maintenance of temperature patterns
13-Recreation	Cultural	Direct	CV, TC, DC, HP	Swimming, recreational fishing, sightseeing
14-Recreational fishing	Cultural	Direct	TC, CV	Sportfishing for smallmouth bass
15-Recreational canoeing/swimming	Cultural	Direct	MP, TC, CV	Canoeing/kayaking, swimming
16-Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	Matter for research, artistic representation
17-Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	Sense of being
18-Raw abiotic materials	Extra abiotic	Direct	PF, MP	Extraction of sand and gravel
19-Abiotic energy sources	Extra abiotic	Direct	PF, MP	Hydropower generation

<sup>a</sup> Provisioning, Regulation and maintenance, Cultural, Extra abiotic services.

<sup>b</sup> Contingent valuation (CV), Hedonic price (HP), Market price (MP), production function (PF), Replacement cost (RC), travel cost (TC).

## 5.2 Subwatershed Implementation Teams

The greatest efficacy in implementing watershed management plans, and protecting and improving water quality, is typically achieved through individual subwatershed implementation teams. These subwatershed implementation teams serve to coordinate and track voluntary implementation of nonpoint source management practices and studies within their subwatersheds. While there is general interest in activities occurring within other subwatersheds within an 8-digit HUC watershed, the greatest interest, and benefits, are typically associated with stakeholders who live, work, or recreate within subwatersheds of the 8-digit HUC, e.g., local landowners, business operators, county judges or mayors of local towns, and similar individuals who are interested in working together. Therefore, it is recommended that local stakeholders form watershed implementation teams. Two teams may be adequate for the recommended subwatersheds, one for the Hicks Creek subwatershed, and one for the four recommended subwatersheds in the Batesville area, Greenbrier Creek, Lower Salado Creek, Spring Creek, and Miller Creek.

A recent article provided empirical evidence that nonprofit watershed groups or teams can provide public goods (Grant and Langpap 2018). In economics, a public good is a commodity or service available to all individuals and where one individual cannot reduce the availability to others. Grant and Langpap reviewed information from 2,150 watersheds across the lower U.S. from 1996 to 2008. Watershed groups in these watersheds increased from 500 to 1,500 over this same period. They found the activity of these watershed groups resulted in improved water quality, specifically a decrease in dissolved oxygen deficiency (i.e., increase in dissolved oxygen concentrations in waterbodies), compared to watersheds in which there were no groups. Donations to watershed groups were associated with reduced dissolved oxygen deficiency. Watershed groups can make a significant difference in improved water quality within a watershed through their activities.

Individuals will need to be contacted to determine their interest in each subwatershed as well as their willingness to work with individuals and organizations interested in implementing the watershed management plan within the subwatershed. Teams could include one to five members, who would be asked to commit to a three-year term. Team responsibilities could

include planning implementation projects or studies, obtaining funding for projects or studies, and serving as a clearing house for information on the amount and types of nonpoint source pollution management practices and water quality studies occurring in the subwatershed. An example of the team approach for implementation is the work the Friends of the North Fork and White Rivers did preparing a Watershed Restoration Action Strategy for the White River from Bull Shoals Dam to the Independence County Line, and the North Fork River from Norfork Dam to the White River (Friends of the North Fork and White Rivers, Inc. 2007).

### **5.3 Subwatershed Implementation Plans**

The process of developing a local subwatershed implementation plan can increase the implementation of voluntary management practices by encouraging stakeholder buy-in and leveraging technical and financial resources. An example is the Watershed Restoration Action Strategy developed by the Friends of the North Fork and White Rivers. Subwatershed implementation plans developed by the watershed implementation teams can be a mechanism for implementing management practices in the Middle White River recommended subwatersheds. These plans will include more specific information about pollutant sources that exist and how these sources will be addressed by management practices. The purpose of these plans is to provide a roadmap for how the water quality will be protected and/or improved so that it meets state water quality standards. Subwatershed implementation plans can be prepared for each HUC12 recommend subwatershed, as supplements to this watershed management plan.

### **5.4 Implement Nonpoint Source Pollution Management Strategies**

Nonpoint source pollution management practices that are being and will be implemented in the Middle White River watershed are listed in Table 5.4, along with an indication of the target nonpoint source pollutants within the recommended subwatersheds that they address. The practices are organized by the land use where they apply. Focus areas for management include pasture and haylands along streams and on ridge tops, areas within 50 feet of streams, and, finally, areas on ridge tops, particularly where karst features are present.

There is no legal requirement that anyone implement any of the practices listed in Table 5.4. These are practices that are suggested for landowners, operators, and other stakeholders interested in protecting water quality in the Middle White River watershed. In addition to protecting water quality, these practices can increase the value and returns on the property where they are implemented. This is not an exclusive list of practices, but rather those that are generally accepted within the watershed and suggested by stakeholders. There are other practices not listed that could also improve or protect water quality and habitat. Programs that can provide technical and financial assistance to landowners, operators, and other stakeholders for implementing these practices are listed in Section 6.

Table 5.4. Management practices proposed for recommended subwatersheds of the Middle White River.

Practice	Nitrogen	Phosphorus	Coliforms	Turbidity/ Sediment
<b>Developed and Residential Area Management Practices</b>				
Fertilizer use management	X	X		
Media filter	X	X	X	X
Porous pavement	X	X	X	X
<b>Pasture and Hayland Management Practices</b>				
Nutrient management plans	X	X	X	
Livestock stream access control	X	X	X	X
Alternative water supply	X	X	X	X
Heavy use area treatment	X	X	X	X
Prescribed/rotational grazing	X	X	X	X
Pasture planting and improvement	X	X	X	X
Vegetated treatment area	X	X	X	X
Silvopasture establishment	X	X	X	X
Livestock shelter structure	X	X	X	X
Manure/litter or agrichemical storage	X	X	X	
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X
<b>Management Practices for Multiple Land Uses</b>				
On-site wastewater system management/repair/replace	X	X	X	
Riparian buffers	X	X	X	X
Karst protection practices	X	X	X	X
Ponds	X	X	X	X
Wetlands	X	X	X	X
Filter strips	X	X	X	X

## 5.5 Influencing Implementation of Management Practices and Activities

Over the past decade, there has been considerable work conducted on ways of leading and implementing change within organizations and communities (Grenny, et al. 2013). In general, there are three important domains, and two important subdomains within each domain, that are critical in influencing change. The domains are personal, social, and structural and the sub-domains are motivation and ability. These three domains and two sub-domains form a six-celled matrix (Table 5.5).

Table 5.5. Domain, sub-domain, and elements that can influence behavioral change in implementing management practices and activities.

Domain	Sub-domain	
	Motivation	Ability
Personal	Links to Values and Personal Benefits	Training, Skill Building
Social	Peer Pressure	Social Support
Structural	Rewards, Accountability	Change the Environment

In many instances, the emphasis has only been on personal motivation and ability, ensuring that individuals have the motivation to change and are provided with the training and ability to make the change. However, the importance of social elements of peer pressure and support groups (e.g., Neighborhood Associations, Grazing Land Coalition) is also critical in supporting the personal domain. In addition, making changes in the physical environment (i.e., structural domain) through cost-share and rewards (i.e., motivation), and by changing the physical environment in which individuals interact (e.g., native grass pasture vs. fescue or bermudagrass) are also critical in bringing about changes in how land and water are viewed and managed. The key is to simultaneously address all six cells, not just one or two of the cells. In some cases, it might not be possible to address all six, but the emphasis should be on implementing as many of the six cells as possible to encourage and promote change.

Pasture management and stormwater management represent two recommended approaches for improving water quality within the Middle White River watershed. Examples of factors that might influence change for each of the elements in the matrix for these two

management efforts (i.e., pasture management, stormwater management) are shown in Tables 5.6 and 5.7, respectively.

The recommendation is that all six elements of the influence matrix be considered during implementation of management practices and activities in the Middle White River watershed.

Table 5.6. Elements that might help influence implementation of pasture management practices.

Domain	Motivation	Ability
Personal	<ul style="list-style-type: none"> <li>• Better pasture/forage quality</li> <li>• Increased rate of gain</li> <li>• Reduced hay feeding</li> <li>• Sustain water supply</li> <li>• Cost-share programs</li> </ul>	<ul style="list-style-type: none"> <li>• Grazing land conference</li> <li>• Field days</li> <li>• YouTube/other videos</li> <li>• Grazing stick</li> <li>• NRCS tech assistance</li> <li>• UofA Cooperative Ext.</li> </ul>
Social	<ul style="list-style-type: none"> <li>• Leaders implementing practices</li> <li>• Cattleman of the Year Award</li> </ul>	<ul style="list-style-type: none"> <li>• Grazing land coalition</li> <li>• Field days</li> <li>• Rancher to rancher exchanges</li> <li>• Conferences</li> </ul>
Structural	<ul style="list-style-type: none"> <li>• NRCS EQIP funding</li> <li>• NRCS RCPP funding</li> <li>• 319 funding</li> <li>• US Fish and Wildlife Service Controlled Access for Livestock Fencing funding</li> </ul>	<ul style="list-style-type: none"> <li>• Grow grass, not algae campaign</li> <li>• Grazing stick</li> <li>• Promote 2 strand electric fence</li> <li>• AGFC Acres for Wildlife</li> <li>• 4-5 forage paddocks</li> <li>• Stockpile paddock</li> <li>• Alternative water supply</li> </ul>

Table 5.7. Elements that might help influence implementation of stormwater management practices in developed and residential areas.

Domain	Motivation	Ability
Personal	<ul style="list-style-type: none"> <li>• Aesthetics</li> <li>• Reduced flood damage</li> <li>• Cost-share programs</li> </ul>	<ul style="list-style-type: none"> <li>• UofA Cooperative Ext.</li> <li>• The Nature Conservancy technical assistance</li> </ul>
Social	<ul style="list-style-type: none"> <li>• Leaders implementing practices</li> <li>• Conservationist of the Year Award</li> <li>• NPDES permit</li> </ul>	<ul style="list-style-type: none"> <li>• Rain garden demonstrations</li> <li>• Good neighbor YouTube</li> <li>• Master Gardener programs</li> </ul>
Structural	<ul style="list-style-type: none"> <li>• 319 funding</li> <li>• Tax breaks for riparian buffers</li> </ul>	<ul style="list-style-type: none"> <li>• Grow grass not algae campaign</li> <li>• Trash cans for dog waste</li> </ul>

## 5.6 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of the ongoing and proposed monitoring programs and special studies in the Middle White River watershed include:

- Determine compliance with state water quality standards,
- Characterize current water quality conditions, including patterns,
- Characterize water quality trends and impacts, and
- Identify sources of pollutants.

For all water quality monitoring, existing and proposed, it is recommended that the frequency and timing of sampling result in data that meet ADEQ data requirements for evaluation of water quality standards, e.g., assessment methodology, 2018 Integrated Assessment (ADEQ 2018d). For example, at least 8 *E. coli* samples collected per season (primary contact and secondary contact seasons) in a year, and at least 10 dissolved oxygen measurements collected per season (primary and critical seasons) over a two- to five-year period.

### 5.6.1 Routine Surface Water Quality Monitoring

Water quality data are collected from the White River and several of its tributaries at 13 locations through active routine monitoring programs of ADEQ, USGS, and local Stream Teams (supported by AGFC). Sampling locations are mapped on Figure 3.1, and information about these sampling locations is summarized in Table 3.1. Table 5.8 lists water quality parameters monitored through these programs, which include the indicator pollutants, dissolved oxygen and *E. coli*, and other parameters of concern (nitrogen, phosphorus, TSS, temperature). All routine water quality monitoring programs are expected to continue. Note that these monitoring programs are operated according to agency data quality control programs.

Table 5.8. Water quality parameters monitored 2013-2017 in active monitoring programs and studies in the Middle White River watershed.

Parameters	ADEQ ambient	ADEQ roving	ADEQ special study	USGS	Stream Teams
Metals	X	X	X	X	--
Dissolved Oxygen	X	X	X	X	X
Turbidity	X	X	X	--	X
Nutrients	X	X	X	X	X
TSS	X	X	X	--	--
Pathogens			X	X	--
Alkalinity	X	X	X	--	--
Minerals	X	X	X	X	--
Temperature	X	X	X	X	X
Conductivity	X	X	X	X	--
pH	X	X	X	X	X
Hardness	X	X	X	X	--
Total organic carbon	X	X	X	X	--
Suspended sediment	--	--	--	X	--
Organics	--	--	--	X	--

ADEQ routinely monitors surface water quality at seven locations in the Middle White River watershed through different programs. There are four ADEQ ambient water quality monitoring network sites in the watershed that are sampled monthly (Figure 3.1). There are also three ADEQ roving water quality monitoring network sites in the watershed, currently scheduled for sampling in 2024. Roving sites throughout the state are divided into four regional groups. Each group of roving sites is sampled for chemical and bacterial analysis on a rotating basis,

bimonthly over a 2-year period, every 6 years. In addition, there are sites in the watershed where ADEQ is collecting water quality data as part of special studies (ADEQ 2016).

The USGS collects surface water quality data at two flow gage stations in the Middle White River watershed. Historically, the USGS has collected water quality at 35 surface water sites within the Middle White River watershed. Water quality data are no longer collected at the majority of these sites. USGS has collected water quality data within the last 5 years from two of the sites (USGS 2018c). The North Sylamore Creek (07060710) location is sampled as part of the USGS NAWQA program.

In addition to agency water quality monitoring programs, there are three interest groups that are currently monitoring water quality at locations in the Middle White River watershed as part of the AGFC Stream Team program (listed in Table 5.9). Water quality data collected by stream teams is used for water quality screening and planning voluntary water quality or habitat improvement projects, but not for determining if water quality standards are being met (W. Posey, AGFC, personal communication 6/13/18).

Table 5.9. Active Stream Team water quality monitoring locations in the Middle White River watershed (W. Posey, AGFC, personal communication 6/13/18).

Entity	Station Id	Stream	Location	Start Year	End Year
Stream Team 794	1750	Calico Cr	--	2018	2018
Stream Team 794	1708	Calico Cr	--	2016	2018
Stream Team 794	1758	South Sylamore Cr	--	2018	2018
Stream Team 821	1365	Dodd Cr	ASU-Mt. Home campus	2001	2018
Stream Team	1465	Poke Bayou	--	2006	2018

For the ADEQ and USGS water quality monitoring programs, it is recommended that data adequate to assess water quality with regard to state numeric water quality standards, be collected at least once every five years. In particular, it is important to be able to check the status of stream reaches currently included on the state list of impaired waterbodies, Hicks Creek and Greenbrier Creek.

## **5.6.2 Biological Monitoring**

ADEQ is in the process of incorporating more biological surveys into its routine water quality monitoring and assessment programs (T. Wentz, ADEQ, personal communication, 12/11/18). We recommend the continuation of the fish survey programs of the USFS (USFS 2016), University of Oklahoma (Matthews and Marsh-Matthews 2016), and Adams Fish Ecology Lab (University of Central Arkansas 2018) already active in the Middle White River watershed, and invertebrate surveys by Stream Teams. In addition, we suggest regular surveys of populations of aquatic Threatened and Endangered species, and Species of Greatest Conservation Need located within the Middle White River watershed. Regular surveys of populations associated with designated Critical Habitat (White River from Batesville to Black River) and Ecologically Sensitive Waters (Foushee Cave Spring and unidentified spring) are of particular interest. Other than the work done by the USFS, much of the work surveying aquatic species in the Middle White River watershed has been at least partially sponsored and funded by the AGFC through the State Wildlife Grant program. Fish surveys on Piney Creek were funded by EPA (Matthews and Marsh-Matthews 2016).

## **5.6.3 Special Studies**

Special studies are proposed in recommended subwatersheds to evaluate existing water quality, and characterize sources of target nonpoint source pollutants to assist with implementation of management practices. These studies will include data quality assurance planning.

### **5.6.3.1 Proposed Study – Subwatershed Water Quality Assessments**

Two of the recommended subwatersheds, Spring Creek and Miller Creek, have no water quality monitoring data associated with them. However, based primarily on land use, these subwatersheds were ranked high with regard to the potential for water quality issues. Therefore, it is recommended that a set of water quality data be collected from each of these subwatersheds, that can be used to assess whether applicable water quality standards are being met in the primary streams – Spring Creek and Miller Creek. A single water quality monitoring location is

proposed near the downstream end of each of the subwatersheds. Sampling frequency and analytical methods will be determined by ADEQ data requirements for the biannual statewide assessment of water quality. It may be possible for ADEQ to sample these streams as part of the agency roving monitoring program. The studies could also be conducted by a university, or, with outside funding, by the USGS or a contractor.

#### **5.6.3.2 Proposed Study – Dissolved Oxygen Assessment**

ADEQ is having difficulty collecting sufficient dissolved oxygen measurements from Greenbrier Creek and Salado Creek during the critical season to assess attainment of the dissolved oxygen critical season numeric criteria. There are too few incidences of water temperatures above 22°C (i.e., critical condition for dissolved oxygen) during the summer at the water quality stations. This may be because of shading, or inputs of cooler groundwater from springs during the low flow critical period. In order to collect sufficient data points to assess dissolved oxygen, continuous or remote monitoring of dissolved oxygen is recommended for the next roving station monitoring event in the Middle White River watershed, tentatively scheduled for 2024.

#### **5.6.3.3 Proposed Studies – Synoptic Nutrient Sampling Lower Salado Creek**

A synoptic water quality survey is proposed to be undertaken in the Lower Salado Creek subwatershed to identify areas with high loads of nitrogen that may be causing the low dissolved oxygen conditions. This will provide insight into the nonpoint source pollution management practices and implementation locations that will reduce the inputs of nitrogen that may be causing low dissolved oxygen conditions. Proposed sampling locations would be: 1) Upper Salado Creek below the confluence with Bear Branch; 2) Middle Salado Creek below the confluence with McCoy Branch, but above the bifurcation of Salado Creek; 3) Lower Salado Creek below the confluence with Caney Creek; and 4) Lower Salado Creek at the current water quality monitoring station before the confluence with the White River. Two sampling periods are proposed – Spring elevated flow (March/April) and summer low flow (July/August). Duplicate samples would be collected at each site during each sampling period. These surveys

---

could be completed by a local university, or contractor hired by the watershed implementation team or another interest group.

#### **5.6.3.4 Nutrient and Sediment Loads**

The majority of the current water quality monitoring programs active in the Middle White River watershed are not designed to collect the data needed to calculate realistic estimates of nutrient or sediment loads for the White River tributaries. It would therefore be beneficial to develop a new, or updated, model of the watershed to estimate sediment and nutrient loads. An intensive, synoptic study collecting appropriate water quality and flow measurements is recommended to collect data for model input and calibration. ANRC has sponsored load modeling studies for several 8-digit HUC watersheds in the state. The USGS has also conducted water quality modeling studies for several water bodies in the state. If at all possible, the nutrient and sediment loads from this study should be such that they can be compared to previous model results (e.g., SPARROW in USGS 2011), so that it may be possible to track changes in loads over time.

#### **5.6.3.5 Geomorphological Study**

As noted in Section 3.4, no geomorphological studies of areas within the Middle White River watershed were found. If there have not been any such studies, it may be useful to conduct one. Stakeholders attending public meetings during the development of this plan expressed concern about eroding streambanks, particularly along the White River. Available LiDAR, satellite, and aerial imagery may be useful for evaluating the extent of streambank erosion. In addition to sediment, streambank erosion can contribute nutrient loads to surface waters (Watershed Conservation Resource Center 2018).

### **5.7 Evaluation**

This watershed management plan for the Middle White River watershed was developed within an adaptive management framework. Adaptive management is an iterative process of optimal decision-making through evaluating results and adjusting actions based on what has been

---

learned. The evaluation framework outlined below considers three major elements of the implementation of a watershed-based plan: program inputs, outputs, and outcomes. These elements will be evaluated for information/education, monitoring, and implementation of management practices. State and federal agencies, nonprofit organizations, and watershed implementation teams will provide information they have collected about implementation activities to the organization conducting the evaluation.

It is recommended that an evaluation of plan implementation occur approximately every five years. Therefore, the first evaluation of this plan would occur in 2024.

### **5.7.1 Inputs**

The inputs for implementation of this plan are the assistance programs available, and stakeholder participation. Indicators that measure this component of the plan implementation are listed in Table 5.10. The stakeholders and organizations that participate in implementation of this plan should provide the subwatershed implementation teams and/or the evaluating organization with annual totals for these input indicators for the period 2018 through 2023 by February 2024.

Table 5.10. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	Resources spent on monitoring in Middle White River watershed Hours and number of personnel involved
	Stream Teams	Number of inquiries Number of teams formed Number of participants on teams Hours and number of AGFC personnel involved
	Special studies	Resources spent on special studies Hours and number of personnel involved
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conference attendees from Middle White River watershed
	Events – field days, festivals, river clean ups	Number of attendees Hours and number of people involved Cost
	Community presentations	Number of attendees Hours and number of people involved Cost
	K-12 education programs	Number of attendees Hours and number of people involved Cost
	Interest groups meetings, websites, newsletters	Number of meeting attendees Number of website posts/updates Hours and number of people involved Cost
	Middle White River social media	Number of posts, Tweets, etc. Cost
Implement management practices	Assistance programs in the Middle White River watershed	Resources distributed to Middle White River watershed Hours and number of people assisting stakeholders in Middle White River watershed Number of Middle White River watershed stakeholders requesting assistance
	Subwatershed implementation teams	Number of teams active in watershed Number of non-agency people on teams

### **5.7.2 Outputs**

The outputs for implementation of this plan are formation of teams, and implementation of nonpoint source management practices, information and education, monitoring and special studies. Indicators that measure this component of the plan implementation are listed in Table 5.11. The stakeholders and organizations that participate in implementation of this plan should provide subwatershed implementation teams and/or the evaluating organization with annual totals for these indicators for the period 2018 through 2023 by February 2024.

### **5.7.3 Outcomes**

The intended outcomes for this watershed-based management plan include assessment of water quality in Miller and Spring Creek subwatersheds, improvement in water quality and aquatic habitat in Lower Salado Creek subwatershed, prevention of declines in water quality and aquatic habitat in Hicks Creek and Greenbrier Creek subwatersheds, and increased awareness of, and interest in, water quality and aquatic habitat concerns of the Middle White River watershed. The long-term objective of this watershed-based plan is that waterbodies in the Middle White River watershed will meet water quality criteria and attain their designated uses. The primary indicators suggested for this goal are dissolved oxygen and *E. coli* levels. Fecal coliform levels; water temperatures; total nitrogen, total phosphorus, and TSS concentrations; and indicators of biological integrity are suggested as secondary indicators. These parameters, which are currently being monitored at a number of locations, are recommended for use in evaluation of the overall effectiveness of nonpoint source pollution management within the Middle White River watershed. Within the next four to six years, the goal of this plan is to see incremental progress toward the target dissolved oxygen level, and document stakeholder activities contributing to good water quality and quality of life in the Middle White River watershed.

The monitored waterbodies in the Middle White River watershed are assessed by ADEQ every two years to develop the Arkansas integrated water quality assessment report, which includes the 303(d) list of impaired waterbodies. This assessment will be used to evaluate achievement of the goals of delisting impaired waterbodies, and no new impaired waterbodies in the watershed.

Table 5.11. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	Number of active water quality monitoring stations Number of stations sampled Number of water quality parameter measurements collected Number of sampling events Number of biological surveys
	Stream Teams	Number of teams Number of streams monitored Number of active water quality monitoring stations Number of stations sampled Number of water quality parameter measurements collected Number of sampling events Number of invertebrate surveys
	Special studies	Number of studies completed Number of subwatersheds studied Study results reported
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conferences
	Events	Number of events in watershed Number of events outside watershed where watershed information presented
	Community presentation	Number of presentations
	K-12 education programs	Number of programs
	Interest group meetings, websites, newsletters	Number of meetings Number of website visits Number of newsletters distributed
Implement management practices	Assistance programs in the Middle White River watershed	Number/amount of management practices implemented Number of contracts/projects started and finished
	Subwatershed implementation teams	Number of teams formed Number of subwatersheds with teams Number of projects and studies organized by teams

Implementation of this plan will be considered successful if the following are achieved by 2024:

- A watershed implementation team has been formed for at least one recommended subwatershed and initiated at least one project or study;
- Greenbrier Creek is removed from the state impaired waters list;
- Salado Creek at station WHI0166 has been assessed for meeting the Delta Least-altered Stream DO standard;
- Water quality data sufficient for the ADEQ biennial assessment have been collected from Spring Creek and Miller Creek recommended subwatersheds;
- The median total nitrogen values, adjusted for flow, at the routine water quality monitoring station in the Lower Salado Creek recommended subwatershed decreases;
- All dissolved oxygen measurements at the routine water quality monitoring stations in the Hicks Creek and Greenbrier Creek recommended subwatersheds meet the applicable dissolved oxygen numeric criteria; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Middle White River watershed.

If these criteria are not satisfied, the management approaches, scientific knowledge, and stakeholder knowledge and opinions in the recommended subwatersheds will be re-evaluated by the stakeholders involved in managing water quality and nonpoint sources in the recommended subwatershed(s) (e.g., watershed implementation team), and management elements adjusted accordingly. This evaluation will need to take into account the fact that it can take more than five years, or even decades, before water quality improvements resulting from implementation of management measures become apparent (Meals, Dressing and Davenport 2010). The time period required to see significant changes in water quality is, in part, a function of how close water quality measurement locations are to where management activities are implemented.

## **5.8 Update Watershed Management Plan**

Development of the subwatershed implementation plans for the recommended subwatersheds will be part of the update of this watershed management plan. The responsibility for updates to the subwatershed implementation plans will be established in those plans. A comprehensive update of this watershed management plan will be prepared in 2024 by the agency/organization with responsibility for the plan evaluation.

This update will consider and address the following information:

- Results of the evaluation of the implementation of this plan, described in Section 5.7;
- Relevant information about the Middle White River system and how it works, nonpoint source management practices, and pollutant sources in the watershed that has been developed since 2019;
- Changes in water quality related issues in the watershed;
- Changes in water quality management assistance programs; and
- Changes in land use, industry, population, and/or economy in the watershed.

A summary of changes in the watershed over the period since completion of the previous watershed management plan, will be prepared. This summary will be presented at one or more public stakeholder meetings. At the meeting(s), stakeholders will provide input on adjustments to management of, and/or goals for, the Middle White River watershed. This may include a focus on management in other subwatersheds for water quality improvement or protection.

An update of this watershed management plan, utilizing the information from the implementation evaluation and the public meeting(s), and any other information deemed appropriate, will be prepared. This update will be presented at one or more public stakeholder meetings to elicit feedback. The final update of the watershed management plan will then be prepared, incorporating stakeholder comments.

## **5.9 Implementation Schedule**

This section describes the schedule for implementation of this watershed plan for the Middle White River watershed. Table 5.12 summarizes the schedule. Implementation of nonpoint source pollution management practices can start any time. However, it may be more effective, and allow for more efficient use of resources, to wait to implement management practices and information and education programs to reduce nitrogen loads in the Lower Salado Creek subwatershed until after studies have been completed to identify whether the dissolved oxygen water quality standard is being achieved at station WHI0166, and the areas or tributaries contributing to the nutrient load affecting dissolved oxygen. The schedule reflects this approach.

This schedule includes the elements of the adaptive management approach, where practices are implemented, monitoring is conducted to document results, the results are evaluated relative to the goals and criteria specified in the plan, and the plan is modified based on the results of the evaluation, accommodating any changes in regulations, available assistance programs, understanding of the watershed, or management priorities.

Table 5.12. Proposed implementation schedule for Middle White River watershed.

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Monitoring	Roving monitoring program (ADEQ)	2024	2026	Water quality data collection initiated	Number of sampling events	Identify and track changes in water quality Assess water quality relative to water quality standards
	Ambient monitoring program (ADEQ, USGS)	2019	Expected to continue indefinitely	Five additional years of water quality data collected	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	ADEQ aquatic invertebrate surveys (ADEQ)	2021	Expected to continue indefinitely	At least one new survey completed at routine ambient water quality monitoring stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Stream Team aquatic invertebrate surveys (Stream Teams, USGS)	2001	Expected to continue indefinitely	At least three new surveys at active stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Ozark National Forest Fish surveys (USFS)	2007	Expected to continue indefinitely	At least one new survey completed at a previously surveyed location	Number of surveys Number of locations surveyed	All surface waters in Ozark National Forest achieve aquatic life support use
	ADEQ Fish Surveys (ADEQ)	1984	Expected to continue indefinitely	At least one new survey for at least one location	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	USGS North Sylamore Creek Fish Surveys (USGS)	1993	Expected to continue indefinitely	At least one new survey	Number of surveys	North Sylamore Creek achieves aquatic life support use
	Surveys of aquatic species of concern (AGFC, USFS, ANHC)	2002	Expected to continue indefinitely	At least one new survey of a population of aquatic species of concern within the Middle White River watershed	Number of surveys Number of survey locations	Stable populations of designated Threatened and Endangered aquatic species present in Middle White River watershed
Special Studies	Water quality assessment of Spring Creek and Miller Creek (Watershed Implementation Team?)	2021	2023	Spring Creek and Miller Creek water quality assessed as part of a state biennial assessment	Number of sampling events	All surface waters in Middle White River watershed meet water quality standards
	Synoptic nutrient sampling in Lower Salado Creek subwatershed (Southside or Implementation Team)	2026	2027	Decision made about whether synoptic survey is needed	Number of sampling events Number of sampling locations Sources and critical tributaries identified	Salado Creek meets water quality standards
	Nutrient and sediment load estimates (ANRC or USGS)	2021	2023	Load estimates modeled and reported	Load estimates report completed	All surface waters in Middle White River watershed meet water quality standards
	Geomorphological study	2023	2025	Geomorphological study initiated	Geomorphological study plan developed	All surface waters in Middle White River watershed achieve designated uses

Table 5.12. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Information and Education	Outreach and education to homeowners and landscape managers regarding fertilizer use to reduce nitrogen runoff	2023	2025	Outreach initiated in Southside or Mountain Home	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	All surface waters meet water quality standards
	Stormwater pollution prevention outreach in Mountain Home (Subwatershed Implementation Team)	2020	2030	Stormwater pollution prevention outreach program developed and initiated	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	Hicks Creek meets water quality standards
	Onsite wastewater system maintenance outreach (White River Waterkeeper)	2020	2025	Outreach initiated in Hicks Creek, Greenbrier Creek, and Lower Salado Creek subwatersheds	Number of people contacted/reached	All surface waters meet water quality standards
	Outreach through Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	Two field days Four presentations Radio ads Newspaper ads Newsletters mailed & emailed	Number of field days Number of presentations Number of newsletters sent Number of radio & newspaper ads Number of people reached	All surface waters meet water quality standards
Planning	Establish subwatershed implementation teams	2020	2025	At least one team formed	Number of teams	All surface waters meet water quality standards
	Develop subwatershed implementation plans	2021	2025	Preparation of at least one subwatershed implementation plan initiated	Number of plans	All surface waters meet water quality standards
Implement Management Practices	Pasture and hayland management practices in Lower Salado Creek subwatershed through NRCS programs (Independence County Extension Service)	2014	Expected to continue indefinitely	At least two new contracts signed	Number of contracts signed Amount of practices implemented	All surface waters in meet water quality standards
	Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	At least 24 contracts signed At least 55 BMPs implemented At least 60 farm plans	Number of contracts signed Amount of practices implemented Number of farm plans	All surface waters meet water quality standards
	Controlled Access for Livestock Fencing (CALF) (Arkansas Association of Conservation Districts, US Fish and Wildlife Service)	2015	2025	At least 5 new contracts signed in Middle White River watershed	Number of contracts signed Amount of practices implemented	All surface waters meet water quality standards
	Developed and residential area management practices in Hicks Creek and Lower Salado River (Mountain Home, Southside)	2020	2025	Implementation of at least one management practice planned for at least one subwatershed	Number/amount of practices implemented	All surface waters meet water quality standards
	Petition for change of ecoregion designation for monitoring stations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0166) (ANRC)	2019	2020	Ecoregion designation for stations WHI0167 and WHI0166 officially changed.	Greenbrier Creek removed from impaired waters list	Greenbrier Creek meets applicable water quality standards

Table 5.12. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Evaluate	Biennial water quality assessment (ADEQ)	2020	Expected to continue indefinitely	EPA approved final impaired waters lists for 2020 and 2022	Attaining and non-attaining stream reaches in Middle White River watershed	All water quality criteria met in Greenbrier Creek All water quality criteria met in all monitored stream reaches in watershed
	Track implementation of management practices in Middle White River watershed	2019	2025	Information for period 2019 – 2024 compiled	Amount (acres, linear feet, number) of practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches
	Evaluation of watershed management plan	2025	2025	Data needed for evaluation compiled	Evaluation completed Evaluation made public	All water quality criteria met in all monitored stream reaches
Update watershed management plan for Middle White River watershed	Public meetings	2024	2025	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management
	Update watershed management plan	2024	2026	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan complete and approved by ANRC and EPA Recommended subwatersheds identified Stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Middle White River watershed.

## **6.0 IMPLEMENTATION COSTS, BENEFITS, AND ASSISTANCE**

This section of the plan includes estimates of costs expected for implementation of the recommended practices, benefits associated with implementing management practices, and technical and funding assistance available to stakeholders who elect to implement recommended practices.

### **6.1 Implementation Cost Estimates**

The cost information provided below is estimated. Actual costs may differ from those given below.

#### **6.1.1 Planning**

Support for watershed implementation teams is expected to cost approximately \$5,000 per year, for three years. These moneys will provide for team members' travel and expenses associated with meetings.

#### **6.1.2 Monitoring**

The costs of existing routine water quality and biological monitoring in the Middle White River watershed are included in agency budgets.

#### **6.1.3 Proposed Special Studies**

Table 6.1 lists estimated costs for each of the proposed special studies. See Section 5.6.3 for descriptions of the activities included in these cost estimates. In addition, it is expected that ADEQ will conduct water quality monitoring of Spring Creek and Miller Creek as part of an upcoming roving water quality monitoring program. The cost of sampling new water quality monitoring stations for Spring Creek and Miller Creek could range up to \$40,000-\$50,000 per year for the USGS to monitor one site. The cost of sample analysis for, by a commercial laboratory, is estimated to be around \$800 per sample.

Table 6.1. Estimated costs for proposed special studies.

Study	Component Costs	Total Cost
Two-year DO assessment for Greenbrier Creek and Salado Creek (station WHI0166 only)	~\$2,000 per site for equipment \$10,000/year for personnel to manage two sites (install equipment, data retrieval, travel)	\$24,000
One-year Synoptic survey of nutrients in Lower Salado Creek subwatershed	Analysis of 16 samples @\$800/sample (\$14,400) 2 people at \$1,000/trip (\$2,000) \$500 for statistical analysis	\$16,900
Nutrient and sediment load estimates – SWAT model	-	\$130,000

#### 6.1.4 Estimated Cost of Nonpoint Source Pollution Management

Over the years, funding has been provided for implementation of management practices in the Middle White River watershed. There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices in the Middle White River watershed.

The cost of implementing management practices to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Table 6.2 lists available cost information for management practices identified in Section 4.5. While NRCS EQIP reimbursement allocations do not necessarily reflect the actual cost of implementing the practice, they provide an idea of relative costs of the shown management practices.

Table 6.2. EQIP reimbursements (NRCS 2019) and reported implementation costs for selected nonpoint source pollution management practices applicable in the Middle White River watershed.

Practice	Unit	2019 EQIP (non-HU*) reimbursement per unit	Unit Cost
Fence	Feet	\$0.90-\$1.67	\$2.15-\$2.60 <sup>a</sup>
Watering facility	Gallons	\$0.40-\$2.82	--
Watering facility	Each	\$701.34	\$2,000-\$10,000 <sup>a</sup>
Livestock pipeline	Feet	\$1.10-\$3.58	--
Riparian forest buffer plants	Each	\$0.44-\$0.77	--
Riparian forest buffer forgone pasture income	Acres	\$211.70	--
Riparian forest buffer establishment & maintenance	Acres	--	\$218- \$7,112 <sup>a-d</sup>
Riparian herbaceous buffer	Acres	\$188.32-\$307.50	\$168- \$400 <sup>a</sup>
Prescribed grazing	Acres	\$21.30-\$66.59	--
Forage planting	Acres	\$132.65-\$239.18	--
Nutrient management plan written	Each	\$ 1,796-\$ 5,089	--
Nutrient management	Acres	\$4.46-\$29.46	--
Heavy use area protection	Square feet	\$0.57 - \$2.71	--
Vegetated treatment area	Acres	\$ 1,438.67 - \$ 8,619.76	--
Silvopasture establishment	Acres	\$188.15 - \$242.23	--
Livestock shelter structure	Square feet	\$2.47	--
Manure/litter storage structure	Square feet	\$1.80 - \$4.40	--
Agrichemical handling facility	Square feet	\$5.24	--
Feral hog control	Each	\$676.11 - \$751.58	
Media filter	Cubic meters treated water	--	\$5 - \$10,000 <sup>e</sup>
Porous pavement	Square feet	--	\$1.81 - \$74.42 <sup>f</sup>
Ponds	Cubic yard	\$2.61 - \$4.51	--
	Cubic meters of treated water	--	\$3 - \$400 <sup>e</sup>
Constructed wetlands	Square feet	--	\$2.10 - \$12.90 <sup>f</sup>
	Cubic meters of treated water	--	\$5 - \$70 <sup>e</sup>

\* HU = historically underserved producers

<sup>a</sup> (Lynch & Tjaden 2000)

<sup>b</sup> (Butler & Long 2005)

<sup>c</sup> (Whitescarver 2013)

<sup>d</sup> (Washington State University 2006)

<sup>e</sup> (Narayanan and Pitt 2006)

<sup>f</sup> (Herrera Environmental Consultants 2012)

Table 6.3 provides examples of potential relative costs for implementation of selected management practices for pasture and hayland that achieve the target inorganic nitrogen load reduction for the Lower Salado Creek subwatershed. Table 6.4 lists examples of potential costs for implementation of selected management practices for developed areas that achieve the target nitrogen load reduction in the Lower Salado Creek subwatershed. Note that the estimated costs shown in Table 6.3 and 6.4 have been rounded to two significant digits. Calculations for these cost estimates are included as Appendix G.

Part of the difference in the estimated costs for reducing nitrogen inputs from pasture and from developed areas are a result of differences in the cost estimation. However, the fact that nonpoint pollution sources in developed areas tend to be more concentrated, means that removing pollutants from runoff in developed areas can be expensive. In addition, it is usually more expensive to install pollution removal practices in already developed areas, than it is to incorporate them during development, i.e., low impact development.

Table 6.3. Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for pasture and hayland.

Practice	Assumed unit cost	Amount of practice	Estimated cost (\$1,000)
50 foot forested riparian buffer	\$2,000 per acre	49 acres	\$98
50 foot non-forest riparian buffer	\$400 per acre	68 acres	\$27
Restrict livestock stream access	\$1.75 per foot fence, \$1,500 per 1,000-gallon tank	99,000 foot fence 99 tanks	\$320
Prescribed grazing	\$68 per acre	7,000 acres	\$490

Table 6.4. Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for developed areas.

Practice	Assumed cost per cubic meter of runoff treated	Assumed volume of runoff treated (cubic meters)	Estimated cost (\$1,000)
Sand stormwater filter	\$18	37,000	\$660
Stormwater pond	\$7	42,000	\$290
Constructed wetland	\$15	44,000	\$660
Porous pavement	\$5	23,000	\$120

## 6.2 Estimated Economic and Environmental Benefits

While there are costs associated with implementing best management practices, as noted in Section 6.1 above, there are also benefits. Some of these are environmental benefits that are enjoyed by both to the landowner and downstream users. Environmental benefits that humans receive from nature are called ecosystem services, and include goods or products (provisioning services) that typically have market value, such as timber production, commercial fisheries, agricultural production, and biochemical extracts. In addition, there are other services and benefits provided by ecosystems that are not as easy to value economically, but are critical to our quality of life. These include regulating services such as erosion control, improved air and water quality through contaminant removal, and pollination; supporting services such as soil moisture retention, nutrient cycling, and soil formation; and cultural services such as fishing, bird watching, and wildflowers that provide aesthetic pleasure. Additional examples of environmental benefits associated with ecosystem services are listed in Table 6.5.

Table 6.5. Environmental benefits and ecosystem services associated with increased soil health and best management practices.

Ecosystem service or environmental benefit	Description
Contaminant removal	Contaminants (sediment, pathogens, nutrients, heavy metals, pesticides) are absorbed onto soils, chelated by organic matter, filtered from runoff, or taken up by vegetation, reducing contaminant loading/concentrations in receiving waterbodies.
Erosion control	Vegetation, soil cover, or impounded water reduces impacts of rainfall in disrupting soil particles and/or reducing soil transport in runoff, including settling in constructed ponds or wetlands, to receiving waterbodies.
Fish habitat	Riparian vegetation and organic debris reduce soil and bank erosion and provide structure in streams for fish and other aquatic organisms.
Flood mitigation	Soil organic matter, vegetation covering soil, and constructed ponds and wetlands retain water, slow water flow, and attenuate peak flow to reduce flooding.
Forage quality	Improved vegetative cover, soil organic matter, and nutrient cycling increase forage quality for grazing and increase animal production.
Nutrient retention - cycling	Nutrient retention and slow release to crops reduces fertilizer requirements and associated costs, improves yields and reduces nutrient loading to receiving waterbodies. Carbon sequestration?
Soil formation	Vegetation, no/reduced tillage, and mulch add organic matter to soils, increase infiltration, reduce compaction, and improve soil structure and soil health, for potential increased crop yields or animal production.

Table 6.5. Environmental benefits and ecosystem services associated with increased soil health and best management practices. (continued).

Ecosystem service or environmental benefit	Description
Soil moisture retention	Increased soil organic matter from vegetative cover or residue retains water and increases soil moisture. Each 1 percent increase in soil organic matter helps soils hold about 20,000 gallons more water per acre, reducing irrigation costs.
Timber production	Forested riparian buffers and silvopasture can provide harvestable timber for additional revenue.
Water purification	Contaminant sorption, filtering through soils and vegetative/organic debris, and uptake improves water quality by purifying the water.
Waterfowl habitat	Constructed ponds and wetlands increase habitat for waterfowl.
Wildlife habitat	Filter strips, riparian buffers, pastures of native grasses and forbs, and conservation reserve lands, some of which many be leased for hunting, provide additional habitat for pollinators, sport birds, sportfish, and other wildlife.

Best management practices proposed for the Middle White River subwatersheds recommended for initial management are listed in Table 6.6 along with the environmental benefits that accrue from the implementation of these practices. While not all of these benefits have directly marketable economic value, there have been economic assessments of several of them. For example, excluding cattle from streams, providing alternative water supplies, and rotational grazing have resulted in increased cattle production, which has a direct economic value. Alternative water supply alone was documented to improve production in steers and heifers from 0.6 to 1.8 lb/day through reduction in foot rot, bovine virus diarrhea, fever, tuberculosis, and environmental mastitis (Faulkner 2000, Zeckoski, Benham and Lunsford 2012). In Missouri, beef cattle raised and finished on high quality pasture through prescribed grazing had an average daily gain of two or more pounds and reached marketable weight within 20 months (NRCS 2006). One of the hazards for stream exclusion is flooding, which can destroy fences, requiring repeated replacement. GPS-enabled ear tags, currently being researched at the USDA Jornada Experimental Rangeland, will, in the near future, eliminate the need for actual fences, reduce the effects of flooding on stream exclusion, and reduce the time required to move cattle from one area to another (<http://www.ediblegeography.com/invisible-fences-an-interview-with-dean-anderson-2/>).

Table 6.6. Environmental benefits associated with implementing best management practices in the Middle White River subwatersheds.

Best Management Practice	Contaminant removal	Erosion control	Fish habitat	Flood mitigation	Forage quality	Nutrient retention	Soil formation	Soil moisture	Timber production	Water purification	Wildlife habitat
Riparian buffer	•	•	•	•		•			•	•	•
Livestock stream access control	•	•	•	•	•	•	•	•		•	•
Pasture planting	•	•		•	•	•	•	•		•	•
Prescribed grazing	•	•		•	•	•	•	•		•	•
Filter strips	•	•		•	•	•	•	•		•	•
Farm pond, stormwater detention or retention pond	•	•	•	•		•		•		•	•
Silvopasture	•	•		•	•	•	•	•	•	•	•
Nutrient management	•				•	•	•				
Control of invasive and destructive species		•	•		•	•					•
Karst protection practices	•	•	•			•				•	•
Constructed wetland	•	•	•	•		•				•	•
Porous pavement	•	•		•		•		•		•	

## **6.3 Technical Assistance**

### **6.3.1 Monitoring**

Agencies and universities conducting water quality monitoring generally have their own technical resources. Technical assistance for volunteer water quality monitoring programs is available through the AGFC Stream Team Program.

### **6.3.2 Information and Education**

Information for and assistance with education and outreach activities is available through the ADEQ Public Outreach and Assistance Division, Watershed Conservation Resource Center, Clear Choices Clean Water, Arkansas Cooperative Extension Service, and others. A number of resources are also available from EPA through the Nonpoint Source Outreach Toolbox (<http://cfpub.epa.gov/npstbx/index.html>).

The ADEQ Public Outreach and Assistance Division offers technical assistance and resources to interested citizens and groups. The Watershed Outreach and Education program of this division provides “a variety of tools and services to facilitate and promote awareness, appreciation, knowledge, and stewardship of water resources” (ADEQ 2019).

Arkansas Cooperative Extension Service implements stormwater education programs required by municipal storm runoff NPDES permits in Northwest and Southeast Arkansas (UofA Division of Agriculture Cooperative Extension Service 2018). Information and education sources related to public education about urban stormwater (see Section 5.5.1) are available on the Arkansas Cooperative Extension Service website, <https://www.uaex.edu/environment-nature/water/stormwater/default.aspx>.

### **6.3.3 Technical Assistance for Nonpoint Source Pollution Management**

There are a number of sources for technical assistance for management practices in recommended subwatersheds. These are summarized in Table 6.7 and discussed below.

Table 6.7. Examples of sources of technical assistance for nonpoint source management practices for the Middle White River watershed.

Practice	UofA Division of Agriculture Cooperative Extension Service	County Conservation Districts	NRCS, Farm Services Agency	AGFC	Arkansas Department of Parks and Tourism	ANRC	US Fish and Wildlife Service	USFS	The Nature Conservancy
Fertilizer use management	X					X			
Media filter						X			
Porous pavement						X			
Nutrient management plans	X	X	X			X			
Livestock stream access control	X	X	X			X			X
Alternative water supply		X	X			X			
Heavy use area treatment	X	X	X			X			
Prescribed/rotational grazing	X	X	X			X			X
Pasture planting and improvement	X	X	X	X		X	X		
Vegetated treatment area		X	X			X			
Silvopasture establishment		X	X			X			
Livestock shelter structure		X	X			X			
Manure/litter or agricultural storage		X	X			X			
Riparian buffers	X	X	X	X	X	X	X	X	X
On-site wastewater system management/repair/replace									
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X			X		
Karst protection practices		X	X			X	X		X
Ponds	X	X	X	X		X			
Constructed wetlands		X	X			X			
Filter strips	X	X	X	X		X	X		X

### **6.3.3.1 County Conservation Districts**

Conservation Districts for the counties in the Middle White River watershed are active in nonpoint source management within the watershed. They work closely with NRCS to provide technical support to landowners, including information and guidance about management practices for protecting soil and water resources, including benefits, costs, implementation, and maintenance.

Conservation Districts within the Middle White River watershed can provide technical support through a number of special projects including the Feral Swine Initiative, Acres for Wildlife, Controlled Access for Livestock Fencing, and Quail Special Project. The Middle White River watershed is within one of the target areas for the Controlled Access for Livestock Fencing program (Arkansas Association of Conservation Districts 2015). Baxter County, Izard County, and Stone County are part of the North Focal Landscape for the Arkansas Quail Special Project (AGFC n.d.).

### **6.3.3.2 UofA Division of Agriculture**

The UofA Cooperative Extension Service provides technical assistance through a range of programs and services including testing of manure, hay, soil, and water; assistance with rotational (prescribed) grazing, nutrition and feeding of livestock, sprayer calibration, and grassland management; and field days and on-farm demonstrations. Cooperative Extension Service also maintains an extensive library of up-to-date, research-based fact sheets, applied research publications, and best management practice manuals and guidelines. The Arkansas Cooperative Extension Service includes practices to keep fertilizer out of runoff in its factsheet “Fertilizing Your Lawn” available on their website (Patton 2008).

The experiment station program of the UofA Division of Agriculture generates, interprets, and distributes information and technology useful to farmers in Arkansas.

### **6.3.3.3 Arkansas Game and Fish Commission**

Through the AGFC Private Lands Program and Acres for Wildlife Program, Private Lands Biologists can provide technical assistance to volunteer landowners and tenants with

---

managing their lands to improve both upland and aquatic wildlife habitat, in working pastures and haylands, farm ponds, and in set-aside areas like fenced-off riparian areas. AGFC is working with the National Bobwhite Conservation Initiative to help restore quail habitat in Arkansas. The majority of the Middle White River watershed is classified as having a medium quail restoration potential (Jackson, et al. 2015). Through the relatively new Native Warm Season Grass/Forb component of the Acres for Wildlife Program, free technical assistance is available on managing pastures to improve habitat for bobwhite quail and other wildlife. AGFC biologists can also assist landowners and tenants with controlling invasive and destructive species, such as feral hogs. Management actions that improve wildlife habitat usually also improve water quality and reduce nonpoint source pollution.

#### **6.3.3.4 ANRC**

The ANRC provides technical assistance with management practices, implementation, and funding to stakeholders through the Nonpoint Source Pollution Management program, primarily through direct contact with stakeholders. In many cases, ANRC acts as a clearinghouse for stakeholders, directing them to personnel and programs in other agencies where stakeholders can get the assistance they need.

#### **6.3.3.5 NRCS and Farm Services Agency**

The NRCS offers several programs to help landowners address natural resources concerns related to pasture management, including the Grazing Lands Conservation Initiative. NRCS grassland specialists can work with farmers on resource assessments of pastures to design effective grazing systems. These specialists also provide guidance on implementation and maintenance of these grazing systems. All owners and managers of private grazing lands are eligible for NRCS technical assistance (NRCS 2018).

Technical assistance is available for a variety of practices through EQIP. Assistance is available for planning and implementing pasture management, restricted livestock stream access, nutrient management, upland and aquatic wildlife habitat improvement, farm ponds, constructed wetlands, and feral hog capture. Farm Services Agency (FSA) also provides technical assistance

planning and implementing habitat improvement on Conservation Reserve Program lands through their programs, such as State Acres for Wildlife Enhancement Initiative and Pollinator Habitat Initiative (FSA 2018).

#### **6.3.3.6 Southern Sustainable Agriculture Research and Education**

The Sustainable Agriculture Research and Education program (SARE) of the USDA supports farmers, researchers, and educators exploring practices that improve farm stewardship and profitability, and the vigor of farm communities. The program emphasizes outreach and distribution of the results of program research. This information is available from the program website and includes a variety of print and electronic materials appropriate for producers (<http://www.southernsare.org/About-Us>).

#### **6.3.3.7 The Nature Conservancy**

The Nature Conservancy manages the Strawberry River Preserve and Demonstration Ranch to showcase economically feasible and sustainable specialized grazing techniques that protect streambanks and stream ecology. Training workshops and technical assistance for these techniques are available from The Nature Conservancy (The Nature Conservancy 2015). Through their Ozark Highlands Karst program, The Nature Conservancy has worked with communities, developers, and farmers to develop management plans to protect water quality and biota in caves in the karst area of Arkansas (<https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml>).

#### **6.3.3.8 US Environmental Protection Agency**

The EPA website provides access to information on a variety of water quality subjects, including management measures. In particular, information on stormwater management practices for developed and residential areas, including Low Impact Development, is available.

### **6.3.3.9 US Fish and Wildlife Service**

Through its Partners for Fish and Wildlife program the US Fish and Wildlife Service provides technical assistance to private landowners on projects to protect, improve, or restore native habitat. Habitat for endangered species, such as the Rabbitsfoot mussel, is a priority for this program. Assistance is available for designing, installing, and maintaining habitat-enhancing projects, including restoration of riparian habitats, stream habitat, forest, and native grasslands, and protecting karst habitats ([https://www.fws.gov/arkansas-es/PFW\\_Habitat.html](https://www.fws.gov/arkansas-es/PFW_Habitat.html), [https://www.fws.gov/arkansas-es/proj\\_pfw.html](https://www.fws.gov/arkansas-es/proj_pfw.html)).

### **6.3.3.10 US Forest Service**

The USFS develops and makes available technical resources on a range of subjects related to forest management that can be useful to individual landowners, and to communities. Programs are available to assist with stewardship of privately-owned forest land, agroforestry (including silvopasture), and management of trees and forested areas within urban areas and communities (<https://www.fs.fed.us/managing-land/private-land>, <https://www.urbanforestrysouth.org/>). Forested riparian buffers can be used as agroforestry elements in pastures, and as a way to restore lost canopy cover in developed areas.

## **6.4 Financial Assistance**

This section describes programs that can provide financial assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide funding assistance.

### **6.4.1 Monitoring**

ADEQ, USFS, and USGS have funded water quality monitoring projects in the Middle White River watershed. The monitoring programs in the Middle White River watershed are self-funded. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds.

The AGFC Stream Team program can also provide funding for volunteer monitoring programs through mini-grants. ANRC can assist with funding water quality monitoring projects. In 2017, ANRC contributed to water quality monitoring projects in the state that totaled around \$500,000 (ANRC 2017).

State Wildlife Grant funding from the AGFC has been used for biological surveys and monitoring projects in the Middle White River watershed. In 2016, \$577,051 of federal funds were distributed as State Wildlife Grants in Arkansas (<https://www.wildlifearkansas.com/grants.html>).

#### **6.4.2 Information and Education**

Projects funded through the ANRC Nonpoint Source Pollution Management Program (Section 319[h] funds) usually include an education and outreach component. In 2017, approximately \$300,000 were spent on outreach projects in Arkansas through the ANRC 319 grant program. Eighteen percent of these funds were spent on outreach projects (ANRC 2017).

Projects funded through NRCS and Farm Services Agency cost-share and easement programs are often used as demonstrations in NRCS and Conservation District outreach and education programs.

The Arkansas Grazing Lands Coalition sponsors field days.

There are several private foundations that fund education, and which may fund environmental education. The EPA also provides grants for environmental education (<http://www2.epa.gov/education/environmental-education-ee-grants>).

In addition, organizations can often find local businesses or organizations to sponsor information and education activities, such as painting storm drains, festivals, and clean-up days.

### **6.4.3 Nonpoint Source Pollution Management**

There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices recommended for the Middle White River watershed. The majority of these are grant programs, many of which require matching funds from the grant recipient. In addition, at least one tax incentive program is active that addresses practices that reduce nonpoint source pollution. Table 6.8 lists management practices for the recommended subwatersheds along with selected funding sources. It is notable that many federal assistance programs are seeing reductions in available funds. However, it is also notable that use of many of these practices can improve the bottom line for producers or communities (see Section 6.2).

#### **6.4.3.1 NRCS**

There are NRCS programs active in Arkansas that provide funding assistance for development and installation of nonpoint source pollution management practices that are applicable to the recommended subwatersheds of the Middle White River. These programs provide funding to individuals rather than groups or organizations. This includes the Conservation Stewardship Program and EQIP. In these programs, a cost-share is usually required. Information about these programs, including application deadlines, cost-share requirements, and funding caps, is available online (<http://www.ar.nrcs.usda.gov/programs/>) or from a local USDA service center, local conservation district, or local cooperative extension agents. Table 6.9 shows funding provided to individuals in the counties of the Middle White River watershed during the 2017 fiscal year (NRCS 2017a). The 2018 Farm Bill has increased available funding for a number of conservation programs, including EQIP and Conservation Stewardship Program (National Sustainable Agriculture Coalition 2018). The 2019 fiscal year national budget for the EQIP program is \$1,614 million. For the Conservation Stewardship Program, the 2019 fiscal year national budget is \$1,645 million (USDA 2018).

Table 6.8. Examples of programs that can provide funding assistance for recommended nonpoint source management practices.

	Conservation Stewardship Program	Environmental Quality Incentives Program	Conservation Reserve Program	Partners for Fish and Wildlife	Nonpoint Source Program	State Wildlife Grants	Outdoor Recreation Grants	Aquatic Habitat Restoration Program	Controlled Access for Livestock Fencing
Lead/Contact Organization	NRCS	NRCS	FSA	US Fish and Wildlife Service	ANRC	AGFC	Arkansas Department of Parks and Tourism	Southeast Aquatic Resources Partnership	County Conservation Districts, US Fish and Wildlife Service
Who can receive funds	Individuals	Individuals	Individuals	Individuals, counties, organizations	Cities, counties, organizations	State agencies, organizations	Communities, county government	Agencies, organizations	Individuals
Practices that may be funded:									
Fertilizer use management									
Media filter					X				
Porous pavement					X				
Stormwater pond									
Riparian buffers	X	X	X	X	X		X	X	
Filter strips of native plants	X	X	X	X	X	X			
Control of invasive and destructive species		X							
Septic system repair/replace									
Nutrient management	X	X							
Pasture planting and improvement	X	X	X	X					
Farm pond/sediment basin construction		X							
Livestock stream access control	X	X		X	X				X
Prescribed/rotational grazing	X	X							X
Silvopasture establishment	X	X							
Control of invasive and destructive species (e.g., feral hogs)		X							
Karst protection practices		X		X		X			

Table 6.9. Financial assistance provided by NRCS programs to Middle White River counties in 2017 (NRCS 2017a).

County	EQIP	Conservation Stewardship Program
Baxter	\$216,066	\$165,185
Independence	\$312,411	\$531,421
Izard	\$929,844	\$81,435
Stone	\$496,269	\$136,181

#### 6.4.3.2 Farm Services Agency

The Farm Services Agency administers the Conservation Reserve Program (CRP). Through this land conservation program, landowners receive yearly rental payments for land enrolled in the program. CRP land contracts typically are for 10 to 15 years. Marginal pasture land along streams that can be used for establishment of riparian buffers can be eligible for CRP enrollment. In addition to rental payments, the Farm Services Agency may pay up to 50% of eligible costs for establishing riparian buffers or filter strips (<https://www.fsa.usda.gov/programs-and-services/conservation-programs/prospective-participants/index>).

#### 6.4.3.3 US Fish and Wildlife Service

There are two US Fish and Wildlife Service programs active in the Middle White River watershed that provide funding assistance for development and installation of nonpoint source pollution management practices. Funding is available for individuals through the US Fish and Wildlife Service Partners for Fish and Wildlife program, and the Controlled Access for Livestock Fencing program (in cooperation with the Arkansas Association of Conservation Districts). Funding from these programs may require cost-share. The 2019 fiscal year national budget for the Partners for Fish and Wildlife program is \$36 million (US Department of the Interior 2018). It is unknown how much of these funds will be available for projects in Arkansas, or in the Middle White River watershed.

#### 6.4.3.4 ANRC

ANRC manages the state Section 319 grant program. This program provides grants to non-profit groups, organizations, communities, and academic institutions for projects related to

reduction, control or abatement of nonpoint source pollution. Eligible projects can include implementation of best management practices on pastures, as well as stormwater management and low impact development practices in developed areas. Organizations seeking grants must be capable of implementing projects, and are typically required to provide a minimum of 43% non-federal matching contributions. In 2017, approximately \$1.99 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Thirty-three percent of these funds were spent on implementation of management practices (ANRC 2017). The Section 319 grant program is not funded in 2019 proposed presidential budget (EPA 2018b).

#### **6.4.3.5 Arkansas Department of Parks and Tourism**

The Arkansas Department of Parks and Tourism manages grant programs to assist communities with developing or improving outdoor recreation areas. Riparian buffers can be incorporated in community parks and recreation areas.

#### **6.4.3.6 Non-monetary Implementation Support**

Agencies, organizations, and individuals can support implementation of nonpoint source management practices in ways other than providing funds. One way is through the loan of equipment. The AGFC has specialized equipment that can be loaned to landowners for establishment of native warm season grasses and forbs. Over ten years ago, the Newton County Conservation District purchased equipment to be rented to landowners, including a no-till drill, roto-wiper for herbicide application, and a lime spreader. AGFC, USDA-APHIS Wildlife Services, and some Conservation Districts, have feral hog trapping equipment available for short-term loan through the Feral Hog Initiative (Sanders 2016).

Another method of non-monetary support is offering free or low-cost materials. An example is the AGFC competitive program under their Acres for Wildlife initiative, which provides warm season grass seed and herbicide to landowners who want to establish native habitat for bob-white quail (AGFC 2016). Another example is the provision of low-cost or free

tree seedlings by the Arkansas Forestry Commission, Arkansas Urban Forestry Council, and National Arbor Day Foundation.

#### **6.4.3.7 Tax Incentives**

Tax incentives are a slightly different financial mechanism for encouraging the use of management practices. The Arkansas Private Wetland and Riparian Zone Creation, Restoration, and Conservation Tax Credits Act of 1995 allows the application of a tax credit against Arkansas state taxes by taxpayers involved in conservation or restoration of riparian zones. Detailed information on this program is available from ANRC, who manages the program (<http://anrc.ark.org/divisions/water-resources-management/wetlands-riparian-zone-tax-credit/>).

## 7.0 REFERENCES

- Adams, Ginny, and Reid Adams. 2015. "Use of Historical and Current Collections to Assess the Distribution and Status of Fishes in the Ouachita, Strawberry, and White River Drainages." *Arkansas Wildlife Action Plan*. March. Accessed August 2018.  
<https://www.wildlifearkansas.com/proposals/2015Preproposals/Use%20of%20Historical%20and%20Current%20Collections%20to%20Assess%20the%20Distribution%20and%20Status%20of%20Fishes%20in%20the%20Ouachita,%20Strawberry%20and%20White%20River%20Drainages.pdf>.
- Adams, Ginny, Reid Adams, and Matthew Connolly. 2017. "Using Historical and Current Collections to Assess Stream Geomorphology, and Fish Assemblages in the Spring, Myatt, Eleven Point, and Current River Drainages." *Arkansas Wildlife Action Plan - State Wildlife Action Plan Preproposals for 2017*. March 21. Accessed August 2018.  
<https://www.wildlifearkansas.com/proposals/2017Preproposals/Preproposals2017.html>.
- Adamski, J.C., J.C. Petersen, D.A. Friewald, and J.V. Davis. 1995. *Environmental and Hydrologic Setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma*. Water Resources Investigation Report 94-4022, USGS.
- ADEQ. 2008. "Final Impaired Waterbodies List 2008." *Arkansas's Draft Water Quality Limited Waterbodies - 303(d) List*. Accessed January 2015.  
[http://www2.adeq.state.ar.us/water/branch\\_planning/303d/pdfs/2008\\_impaired\\_waterbodies\\_list\\_303%28d%29.pdf](http://www2.adeq.state.ar.us/water/branch_planning/303d/pdfs/2008_impaired_waterbodies_list_303%28d%29.pdf).
- ADEQ. 2016. *Integrated Water Quality Monitoring Assessment Report*. 305(b) 303(d), Little Rock: ADEQ.
- ADEQ. 2017. "Final 2016 303(d) List." *Arkansas' Final/Draft Impaired Waterbodies - 303(d) List by Year*. Accessed June 2018.  
<https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/final-2016-303d-list.pdf>.
- ADEQ. 2018a. "Draft 2018 303(d) list." *Arkansas' Final/Draft Impaired Waterbodies - 303(d) List by Year*. July. Accessed October 2018.  
<https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx>.
- ADEQ. 2018b. *Biological Monitoring - Fish Data*. Accessed May 2018.
- ADEQ. 2018c. *Biological Monitoring - Macroinvertebrate Data*. Accessed June 2018.  
<https://www.adeq.state.ar.us/water/planning/surface/macroinvertebrates.aspx>.
- ADEQ. 2018d. "2018 Assessment Methodology." *Arkansas Final/Draft Impaired Waterbodies - 303(d) List by Year*. July. Accessed October 2018.  
<https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx>.
-

- ADEQ. 2018e. *ADEQ Facility and Permit Summary*. May. Accessed May 22, 2018.  
<https://www.adeq.state.ar.us/home/pdssql/pds.aspx>.
- ADEQ. 2018f. *ADEQ AquaView*. Accessed January 2019.  
<http://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=6df7f199a3e45f99c0a970cb6acf3a2>.
- ADEQ. 2019. *Watershed Outreach and Education Program*. Accessed January 2019.  
<https://www.adeq.state.ar.us/poa/watershed/>.
- AGFC. 2016. *Acres for Wildlife Program*. Accessed September 2017.  
<https://www.agfc.com/en/get-involved/in-the-field/acres-for-wildlife/>.
- AGFC. n.d. "Bringing Back the Bobwhite." *Arkansas Bobwhite Quail Resources*. Accessed December 2018. <https://www.agfc.com/en/hunting/small-game/quail/arkansas-bobwhite-quail-resources/>.
- Aley, Thomas, and Cathy Aley. 1985. "Water Quality Protection Studies Hell Creek Cave, Arkansas."
- Aley, Thomas. 1980. "Delineation of the Recharge Area for Blanchard Springs and the Identification, Location, and Evaluation of Water Quality Hazard Area."
- ANRC. 2007. *Nonpoint Source Pollution Management Program Arkansas 2006 Annual Report*. ANRC.
- ANRC. 2010. *Arkansas 2009 Annual Report*. ANRC.
- ANRC. 2017. *The Arkansas Annual Report, FY 2017*. ANRC.
- Arkansas Agriculture Department. 2018. *Arkansas Feral Hog Eradication Task Force*. Accessed October 2018. <https://www.agriculture.arkansas.gov/feral-hog-eradication-task-force>.
- Arkansas Association of Conservation Districts. 2015. *Special Projects*. Accessed October 2018.  
[https://aracd.org/special\\_projects/default.htm](https://aracd.org/special_projects/default.htm).
- Arkansas Cooperative Extension Service. 2018. *Controlling Feral Hogs in Arkansas*. Accessed October 2018. <https://www.uaex.edu/environment-nature/wildlife/feral-hogs.aspx>.
- Arkansas Department of Health. 2017. *Drinking Water Information for Arkansans*. Accessed September 2018. <https://www.healthy.arkansas.gov/programs-services/topics/drinking-water-information-for-arkansans>.
- Arkansas Department of Parks and Tourism. 2017. *2017 Arkansas Tourism Economic Impact*. Little Rock, AR: Arkansas Department of Parks and Tourism.
- Arkansas Geological Survey. 2001. "Arkansas Mineral Resources." *Arkansas Geological Survey*. July. Accessed August 2018.  
<https://www.geology.arkansas.gov/pdf/Arkansas%20Mineral%20Resources%20.pdf>.
-

- Arkansas Geological Survey. 2015. *Stratigraphy, Ozark Plateaus*. Accessed September 2018. [http://www.geology.ar.gov/geology/strat\\_ozark\\_plateaus.htm](http://www.geology.ar.gov/geology/strat_ozark_plateaus.htm).
- Arkansas Geological Survey. 2018. *Mineral Commodity Search/Map*. Accessed May 2018. [http://www.geology.ar.gov/minerals/amc\\_map.htm](http://www.geology.ar.gov/minerals/amc_map.htm).
- Arkansas Grazing Lands Coalition. 2017. *Programs and Projects*. Accessed August 17, 2017. [http://www.argrazinglandscoalition.org/programs\\_projects.html](http://www.argrazinglandscoalition.org/programs_projects.html).
- Arkansas Natural Heritage Commission. 2018. *Rare Species Search Engine*. Accessed April 2018. <http://www.naturalheritage.com/Research-and-Data/rare-species-search>.
- Arkansas Pollution Control and Ecology Commission. 2014. *Regulation No. 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas*. Little Rock: Arkansas Pollution Control and Ecology Commission.
- Arkansas State Board of Health. 2014. *Rules and Regulations Pertaining to Onsite Wastewater Systems*. Regulation, Arkansas Department of Health. <https://www.healthy.arkansas.gov/programs-services/topics/onsite-wastewater>.
- Association of Arkansas Counties. 2018. *Association of Arkansas Counties*. Accessed February 2017. <http://www.arcounties.org>.
- Bagshaw, CS, B Thorrold, M Davison, LJH Duncan, and LR Matthews. 2008. "The influence of season and providing a water trough on stream use by beef cattle grazing hill-country in New Zealand." *Applied Animal Behaviour Science* 155-166.
- Bagstad, Kenneth, Darius Semmens, Sissel Waage, and Robert Winthrop. 2013. "A comparative assessment of decision-support tools for ecosystem services quantification and valuation." *Ecosystem Services* 5: 27-39.
- Barry, Jon. n.d. *Forests and Urban Stormwater*. FSA5029, University of Arkansas Division of Agriculture.
- Bradley, Patricia, and Susan Yee. 2015. *Using the DIPSR Framework to Develop a Conceptual Model: Technical Support Document*. EPA/600/R-15/154, Narragansett, RI: US Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division.
- Brasel, Karen, and Margaret Lonadier. 2004. *Little Buffalo River Streambank Stabilization Project*. Arkansas Natural Resources Commission.
- Butler, Sally, and John Long. 2005. *Economics and Survival of Hand-planted Riparian Forest Buffers in West Central Maine*. Bangor: US Natural Resources Conservation Service.
- Center for Advanced Spatial Technologies. 2006. *Arkansas Watershed Information System*. Accessed July 2018. <http://watersheds.cast.uark.edu/viewhuc.php?hucid=11010004>.
- Center for Advanced Spatial Technologies. 2006. *Middle White*. Accessed July 2018. <http://watersheds.cast.uark.edu/viewhuc.php?hucid=11010004>.
-

- Center for Watershed Protection. 2007. *National Pollutant Removal Performance Database, version 3*. Center for Watershed Protection.
- Clary, Jane, Johnathan Jones, Marc Leisenring, Paul Hobson, and Eric Strecker. 2017. *International Stormwater BMP Database 2016 Summary Statistics*. Water Environment & Reuse Foundation.
- Dauwalter, Daniel, Edmund Pert, and William Keith. 2003. "An index of biotic integrity for fish assemblages in Ozark Highland streams of Arkansas." *Southeastern Naturalist* 447-468.
- EPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. 841-B-08-002, Washington DC: EPA.
- EPA. 2013. *National Aquatic Resource Surveys*. September 12. Accessed July 2018. [http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey\\_index.cfm](http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm).
- EPA. 2018a. *Enforcement Compliance History Online, Effluent Limit Exceedences Report*. December. Accessed January 15, 2019. [https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedences/?permit\\_id=ARR000063](https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedences/?permit_id=ARR000063).
- EPA. 2018b. *FY 2019 Budget in Brief*. EPA-190-R-18-002, Washington, DC: US Environmental Protection Agency. <https://www.epa.gov/planandbudget/fy-2019-epa-budget-brief>.
- Faulkner, David. 2000. "Economics Section." In *Virginia Forage and Grassland Council Grazing Handbook*, by Natural Resources Conservation Service. unpublished.
- Fowler, Allison (Ed). 2015. *Arkansas Wildlife Action Plan*. Little Rock, AR: Arkansas Game and Fish Commission.
- Friends of the North Fork and White Rivers, Inc. 2007. *Watershed Restoration Action Strategy (WRAS) for the North Fork and White Rivers (Middle White River Watershed)*. Friends of the North Fork and White Rivers, Inc.
- Friends of the North Fork and White Rivers. 2018. *Friends of the North Fork and White Rivers*. Accessed January 15, 2019. <http://friendsoftherivers.org/education-action/home/>.
- FSA. 2018. *Conservation Reserve Program*. June. Accessed January 2019. <https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index>.
- Garrett, H.E. 2011. "Silvopasture Ecosystem Services." *Publications*. November. Accessed May 2017. <http://www2.dnr.cornell.edu/ext/info/pubs/>.
- Geosyntec Consultants. 2018. *International Stormwater Database - Query Builder*. Accessed October 2018. <http://www.bmpdatabase.org/bmpstat.html>.
- Gilip, Johnathan, Joel Galloway, and Rheannon Hart. 2009. *Assessment of Local Recharge Area Characteristics for Four Caves in Northern Arkansas and Northeastern Oklahoma, 2004-07*. Scientific Investigations Report 2009-5118, Reston, VA: US Geological Survey.
-

- Graening, G.O., Michael Slay, and Karen Tinkle. 2003. "Subteranean biodiversity of Arkansas, Part 1: Bioinventory and bioassessment of caves in the Sylamore Ranger District, Ozark National Forest, Arkansas." *Journal of the Arkansas Academy of Science*, Vol. 57 44-58.
- Grant, Laura, and Christian Langpap. 2018. "Private provision of public goods by environmental groups." *Proceedings of the National Academy of Sciences of the United States of America*. <https://www.pnas.org/content/early/2018/10/02/1805336115>.
- Grenny, Joseph, Kerry Patterson, David Maxfield, Ron McMillan, and Al Switzler. 2013. *Influencer: The Science of Leading Change, Second Edition*. McGraw Hill.
- Grizzetti, Bruna, Denis LanzaNova, Camino Liquiete, Arnaud Reynaud, and Anna C Cardoso. 2016. "Assessing water ecosystem services for water resources management." *Environmental Science and Policy* 61: 194-203.
- Herrera Environmental Consultants. 2012. "Technical Memorandum for Puget Sound Stormwater BMP Cost Database." January. Accessed January 2019. <https://fortress.wa.gov/ecy/publications/othersupplements/1303009other.pdf>.
- Hobbie, Sarah, Jacques Finlay, Benjamin Janke, Daniel Nidzgorski, Dylan Millet, and Lawrence Baker. 2017. "Contrasting nitrogen and phosphorus budgets in urban watersheds and implications for managing urban water pollution." *PNAS* 4177-4182.
- Homer, CG, JA Dewitz, L Yang, S Jin, P Danielson, G Xian, J Coulston, ND Herold, JD Wickham, and K Megown. 2015. "Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information." *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5 345-354.
- Inlander, Ethan, Cory Gallipeau, and Michael Slay. 2011. *Mapping the Distribution, Habitat, and Threats for Arkansas' Species of Greatest Conservation Need*. The Nature Conservancy.
- Izard County Conservation District. 2008. *05-500 Final Report*. ANRC.
- Jackson, Clifton, Allison Fowler, Steven Fowler, Jason Honey, Brian Infield, Trevor Mills, Eley Talley, and Ted Zawislak. 2015. *Strategic Quail Management Plan*. Arkansas Game and Fish Commission.
- Jacobson, Robert B, and Alexander T Primm. 1997. *Historical Land-use Changes and Potential Effects on Stream Disturbance in the Ozark Plateaus, Missouri*. Water Supply Paper 2484, USGS.
- James, E, P Kleinman, T Veith, R Stedman, and A Sharpley. 2007. "Phosphorus contributions from pastured dairy cattle to streams of the Cannonsville Watershed." *Journal of Soil and Water Conservation* 40-47.
- Justus, B, James Petersen, Suzanne Femmer, Jeri Davis, and J Wallace. 2010. "A Comparison of Algal, Macroinvertebrate, and Fish Assemblage indices for assessing low-level

- nutrient enrichment in wadeable Ozark streams." *Ecological Indicators* 10(3) 627-638.
- Kahneman, Daniel, and Amos Tversky. 1979. "Prospect theory: An analysis of decision under risk." *Econometrica* 47 (2): 263-291.
- Kemper, Nathan, Archie Flanders, Brad Watkins, and Michael Popp. 2012. *Impact of the 2012 Drought on Field Crops and Cattle Production in Arkansas*. UofA Division of Agriculture.
- Klapproth, Julia, and James Johnson. 2009. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality*. Publication 420-151, Petersburg: Virginia Cooperative Extension. [pubs.ext.vt.edu/420/420-151/420-151\\_pdf.pdf](http://pubs.ext.vt.edu/420/420-151/420-151_pdf.pdf).
- Koelsch, Richard, Jeffrey Lorimer, and Kyle Mankin. 2006. "Vegetative treatment systems for open lot runoff: Review of literature." *Conference Presentations and White Papers: Biological Systems Engineering* 5: 575-607. [digitalcommons.unl.edu/biosysengpres/5](http://digitalcommons.unl.edu/biosysengpres/5).
- Kresse, TM, PD Hays, KR Merriman, JA Gillip, DT Fugitt, JT Spellman, AM Nottmeier, DA Westerman, JM Blackstock, and JL Battreal. 2014. *Aquifers of Arkansas - Protection, Managment, and Hydraulic and Geochemical Characteristics of Groundwater Resources in Arkansas*. Scientific Investigations Report 2014-5149, USGS.
- Kumar, Pushpam (Editor). 2010. *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations*. London and Washington DC: Earthscan.
- Lynch, Lori, and Robert Tjaden. 2000. *When a Landowner Adopts a Riparian Buffer - Costs and Benefits*. College Park: Maryland Cooperative Extension Service.
- Matthews, William J, and Edie Marsh-Matthews. 2016. "Dynamics of an upland stream fish community over 40 years: trajectories and support for the loose equilibrium concept." *Ecology* 97(3) 706-719.
- Matthews, William, and Henry Robison. 1988. "A distribution of the fishes of Arkansas: A multivariate analysis." *COPEIA* 358-374.
- McCallister, Chris T. 2018. *Endemic Biota*. February 16. <http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=6598>.
- McFarland, John David. 2004. *Stratigraphic Summary of Arkansas*. Little Rock: Arkansas Geological Survey.
- Meals, Donald W, Steven A Dressing, and Thomas E Davenport. 2010. "Lag time in water quality response to best management practices: A review." *Journal of Environmental Quality* 39(1) 85-96.
-

- Merriman, KR, MW Gitau, and I Chaubey. 2009. "A tool for estimating best management practice effectiveness in Arkansas." *Applied Engineering in Agriculture* 25(2) 199-213.
- Mickey, Beth. 2018. "2018 Stats: Social Media Network Usage by Age Group", February 23, 2018, <https://knowledge.creatingresults.com/2018/02/23/2018-stats-social-media-network-usage-by-age-group/>. This is an online article at [www.CreatingResults.com](http://www.CreatingResults.com). Accessed January 2019.
- Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being*. Washington DC: Island Press.
- Mott, David, Mark Hudson, and Thomas Aley. 2000. "Nutrient loads traced to interbasin groundwater transport at Buffalo National River, Arkansas." *Inside Earth* 6-10.
- Myers, Robert A. 2012. "Lead and Zinc Mining." *The Encyclopedia of Arkansas History & Culture*. February 29. Accessed August 2018. <http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=5405>.
- Narayanan, Arvind, and Robert Pitt. 2006. "Costs of Urban Stormwater Control Practices (Preliminary Report)." *Costs of Urban Stormwater Control Practices*. February. Accessed January 2019. [http://rpitt.eng.ua.edu/class/International%20urban%20water%20systems/Arvind%20Costs%20of%20Urban%20Stormwater%20Control%20Feb%202005%202006%20clean%20copy.htm#\\_Toc126933204](http://rpitt.eng.ua.edu/class/International%20urban%20water%20systems/Arvind%20Costs%20of%20Urban%20Stormwater%20Control%20Feb%202005%202006%20clean%20copy.htm#_Toc126933204).
- National Research Council. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. Washington DC: National Academies Press.
- National Sustainable Agriculture Coalition. 2018. *2018 Farm Bill by the Numbers*. December 18. Accessed February 15, 2019. <http://sustainableagriculture.net/blog/2018-farm-bill-by-the-numbers/>.
- National Water Quality Monitoring Council. 2018. *Water Quality Portal*. April. Accessed April 2018. <https://www.waterqualitydata.us/portal/>.
- NatureServe. 2018. *NatureServe explorer*. Accessed September 25, 2015. <http://explorer.natureserve.org/>.
- NOAA, Anthony Arguez, Imke Durre, Scott Applequist, Mike Squires, Russell Vose, Xungang Yin, and Rocky Bilotta. 2018. "NOAA's U.S. Climate Normals (1981-2010)." *NOAA National Centers for Environmental Information*. August. Accessed March 2, 2017. doi:10.7289/V5PN93JP.
- North Carolina Department of Environment and Natural Resources. n.d. "A Review of the Scientific Literature on Fecal Coliform Attenuation by Riparian Buffers." Accessed Month 2018. <https://ncdenr.s3.amazonaws.com/.../Fecal%20Coliform%20Attenuation%20by%20Ri...>
-

- Northern Virginia Regional Commission. 2004. "Implementation Plan for the Fecal Coliform TMDL (Total Maximum Daily Load) for Four Mile Run, Virginia."
- NRCS. 2006. "Conservation Practices that Save: Prescribed Grazing Systems." *USDA Natural Resources Conservation Service*. April. Accessed 2017.  
[http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/energy/conservation/?cid=nrcs143\\_023633](http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/energy/conservation/?cid=nrcs143_023633).
- NRCS. 2017a. *2017 Arkansas NRCS Annual Report*. December. Accessed October 2018.  
<https://www.nrcs.usda.gov/wps/portal/nrcs/ar/newsroom/factsheets/NRCSEPRD1380442/>.
- NRCS. 2017b. "RMS Planning Tool, Identify resource problems and recommended practices." *Conservation Practice Physical Effects CPPE; NRCS Economics*. August. Accessed October 2018.  
[https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/tools/?cid=nrcs143\\_009740](https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/tools/?cid=nrcs143_009740).
- NRCS. 2018. *Grazing Lands Conservation Initiative*. Accessed March 2019.  
<https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/people/partners/glci/>.
- NRCS. 2019. *Arkansas Payment Schedules*. January.  
<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328226>.
- Panfil, Maria, and Robert Jacobson. 2001. *Relations Among Geology, Physiography, Land Use, and Stream Habitat Conditions in the Buffalo and Current River Systems, Missouri and Arkansas*. USGS.
- Patton, Aaron. 2008. *Fertilizing Your Lawn*. FSA2114, Arkansas Cooperative Extension Service.
- Petersen, James, and Suzanne Femmer. 2003. *Periphyton Communities in Streams of the Ozark Plateaus and Their Relations to Selected Environmental Factors*. USGS.
- Petersen, James. 2004. *Fish Communities of the Buffalo River Basin and Nearby Basins of Arkansas and their Relation to Selected Environmental Factors, 2001-2002*. USGS.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011a. *Reducing Bacteria with Best Management Practices for Livestock, Prescribed Grazing*. Texas AgriLife Extension Service.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011b. *Reducing Bacteria With Best Management Practices for Livestock, Fence*. Texas AgriLife Extension Service.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011c. *Reducing Bacteria with Livestock Best Management Practices - Livestock Shade Structure*. ESP-408, Texas A&M Agrilife Extension Service.
-

- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011d. *Reducing Bacteria with Best Management Practices for Livestock - Heavy Use Area Protection*. ESP-406, Texas A&M Agrilife Extension Service.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011e. *Reducing Bacteria with Best Management Practices for Livestock - Filter Strips*. ESP-405, Texas A&M Agrilife Extension Service.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011f. *Reducing Bacteria with Best Management Practices for Livestock - Stream Crossing*. ESP-416, Texas A&M Agrilife Extension Service.
- Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011g. *Reducing Bacteria with Best Management Practices for Livestock - Watering Facility*. ESP-412, Texas A&M Agrilife Extension Service.
- Pieper, Kevin. 2013. "Geese foul up favorite swimming holes." *USA Today*, August 8. <https://www.usatoday.com/story/news/nation/2013/08/02/geese-foul-up-favorite-swimming-holes/2611491/>.
- Ready, Richard. in preparation. *Valuing Ecosystem Services Generated by Nutrient Reductions: A Spatial Approach*. Montana State University.
- Reynaud, Arnaud, Denis Lanzanova. 2015. *A global meta-analysis of ecosystem services values provided by lakes*. Presented at the 2<sup>nd</sup> Annual Conference of the French Association of Environmental and Resource Economists, 10-11 September in Toulouse.
- Rupar, Bryan, and Mike Slay. 2011. "Foushee Cave Land Acquisition = Protection for Karst-dependent Animal Species." *State Wildlife Action Plan Preproposals for 2011*. Accessed September 2018. <https://www.wildlifearkansas.com/proposals/2011PreProposals/Preproposals2011.html>.
- Rushing, Jaret. 2012. "Feral Hogs and the Effect They Have on Timberland." May 8. Accessed October 2018. [www.arkansas.gov/abof/pdfs/ABRF\\_hogs\\_jrushing.pdf](http://www.arkansas.gov/abof/pdfs/ABRF_hogs_jrushing.pdf).
- Sanders, Carol. 2016. *Feral Hog Initiative Underway to Aid Landowners in Trapping Swine*. August 25. Accessed October 11, 2017. <https://uapbnews.wordpress.com/2016/08/25/feral-hog-initiative-underway-to-aid-landowners-in-trapping-swine/>.
- Smith, James. 2017. "Manganese Mining." *The Encyclopedia of Arkansas History & Culture*. June 6. Accessed August 2018. <http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=4315>.
- Southside Public Water Authority. 2018. *Wastewater Information*. Accessed October 2018. <https://www.spwa.org/wastewater-information-1>.
-

- Stewart, James H. 1988. *A Recovery Plan for the Cave Crayfish Cambarus zophonastes*. US Fish and Wildlife Service.
- Suhm, R.W. 1968. "Manganese in North Arkansas." *Rocks & Minerals* 34.
- Thaler, Richard, Amos Tversky, Daniel Kahneman, and Alan Schwartz. 1997. "The effect of myopia and loss aversion on risk taking: An experimental test." *Quarterly Journal of Economics* 112: 647-661.
- The Nature Conservancy. 2015. *Strawberry River Preserve and Demonstration Ranch*. Accessed January 16, 2015.  
<http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/strawberry-river-preserve-and-demonstration-ranch.xml>.
- The Nature Conservancy. 2017. *Ozark Highlands Karst Program*. Accessed October 2017.  
<https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml>.
- Thornton, KW, and CR Laurin. 2005. "Soft sciences and the hard reality of lake management." *Lake and Reservoir Management* 21(2) 203-208.
- UALR Institute for Economic Advancement. 2015. "County Level Population Projections." *Population Estimates and Projections*. Accessed January 25, 2017.  
<http://iea.ualr.edu/population-estimates-a-projections.html>.
- University of Central Arkansas. 2018. *Adams Fish Ecology Lab Current Projects*. Accessed August 2018. <https://sites.google.com/a/uca.edu/adams-fish-ecology-lab/teaching>.
- University of Georgia Center for Invasive Species and Ecosystem Health. 2018. *EDDMapS, Early Detection and Distribution Mapping System*. August. Accessed August 2018. <http://www.eddmaps.org/>.
- UofA Division of Agriculture Cooperative Extension Service. 2018. *Arkansas Stormwater Education Program*. Accessed December 2018.  
<https://www.uaex.edu/environment-nature/water/stormwater/>.
- UofA Division of Agriculture. 2012. *Economic Contribution of Arkansas Agriculture*. Little Rock: University of Arkansas Division of Agriculture.
- US Census Bureau. 2003. "2000 Census of Population and Housing, Population and Housing Unit Counts, Arkansas." PHC-3-5, Washington DC.
- US Census Bureau. 2012a. *2010 Census of Population and Housing, Population and Housing Unit Counts, Arkansas*. CPH-2-5, Washington DC: US Government Printing Office.
- US Census Bureau. 2012b. "2012 Economic Census of the United States." *American FactFinder*. Accessed April 19, 2018.  
<http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.
- US Census Bureau. 2018. "2013-2017 American Community Survey 5-year Estimates." *American FactFinder*. Accessed April 2018.
-

<http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF>.

- US Department of the Interior. 2018. *The United States Department of the Interior Budget Justifications and Performance Information Fiscal Year 2019 Fish and Wildlife Service*. Washington, DC: US Department of the Interior.  
<https://www.fws.gov/budget/>.
- US Fish and Wildlife Service. 2015. *Rabbitsfoot (Quadrula cylindrica cylindrica)*. Accessed August 2018. <https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=F03X>.
- US Soil Conservation Service. 1982. *Soil Survey of Independence County*. US Department of Agriculture.
- US Soil Conservation Service. 1983a. *Soil Survey of Baxter and Marion Counties Arkansas*. US Soil Conservation Service.
- US Soil Conservation Service. 1983b. *Soil Survey of Stone County Arkansas*. US Soil Conservation Service.
- US Soil Conservation Service. 1984. *Soil Survey of Fulton and Izard Counties Arkansas*. US Department of Agriculture.
- USACE Little Rock District. 2016. *White River Watershed Arkansas and Missouri White River Bull Shoals Lake Master Plan for Development and Management of Bull Shoals Lake*. USACE.
- USACE. 2018. *Fast Facts*. August. <http://www.corpsresults.us/fastfacts/fastfacts.cfm>.
- USDA National Agricultural Statistics Service. 2018. *Census of Agriculture*. August. Accessed August 2018. <https://www.nass.usda.gov/AgCensus/index.php>.
- USDA. 2018. *FY 2019 Budget Summary*. Washington, DC: US Department of Agriculture.
- USFS. 2008. *Fiscal Years 2006 and 2007 Ozark-St. Francis National Forests Fisheries and Wildlife Monitoring Report*. USFS.
- USFS. 2016. *Fiscal Year 2015 Monitoring and Evaluation Report for the Land and Resource Management Plan Ozark - St. Francis National Forests*. US Forest Service.
- USGS. 2011. *Mississippi-Atchafalaya River Basin 2002 Nutrient Loading*. Accessed June 2018. <https://sparrow.wim.usgs.gov/marb/>.
- USGS. 2018a. *USGS Surface-Water Data for Arkansas*. April. Accessed April 2018. <http://waterdata.usgs.gov/ar/nwis/sw>.
- USGS. 2018b. *NAS-Nonindigenous Aquatic Species*. January. Accessed April 2018. <https://nas.er.usgs.gov>.
- USGS. 2018c. *USGS Water Quality Data for Arkansas*. Accessed April 2018. <http://waterdata.usgs.gov/ar/nwis/qw>.
-

- Wagner, Daniel, Joshua Krieger, and Katherine Merriman. 2014. *Trends in Precipitation, Streamflow, Reservoir Pool Elevations, and Reservoir Releases in Arkansas and Selected Sites in Louisiana, Missouri, and Oklahoma, 1951 - 2011*. Scientific Investigations Report 2013-5240, Reston, VA: US Geological Survey.
- Washington State University. 2006. "WSU Experimental Riparian Buffer Site Installation and Maintenance Costs 2003-2005." *Riparian Buffers*. Washington State University. Accessed August 2017. <https://puyallup.wsu.edu/agbuffers/data/>.
- Watershed Conservation Resource Center. 2018. *Project 13-1100 White River Bank Restoration and Monitoring Project Project Summary Report*. Arkansas Natural Resources Commission.
- Westerman, Drew, Johnathan Gillip, Joseph Richards, Phillip Hays, and Brian Clark. 2016. *Altitudes and Thicknesses of Hydrogeologic Units of the Ozark Plateaus Aquifer System in Arkansas, Kansas, Missouri, and Oklahoma*. Scientific Investigations Report 2016-5130, Reston, VA: US Geological Survey.
- White, Michael, Daren Harmel, Haw Yen, Jeff Arnold, Marilyn Gambone, and Richard Haney. 2015. "Development of sediment and nutrient export coefficients for U.S. ecoregions." *Journal of the American Water Resources Association* 758-775.
- Whitescarver, Bobby. 2013. "Planting and Growing a Successful Riparian Forest Buffer." *Whitescarver Natural Resources Management LLC*. Whitescarver Natural Resources Management LLC. July 13. Accessed August 2017. <http://www.gettingmoreontheground.com/2013/07/13/planting-and-growing-a-successful-riparian-forest-buffer/>.
- Woods, AJ, TL Foti, SS Chapman, JM Omernik, JA Wise, EO Murray, WL Prior, JB Jr. Paga, JA Comstock, and M Radford. 2004. *Ecoregions of Arkansas*. color poster with map, descriptive text, summary tables, and photographs, Reston, VA: US Geological Survey.
- York, Alex. 2018. *7 Steps in Creating a Winning Social Media Marketing Strategy in 2018*. April 20. <https://one18media.com/7-steps-creating-winning-social-media-marketing-strategy-2018/>.
- Zeckoski, R, B Benham, and C Lunsford. 2012. *Streamside Livestock Exclusion: A tool for increasing farm income and improving water quality*. Publication number 442-766, Virginia Cooperative Extension.
- Zuo, MH, and MS Miller-Goodman. 2004. "Landscape use by cattle affected by pasture developments." *Journal of Range Management* 426-434.

# **APPENDIX A**

---

**Sign In Sheets from Public Meetings Held for Development of the Middle  
White River Watershed Management Plan**

**MEETING SIGN-IN SHEET**

Project: ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: May 31, 2018  
 Facilitator: Kent Thronton Place/Room: UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
BARRY FERRELL			119 PINE TREE LANE BATESVILLE, AR 72501	BARRYFERRELL@SUDDENLINKMAIL.COM
DAN + PATRICIA STEWART	farmer	870-269-2684	445 SMC ST MAY-UI ST STARGAP FARM @ gmail	stergapfarm@gmail.com
Philip Antici		870-307-2158	2558 Goff Dr, Batesville	philipantici@ffkmail.com
MATT MENTHA	Ark. Dept. of Forest Management	501-682-1227	Matt.Mentha@doarkansas.gov	Capitol Mall, UK, 72201
MARC PHILLIPS	AFC	870-994-2187	P.O. Box 26 ASU FLAT AR 72513	Marc.phillips@agriculture.arkansas.gov
Julia Nail	FCD	870-307-1224	2959 Wilby Dr Batesville AR 72501	Julia.nail@small.com

**MEETING SIGN-IN SHEET**

Project: ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: May 31, 2018  
 Facilitator: Kent Thornton Place/Room: UAACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Rock Gilbert	In. CO. Conservation	870-793-4164 X3	4906 College St. #242 Batesville, AR 72501	rck.gilbert@ar.nadnet.net
Alyssa Bangs	USFWS	501-513-4472	110 S. Amity Rd, Ste 300 Conway, AR 72032	alyssa-bangs@fws.gov
GERARD WEBER	FRIENDS OF THE APP STATE	870-269-2704	1722 HWY 9 MOUNTAIN VIEW AR 72560	jerryabere@yelcat.net
Suzanne Teel	NRCS	870-523-8980	2115 Mt. Vernon Newport AR 72112	Suzanne.teel@ar.usda.gov
CARL LINDSTROM	CITIZEN	870-585-2144	4815 W. Mathews St Newport AR 72112	CEL1281@aol.com
Darin Roulx	ADH	501-861-2856	56137, LK AR 72205	darin.roulx@agrhrns.usda.gov
John Bailey	ArFB	601-251-7337	Batesville, AR 72501	john.bailey@arfb.com
Roger Cousins	NRCS	870-793-4164	490 College St Ln 242	roger.cousins@ar.usda.gov
Scott Roulx	Lyon	870 613-4313	371 Big Pine 72501	scott.roulx@lyon.ar
Dean Gammon	Stonewall Farm	870-213-6675	19749 Hwy 263	djgammon11@hotmail.com
Judge C. Hui	Judge Cady	Judge		
Don Hubbell	UALEST	870-793-7432	70 Exp. Sta Dr Batesville, AR	dhubbell@uark.edu
Jody Nequair	ARFIS	501 224 4400		

**MEETING SIGN-IN SHEET**

Project: ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: May 31, 2018  
 Facilitator: Kent Tharnton Place/Room: UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Tom Hess	Landowner - Farm Business WFOEM	870-205-9046 810-241-5940	3090 Oneal Rd. Batesville PO Box 309 Melbourne, AR 72556	thess@uark.edu omw@uark.edu board@countyar.org
Lynn Cornelius	Future Fire	870 698 5631	2010 Gap Rd Batesville, AR	lynn.cornelius@femail.com
Sam Cooke	Friends North Fork of White River	870 307 8922	22 Southridge Ct Batesville, Ar	sckooke22@gmail.com

**MEETING SIGN-IN SHEET**

Project: ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: May 31, 2018  
 Facilitator: Kent Thompson Place/Room: UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Jim Cunningham	City of Newark	870-799-2663	Newark Ar. 72569	NEWARKCityHall@jsho.com
Carissa Ennis	NKES	(970)		Carissa.ennis@ar.usda.gov
Zach Avery	NRCS	870-615-7851	<del>Springfield Ar</del>	Zachary.Avery@ar.usda.gov
Richard Noland	ADH	501-269-5401		richard.j.noland@arkansas.gov
Tim Burnley	AGFC	870-404-6369	201 E 5th St Attn Home 72653	tim.burnley@agfc.ar.gov

**MEETING SIGN-IN SHEET** Middle White River  
**Project:** ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: 9-11-18  
**Facilitator:** Dr. Kent Thornton - Fwd Place/Room: Calico Roch

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Joseph Krystofik	USFEWS	501-513-4479	110 S. Amity Rd. Ste 300 Conway, AR 72032	joe-krystofik@fws.gov
Tom Hess				
Lynn Cornelius	Future Fuel Chemical			
Tim Burnley	AGFC			
Marcia Seway		870-373-5032	PO Box 296 Pineville AR 72566	mseyay72566@yahoo.com
Marc Phillips	AFC	870-994-2187		
Jessie Cerny				
Carl Lindstrom		870-585-2144		
Kristi Williams	ADEQ			WILLIAMS@adeq.state.ar.us
Dan Stewart				
Jerry Weber				
John Bailey				
MARTIN, A	ADIT	501-682-1227	MM	



**MEETING SIGN-IN SHEET** Middle White River

**Project:** ARKANSAS WATERSHED PLAN Public Meeting **Meeting Date:** 11/28/18

**Facilitator:** NAC's Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Tommy Crenshaw	Ind Co Conservation Dist	870 793-5164		
Kenny Crawford	Fulton Co. COW	870-404-6121	CAMP 323 RIDGE RD AR 72520	
Shannon Davis	CACHE RIVER DRAINAGE DIST	870 926 5050	PO Box 483 BONO AR 72416	Shannon.davis.farms@gmail.com
Rheannon Hart	USGS	501 228 3664	LR	rmhart@usgs.gov
Bill Baldwin	USGS	501 228 3662	LR	bbaldwin@usgs.gov
Sara Sanders	AGFC	501 765-9208		
Alyssa Baugs	USFWS			
JERRY WEBER	FRIENDS OF NF & WRS	870-269-2704	17221 HWY 9 MOUNTAIN VIEW, 22500	jerryweber@yeldot.net
Melisa Varnen	Farmer, Realtor	870-301-4343	P.O. Box 145 Salado, AR 72575	chescarweaver@ymail.com
Tom Hess				thess@uark.edu

**MEETING SIGN-IN SHEET** Middle White River

**Project:** ARKANSAS WATERSHED PLAN Public Meeting **Meeting Date:** 11/28/18

**Facilitator:** Place/Room: LRAC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Carol Bennett	Farmer	506-688-7688	Suburban 114 Sycamore Circle	CRP@batesville.com
Loann Stone	Financial Planner Farmer	870-404-0989	892 Elizabeth Rd Gepp AR	loannrstone@gmail.com
Michael McDavid	City of Batesville	870-698-2442	500 Riverbank Rd. Batesville, AR 72501	wwinspector@cityofbatesville.com
Scott Williams	SPWA	870-251-2508	1401 Batesville Blvd Batesville, AR	southsidewater@sbcglobal.net
Jim Ulmer	City of Batesville	479-790-6428	302 Emillsey Rd Fayetteville, AR 72703	juulmer@colson.com
Shirley Clarke	Friends North Fayetteville			
Henry Clark	JACKSON County, Cons Board member	870-217-3971	170 VH 221 Newport AR 72112	KCCLEARK49@YANCO.
Stan Hayward	Mad Creek	870-512-8647	2770 Hwy 14 Wex	Stan.Hayward@yehc.com

Midd White

**MEETING SIGN-IN SHEET**

Project: ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: 11/28/18

Facilitator: UACC Batesville Place/Room: UACC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Glen Willis	Independence Energy Dist	870-793-8816	1730 Myers St Batesville	glenn.willis@independencenergy.com
Road Builders	Independence Road Dept	870-854-7327	192 East Main Batesville	Roadbyars@cc@6mail.com
Lynn Cornelius	FuhrerFuel	870-698-5634		lynn.cornelius@ffccouncil.com
Susan Curry VPO	FuhrerFuel	870-698-5304		susan@ffccouncil.com
MARC PHILLIPS	AAD - AFC	870-994-2187	P.O. Box 26 Ash Flat Ar 72513	
Henry Smothers	AAD - AFC	870-613-1939	#1 Forestry Rd. Batesville, AR	
Delia Nail				
GARY LYNCH		870-834-6805	P.O. Sulphur Rock Box 326	g.elys/lynch@hotmail.com

**MEETING SIGN-IN SHEET** Middle White River

**Project:** ARKANSAS WATERSHED PLAN Public Meeting Meeting Date: 11/08/15

**Facilitator:** NAAC Batesville Place/Room:

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Dennis Haigwood	RIH Farms	871-217-2424	2805 Stewart, Newport	haigwoodfamily@yahoo.com
Darcia Rosta	ADH-Egypt	501-661-2623	4815 Wilshire, Ste 303	darcia.rosta@arkansas.gov
Richard Norand	"	"	"	richard.norand@arkansas.gov
ZACH FOSTER	ADPT	501- <del>680</del> <sup>682</sup> -6947	Cole Capitol Mall, Little Rock, 7001	zach.foster@arkansas.gov
Matt McNair	"	"	"	mat.mcnair@arkansas.gov

# **APPENDIX B**

---

## **Water Quality Trend Analyses**

## APPENDIX B. WATER QUALITY TREND ANALYSIS

Water quality stations chosen for analysis of long-term trends in water quality are listed in Table B.1 (in downstream order). These are the only stations in the watershed have continuous, or nearly continuous, water quality records of over 15 years that continue through 2017. The parameters analyzed for trends are dissolved oxygen, TSS (ADEQ only), suspended sediment (USGS only), turbidity (ADEQ only), dissolved inorganic nitrogen, total nitrogen, and total phosphorus. Only data from the period 1993 through 2017 is used in the trend analyses so comparable periods are evaluated for all of the stations.

Table B.1. Active water quality monitoring stations with data records of at least 10 years.

Station	Agency	Stream	Location	Data Period
WHI0065	ADEQ	Hicks Cr	D/S Mt. Home	1990-2017
WHI0046	ADEQ	White R	Norfolk	1990-2017
07060500	USGS	White R	Calico Rock	1972-2017
07060710	USGS	N. Sylamore Cr	Near fifty-six	1972-2017
WHI0011	ADEQ	S. Sylamore Cr	d/s Lick Cr (Mountain View WWTP)	1993-2017
WHI0029	ADEQ	White R	Oil Trough	1990-2017

Characteristics of the data determine what type of trend analysis is most appropriate. Data characteristics of concern include the presence of seasonal patterns, whether the data are normally distributed, and whether concentrations appear to be related to flow rate. These characteristics are discussed in the following sections.

### B.1. Dissolved Oxygen

Figure B.1 shows graphs of the dissolved oxygen data for the selected water quality stations for the period 1993 through 2017 (all figures referenced in this subsection are located at end of this subsection). There is an apparent dip in dissolved oxygen concentrations at the South Sylamore station (WHI0011), and the White River at Oil Trough (WHI0029) during the period 2000-2005. This pattern is not apparent in the data from any of the upstream White River stations, nor in the data from any of the other White River tributaries. The dissolved oxygen data from the Hicks Creek station (WHI0065) appear to show an increase in concentrations over time, at least until sometime between 2010 and 2015. Since then, concentrations may be declining.

Dissolved oxygen concentrations may also be increasing at the North Sylamore Creek station (07060710).

Dissolved oxygen data typically exhibits a seasonal pattern, because it is affected by temperature (Figure B.2). Therefore, a trend analysis method that accounts for this effect is used.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics (using SYSTAT version 12.02.00). These statistics are given in Table B.2. For most stations, but not all, the dissolved oxygen data are normally distributed. Because not all of the data sets are normally distributed, a non-parametric statistical trend test is used.

Table B.2. Normality test results for 1993-2017 dissolved oxygen data from long term stations.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.990	0.07	0.866	0.03	Not normal
WHI0029	0.994	0.26	0.577	0.14	Normal
WHI0046	0.994	0.21	0.426	>0.15	Normal
WHI0065	0.980	0.00	1.609	<0.01	Not normal
07060500	0.986	0.00	1.476	<0.01	Not normal
07060710	0.996	0.30	0.589	0.13	Normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved oxygen concentrations. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller and Slack 2006). The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 1. The test results are summarized in Table B.3.

Table B.3. Results of Seasonal Mann-Kendall test of 1993-2017 dissolved oxygen data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	129	1.09	0.59	No
WHI0011 (2004-2017)	S. Sylamore Cr	-243	-4.14	0.02	Yes, decreasing
WHI0029	White R	354	2.87	0.16	No
WHI0029 (2004-2017)	White R	-55	-0.93	0.55	No
WHI0046	White R	215	1.54	0.34	No
WHI0065	Hicks Cr	346	2.48	0.09	Yes, increasing
07060500	White R	28	0.49	0.65	No
07060710	N. Sylamore Cr	426	4.79	0.00	Yes, increasing

Dissolved oxygen concentrations at two of the stations exhibit statistically significant increasing trends, Hicks Creek (WHI0065) and North Sylamore Creek (07060710). The p-values indicate that there is a 91% confidence that there is a statistically significant increasing trend in dissolved oxygen at the Hicks Creek station, while the confidence for the statistically significant increasing trend at the North Sylamore Creek station is over 99%. Usually, increasing dissolved oxygen concentrations would be considered an indicator of improving water quality. However, given that the Hicks Creek station is located downstream of the Mountain Home WWTP, the increasing dissolved oxygen concentrations may result from increased productivity from nutrient inputs.

We wondered if the dip in dissolved oxygen concentrations during the period 2000-2005 at the South Sylamore Creek station (WHI0011) and the White River at Oil Trough (WHI0029) is influencing the trend results. Therefore, the Seasonal Mann-Kendall analysis was also run on a subset of the dissolved oxygen data from these stations for the period 2004-2017 (14 years). These analyses indicate a statistically significant declining trend in dissolved oxygen at the South Sylamore Creek station (WHI0011).

Dissolved oxygen can be affected flow, particularly in smaller streams, as there can be more aeration of the water at faster flows. Flows are measured routinely at the USGS stations, but not the ADEQ stations. However, there are USGS flow gages close to the two ADEQ stations on the White River that can be used to evaluate the relationship between flow and dissolved oxygen concentrations. Flow data from USGS gage 07057370 will be associated with water quality data from ADEQ station WHI0046, both are located on the White River near Norfolk. Flow data from USGS gage 07061000, White River at Batesville, will be associated with water quality data from ADEQ station WHI0029, White River at Oil Trough. Graphs of dissolved oxygen concentration versus flow at the four stations with associated flow measurements are shown in Figure B.3. The graphs in Figure B.3 do not show readily apparent relationships between dissolved oxygen concentrations and flow at the White River stations, but there may be a relationship at the North Sylamore Creek station.

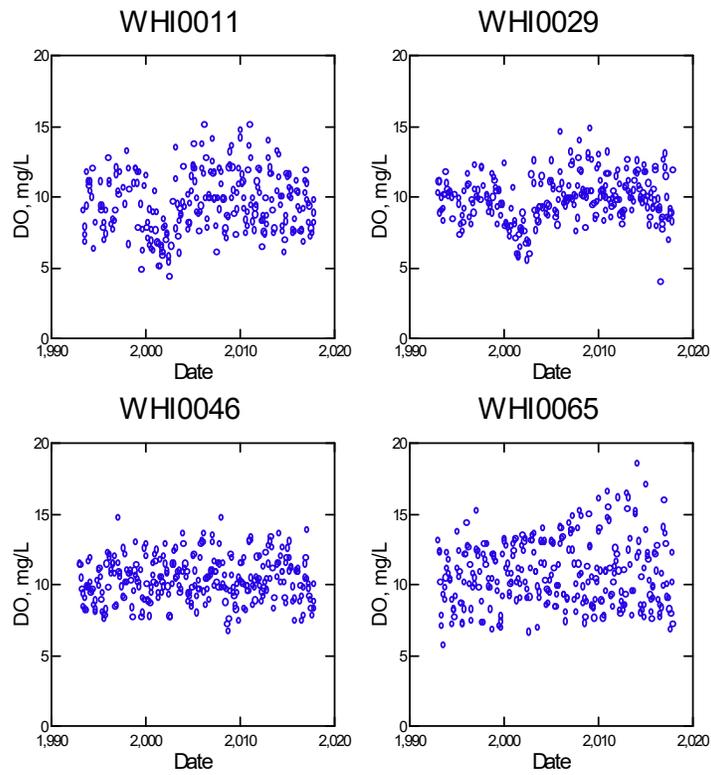
For stations associated with daily flow data, another trend analysis, weighted regression on time, discharge, and season (WRTDS), can be applied (Hirsch, Moyer and Archfield 2010). This analysis was applied using an R software package prepared by the USGS (Hirsch and De Cicco 2015). Figure B.4 shows WRTDS estimates of annual average dissolved oxygen

concentrations.<sup>1</sup> The graphs in Figure B.4 show estimated mean annual dissolved oxygen concentrations increasing over time at all four the stations. Note that there are gaps in the flow records for the White River gages at Norfolk and Batesville, so the WRTDS analysis periods for those stations are shorter. The fact that the mean annual concentration dots on the graphs are close to the line showing the flow normalized concentrations indicates that flow does not have much effect on the dissolved oxygen concentrations at these stations.

---

<sup>1</sup> Flux, i.e., concentration times flow, is the preferred output of the WRTDS analysis for evaluation of trends. However, it is not reasonable to evaluate some parameters in terms of flux, e.g., dissolved oxygen. In addition, the EGRET program does not calculate flux for parameters where concentrations are reported in units other than mg/L, e.g., fecal coliforms, which are reported as cfu/100 mL

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

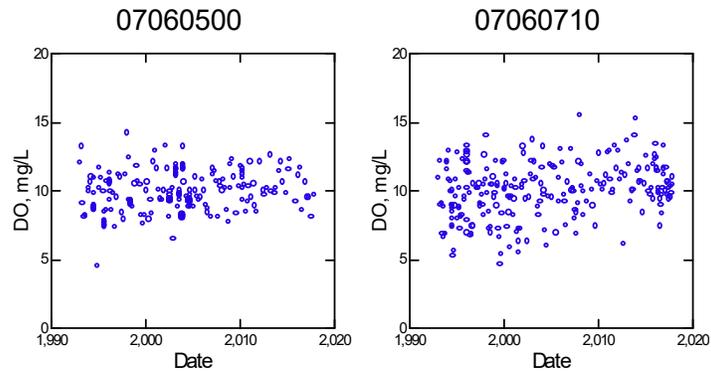
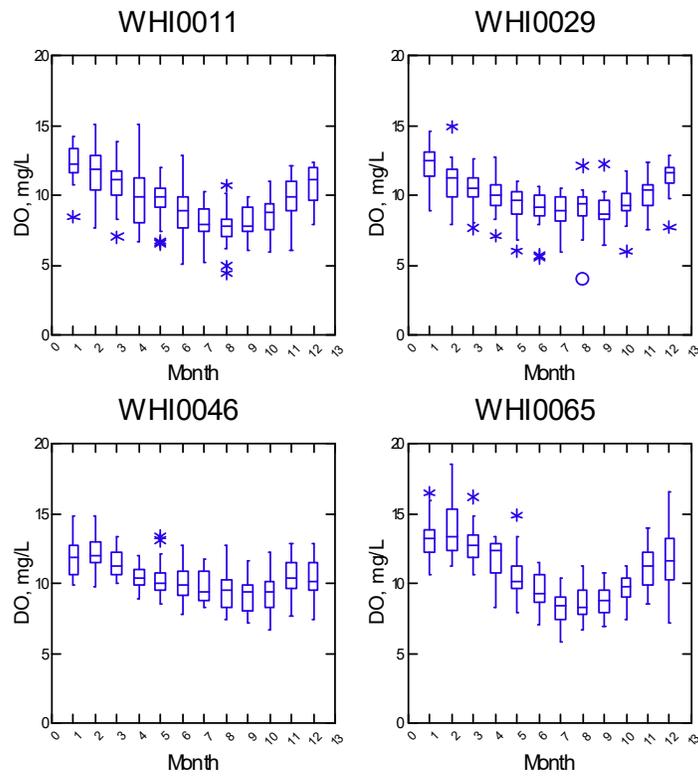


Figure B.1. Dissolved oxygen concentrations from 1993-2017 at long term water quality stations.

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

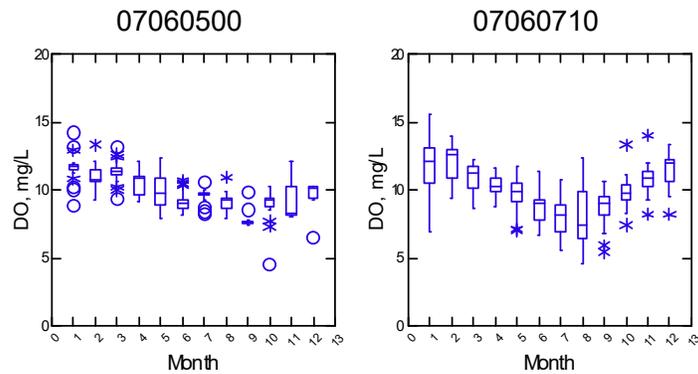


Figure B.2. Dissolved oxygen concentrations from long term stations showing seasonal patterns in data from 1993-2017.

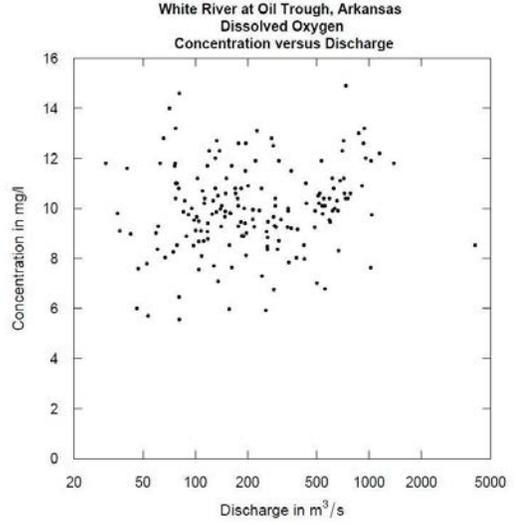
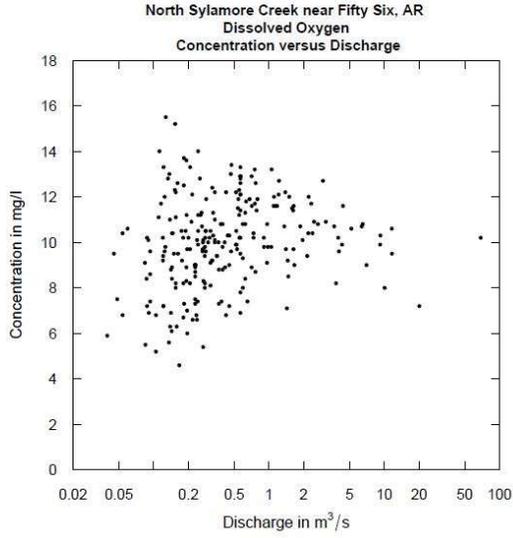
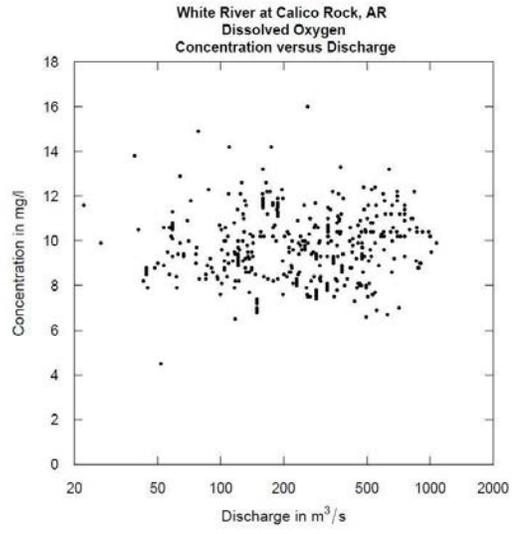
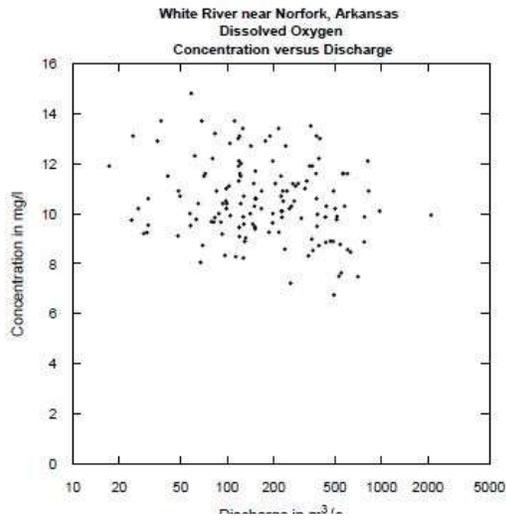


Figure B.3. Dissolved oxygen concentrations versus flow at long term stations associated with flow gages.

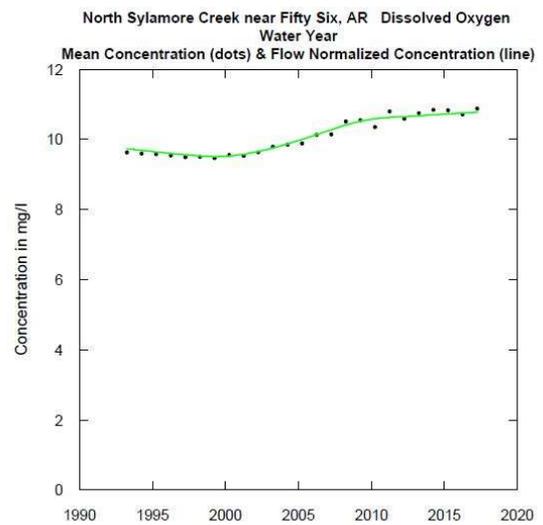
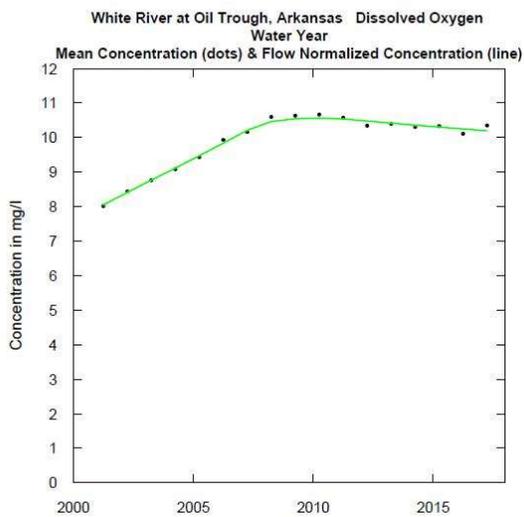
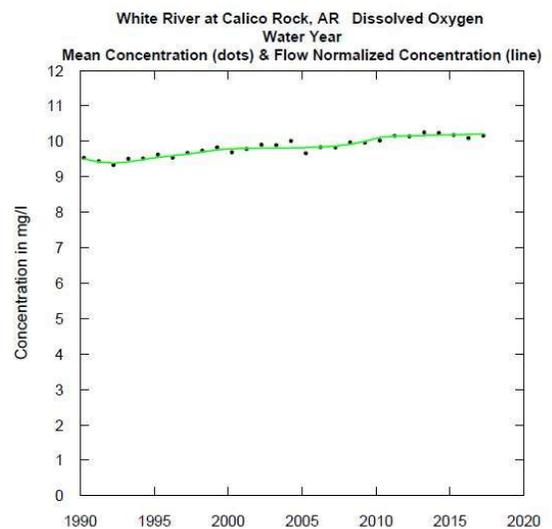
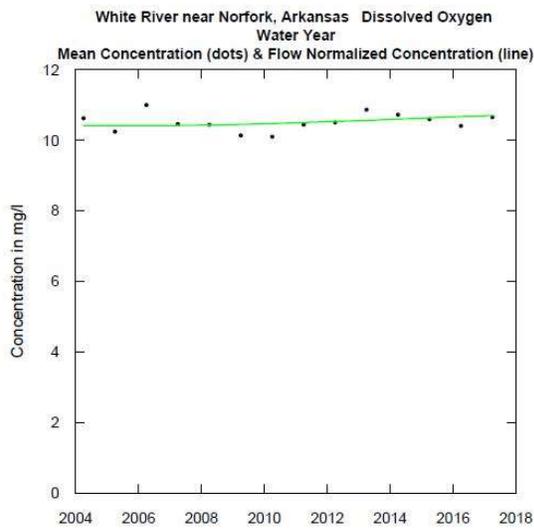


Figure B.4. WRTDS estimates of annual average dissolved oxygen concentrations at long term stations associated with flow gages.

## B.2. Dissolved Oxygen Saturation

To provide insight into the trends observed in dissolved oxygen concentrations, dissolved oxygen saturation values were also evaluated for trends. Algae blooms resulting from nutrient contamination often cause supersaturation of dissolved oxygen in water, i.e., dissolved oxygen saturation greater than 100%. Figure B.5 shows graphs of dissolved oxygen saturation over time for the long-term water quality stations (all figures referenced in this subsection are located at end of this subsection).

DO saturation is reported by USGS, but had to be calculated for the ADEQ stations. For ADEQ station, saturation DO was estimated from water temperature and elevation of the station using the following equation:

$[\exp(7.7117 - 1.31403 \cdot \ln(\text{temperature deg C} + 45.93))] \cdot [(1 - (\text{elevation km}/44.3))^5.25]$ . Elevations for the ADEQ water quality stations are estimated from USGS topographic maps as shown on the ADEQ online AquaView map, and listed in Table B.4. Given these elevations (ranging from 230 ft to 615 ft), the elevation factor of the equation, i.e.,  $[(1 - (\text{elevation km}/44.3))^5.25]$ , is close to 1 (0.98 to 0.99). Therefore, for these estimates, it was assumed to be 1. The DO saturation values were then calculated as the measured DO divided by the saturation DO.

Table B.4. Elevation of ADEQ water quality stations.

Station ID	Elevation, ft	Elevation, km	Elevation factor
WHI0011	355	0.108	0.987
WHI0029	230	0.070	0.992
WHI0046	355	0.108	0.987
WHI0065	615	0.187	0.978

As with dissolved oxygen concentration, dissolved oxygen saturation exhibits seasonal patterns (see Figure B.6).

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.5. Only one set of data appears to have a normal distribution. Because most of the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.5. Normality test results for 1993-2017 dissolved oxygen saturation data from long term stations.

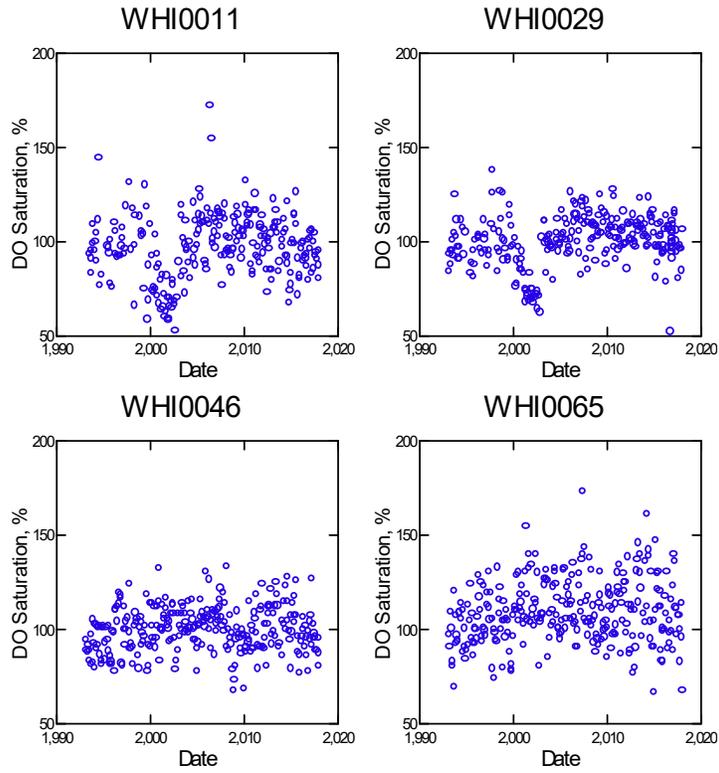
Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.981	0.002	0.705	0.065	Not normal
WHI0029	0.974	0.00	2.388	<0.01	Not normal
WHI0046	0.996	0.606	0.247	>0.15	Normal
WHI0065	0.988	0.013	1.132	<0.01	Not normal
07060500	0.970	0.00	1.065	<0.01	Not normal
07060710	0.988	0.040	1.023	0.010	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved oxygen saturation. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 2. The test results are summarized in Table B.6. Because the stations with increasing DO trends (Table B.3) also have statistically significant increasing trends in DO saturation, it is possible that the increase in DO is the result of increased presence of algal blooms. This would indicate worsening water quality, rather than improving.

Table B.6. Results of Seasonal Mann-Kendall test of 1993-2017 dissolved oxygen saturation data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	121	1.049	0.61	No
WHI0029	White R	386	3.257	0.10	No
WHI0046	White R	248	1.781	0.30	No
WHI0065	Hicks Cr	413	2.970	0.04	Yes, increasing
07060500	White R	97	1.742	0.13	No
07060710	N. Sylamore Cr	440	4.948	0.00	Yes, increasing

### ADEQ Long Term Stations, 1993-2017



### USGS Long Term Stations, 1993-2017

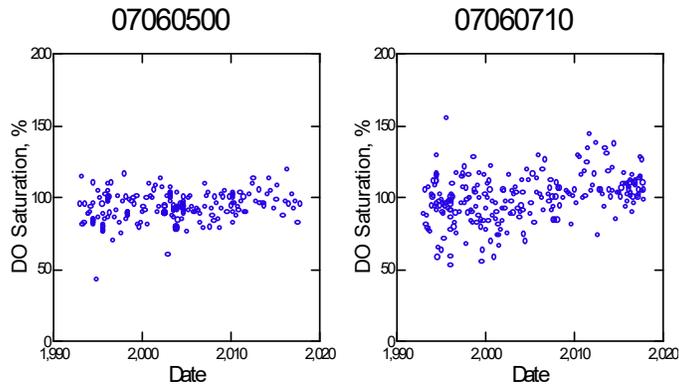
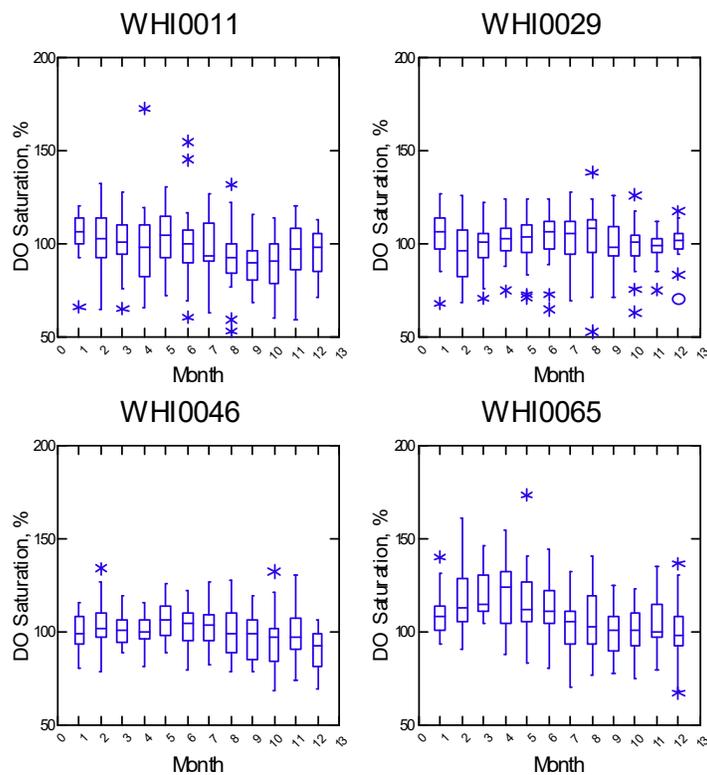


Figure B.5. Dissolved oxygen saturation from 1993-2017 at long term water quality stations.

### ADEQ Long Term Stations, 1993-2017



### USGS Long Term Stations, 1993-2017

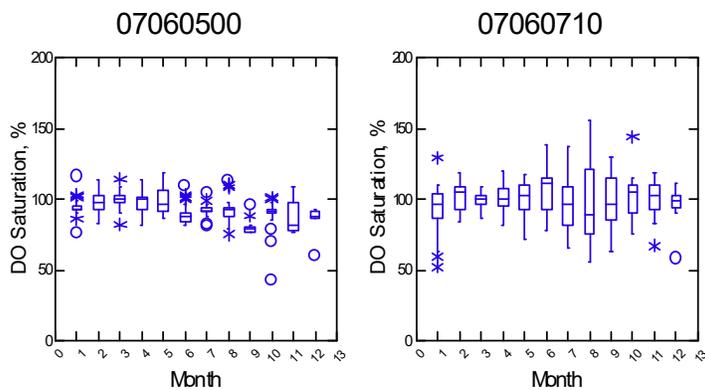


Figure B.6. Dissolved oxygen saturation from long term stations showing seasonal patterns in data from 1993-2017.

### B.3. Dissolved Inorganic Nitrogen

Figure B.7 shows graphs of the available dissolved inorganic nitrogen data for the selected water quality stations for the period 1993-2017 (all figures referenced in this subsection are located at end of this subsection). Note that this is USGS parameter code 00631. There are no readily apparent trends in dissolved inorganic nitrogen concentrations at the stations. However, it is apparent that there was a drop in the dissolved inorganic nitrogen concentrations at the Hicks Creek station (WHI0065) sometime between 1995 and 2000, most likely as the result of a change in the Mountain Home sewerage treatment plant.

Inorganic nitrogen may exhibit seasonal patterns, depending on the sources. Figure B.8 shows box plots of dissolved inorganic nitrogen by month. These plots suggest that inorganic nitrogen exhibits seasonal patterns at some stations. For example, at station WHI0011 (South Sylamore Cr) dissolved inorganic nitrogen appears to usually be lower during the period July through September, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.7. Note that only USGS data after 1970 are used, because prior to that, data was not routinely collected. Dissolved inorganic nitrogen measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.7. Normality test results for dissolved inorganic nitrogen data from long term stations.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.957	0.00	2.84	<0.01	Not normal
WHI0029	0.136	0.00	76.2	<0.01	Not normal
WHI0046	0.980	0.00	1.23	<0.01	Not normal
WHI0065	0.715	0.00	28.9	<0.01	Not normal
07060500	0.980	0.00	1.04	<0.01	Not normal
07060710	0.826	0.00	10.5	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved inorganic nitrogen concentrations. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is

considered a separate season. The program input and output are included as Attachment 3. The test results are summarized in Table B.8.

Table B.8. Results of Seasonal Mann-Kendall test of dissolved inorganic nitrogen data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	-12	-0.081	0.94	No
WHI0029	White R	10	0.064	0.97	No
WHI0046	White R	75	0.526	0.77	No
WHI0065	Hicks Cr	-1181	-8.38	0.00	Yes, decreasing
WHI0065 (1999-2017)	Hicks Cr	-416	-4.38	0.01	Yes, decreasing
07060500	White R	111	2.01	0.22	No
07060710	N. Sylamore Cr	-121	-1.41	0.32	No

A trend in dissolved inorganic nitrogen concentrations is evident only in the data from the Hicks Creek station (WHI0065). Two periods were evaluated for the Hicks Creek Station (WHI0065). As noted previously and shown in Figure B.7, there was noticeable drop in the dissolved inorganic nitrogen concentrations at the Hicks Creek station (WHI0065) sometime between 1995 and 2000. To determine if the decreasing trend identified was solely the result of that drop in concentrations, the data just from the period since the drop was evaluated for trend. These data also show a decreasing trend.

Dissolved inorganic nitrogen can be affected flow. Graphs of dissolved inorganic nitrogen concentration versus flow at the four stations with associated flow measurements are shown in Figure B.9. The graphs in Figure B.9 appear to show relationships between dissolved inorganic nitrogen concentrations and flow at the stations.

For stations associated with daily flow data, WRTDS trend analysis can be applied. This analysis was applied using an R software package prepared by the USGS (EGRET). Figure B.10 shows WRTDS estimates of annual average dissolved inorganic nitrogen flux (or export). The graphs in Figure B.10 show estimated mean annual dissolved inorganic nitrogen flux has increased over time at all four the stations. However, at three of the stations, White River at Norfolk (WHI0046) and Oil Trough (WHI0029) and North Sylamore Creek (07060710), flux appears to show a declining trend since about 2010. At the White River at Calico Rock

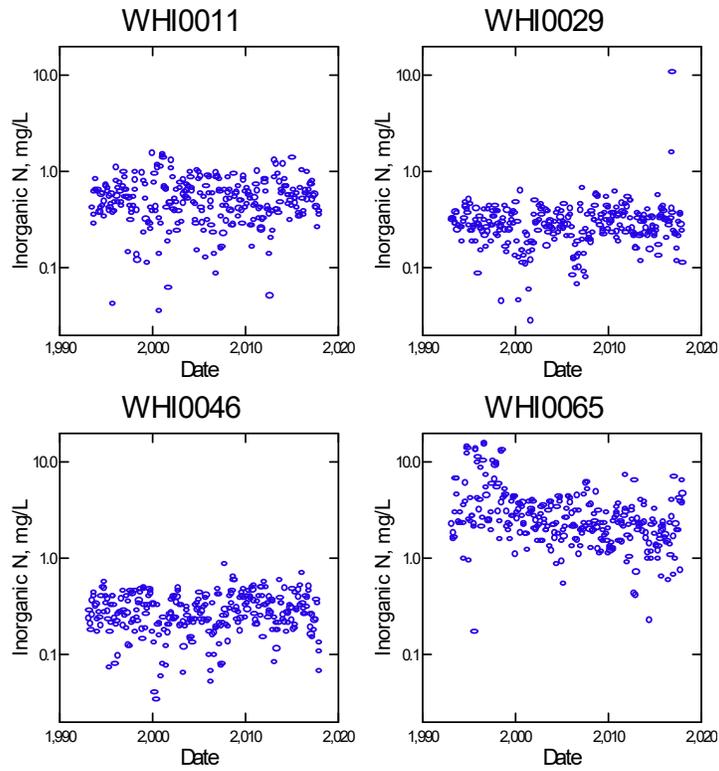
(078060500), there appears to have been little change in dissolved inorganic nitrogen flux over the last several years.

The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.9 lists the flux bias statistics associated with the WRTDS analyses of inorganic nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015). The flux bias statistic for WRTDS results from USGS Station 07060710 suggest that WRTDS estimates for that station are negatively biased, i.e., are lower than true values. Therefore, the apparent declining trend may be false.

Table B.9. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

Station ID	Stream	Flux Bias Statistic
07060500	White R	0.013
07060710	N. Sylamore Cr	-0.234
WHI0029	White R	0.00794
WHI0046	White R	-0.00658

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

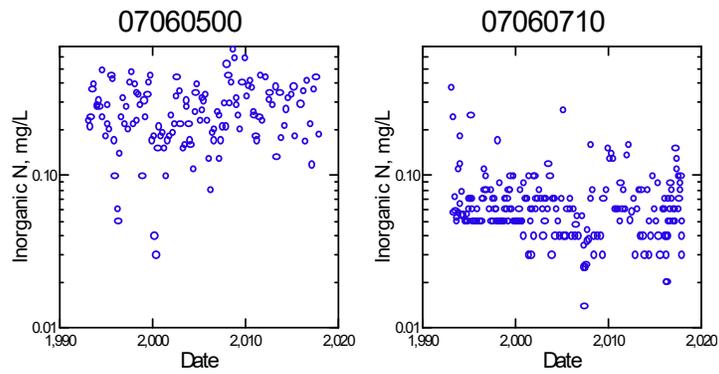
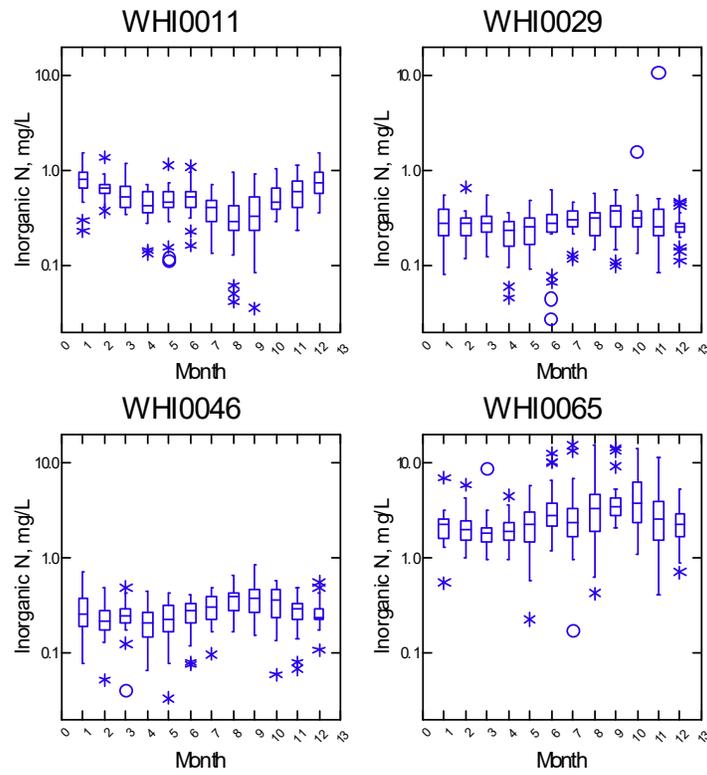


Figure B.7. Dissolved inorganic nitrogen concentrations for 1993-2017 at long term water quality stations.

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

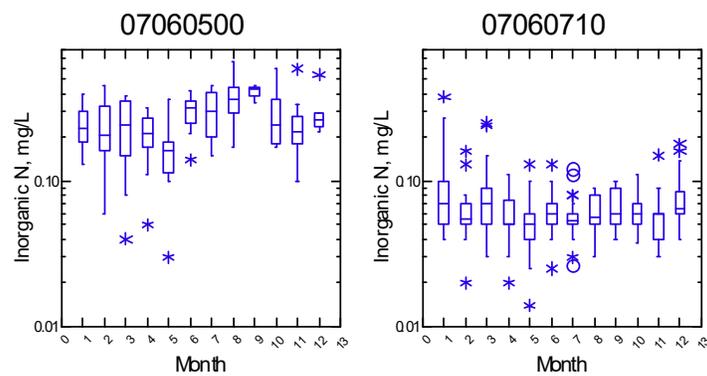


Figure B.8. Dissolved inorganic nitrogen from some long-term stations show seasonal patterns in data from 1993-2017.

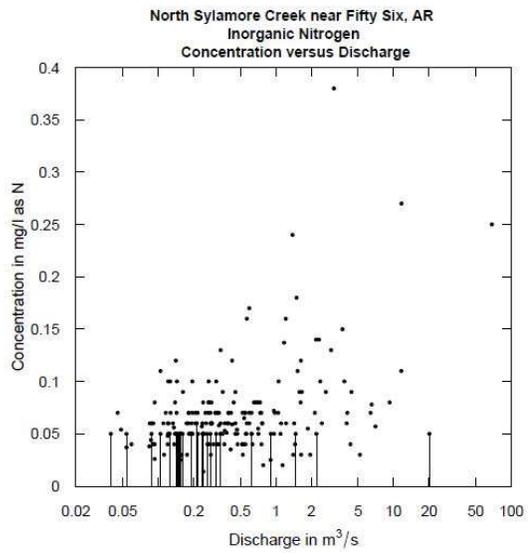
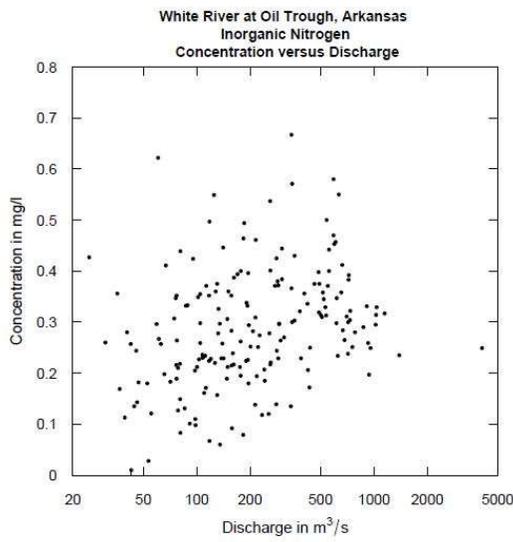
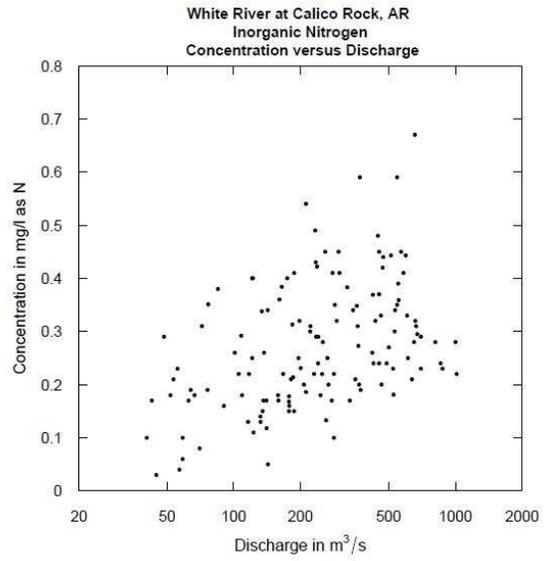
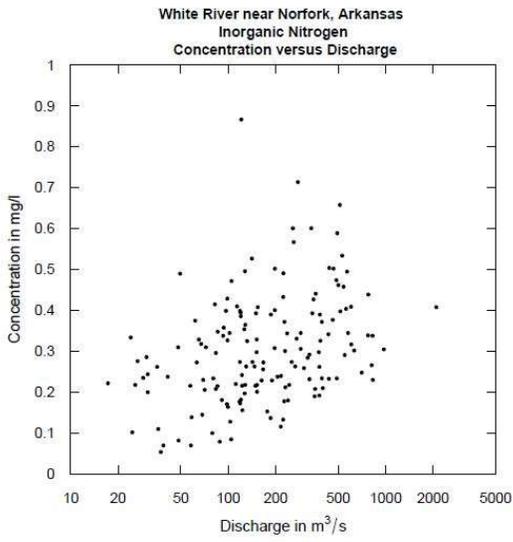


Figure B.9. Dissolved inorganic nitrogen concentrations versus flow at long term stations associated with flow gages.

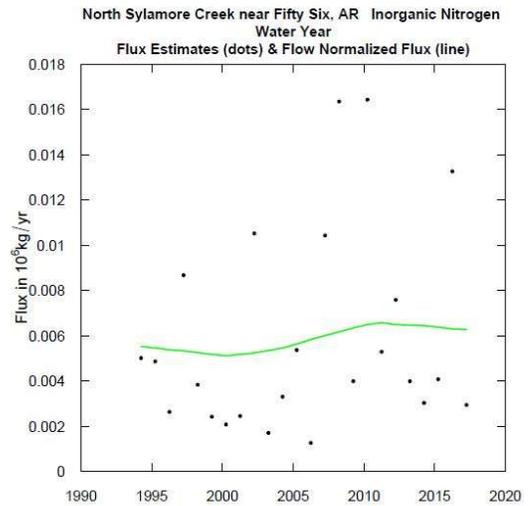
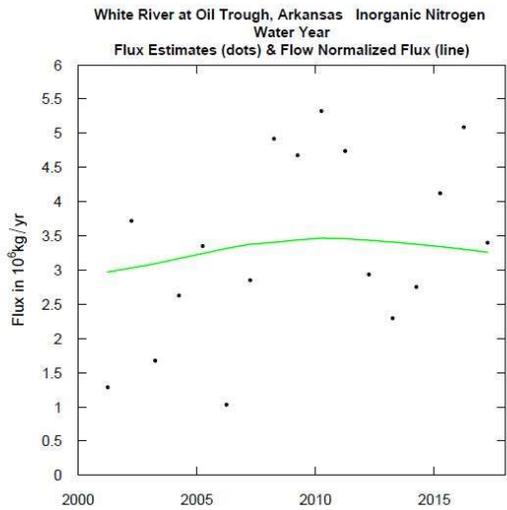
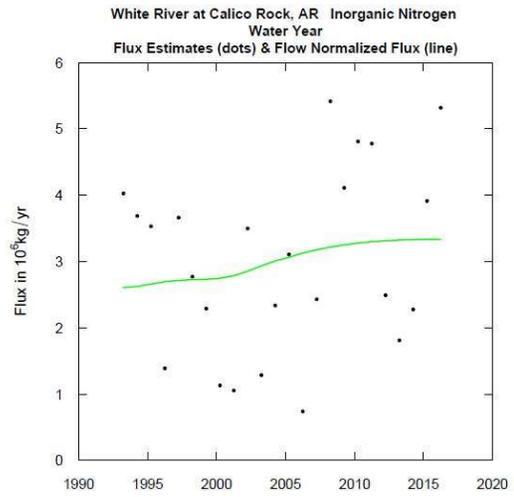
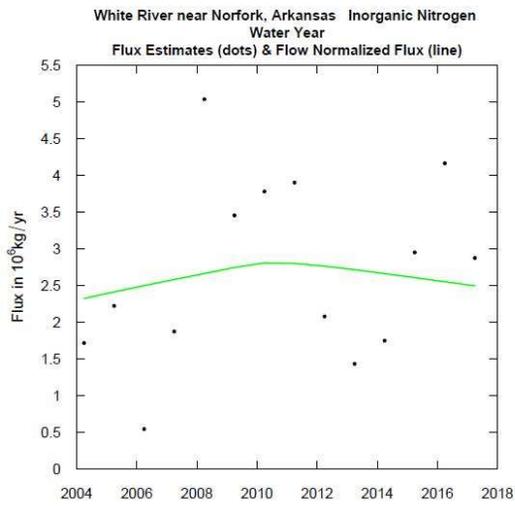


Figure D.10. WRTDS estimates of annual average dissolved inorganic nitrogen flux at long term stations associated with flow gages.

#### B.4. Total Nitrogen

Figure B.11 shows graphs of the available total nitrogen data for the long-term water quality stations for the period 1993-2017 (all figures referenced in this subsection are located at end of this subsection). Note that this is USGS parameter code 00600. For station 07060710, 89 of the 128 total nitrogen values reported are censored, i.e., less than detection. In addition, the reported detection level has declined over time. This fact, and the long gap in the total nitrogen data record, mean that these data are not suitable for evaluation of water quality trends. The total nitrogen data records at all of the stations start after 1993. Therefore, the period of record used for total nitrogen trend analysis is 2000-2017. The data graphs appear to show potential trends in total nitrogen concentrations at some of the stations.

Total nitrogen data may exhibit seasonal patterns, depending on the sources. Figure B.12 shows box plots of total nitrogen by month. These plots suggest that total nitrogen exhibits seasonal patterns at some stations. For example, at station WHI0011 (South Sylamore Cr) dissolved total nitrogen appears to usually be lower during the period July through September, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.10. Total nitrogen measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.10. Normality test results for total nitrogen data from long term stations for the period 2000-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.968	0.00	1.59	<0.01	Not normal
WHI0029	0.192	0.00	59.9	<0.01	Not normal
WHI0046	0.924	0.00	2.72	<0.01	Not normal
WHI0065	0.909	0.00	4.65	<0.01	Not normal
07060500	0.869	0.00	1.44	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in total nitrogen concentrations for the period 2000-2017. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e.,

each month is considered a separate season. The program input and output are included as Attachment 4. The test results are summarized in Table B.11.

Table B.11. Results of Seasonal Mann-Kendall test of total nitrogen data for 2000-2017, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	1.0	0.0	1.0	No
WHI0029	White R	86	1.01	0.58	No
WHI0046	White R	38	0.43	0.76	No
WHI0065	Hicks Cr	-257	-3.12	0.03	Yes, decreasing
07060500	White R	87	2.59	0.05	Yes, increasing

A statistically significant trend is evident in the total nitrogen data from the USGS White River station at Calico Rock (07060500), and at the ADEQ station on Hicks Creek (WHI0065). The data from the Calico Rock White River station (07060500) exhibit an increasing trend over time, with a 95% confidence. The data from the Hicks Creek station (WHI0065) exhibit a decreasing trend over time, with a 97% confidence.

As with dissolved inorganic nitrogen, total nitrogen can be affected flow. Graphs of total nitrogen concentration versus flow at the three stations being analyzed with daily flow measurements are shown in Figure B.13. The graphs in Figure B.13 appear to show relationships between total nitrogen concentrations and flow at the upstream White River stations, Norfolk and Calico Rock. There doesn't appear to be much relationship at the White River station at Oil Trough.

For stations associated with daily flow data, WRTDS trend analysis can be applied. This analysis was applied using an R software package prepared by the USGS. Figure B.14 shows WRTDS estimates of annual average total nitrogen flux (or export). The graphs in Figure B.14 show that flow-normalized estimated mean annual total nitrogen flux has not changed much during the period 2000-2017. This increasing trend identified at the White River at Calico Rock (07060500) by the Mann-Kendall analysis is confirmed by the WRTDS results, but the WRTDS results suggest that total nitrogen concentrations are increasing slowly.

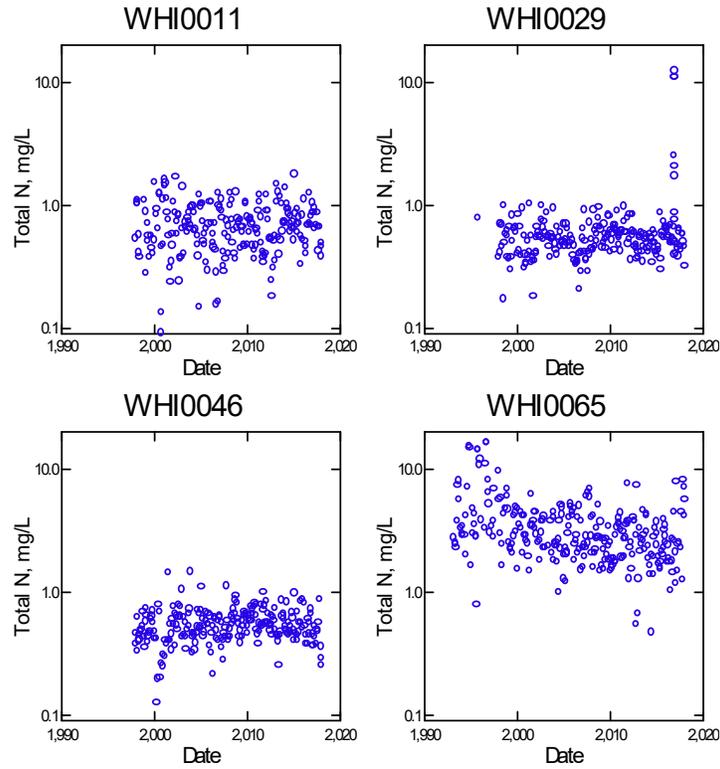
The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.12 lists the flux bias statistics associated with the

WRTDS analyses of total nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015).

Table B.12. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

<b>Station ID</b>	<b>Stream</b>	<b>Flux Bias Statistic</b>
WHI0029	White R	0.0223
WHI0046	White R	-0.00592
07060500	White R	0.0103

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

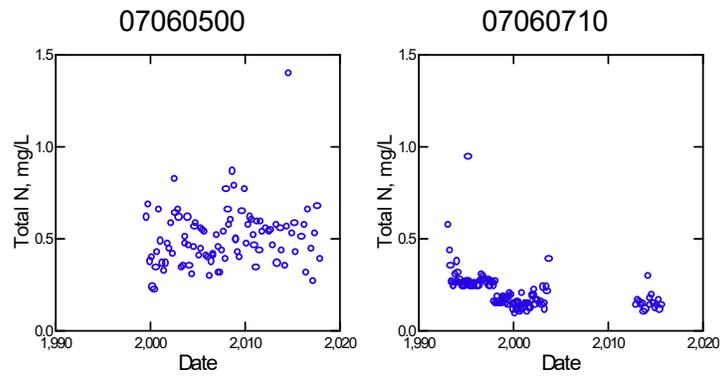
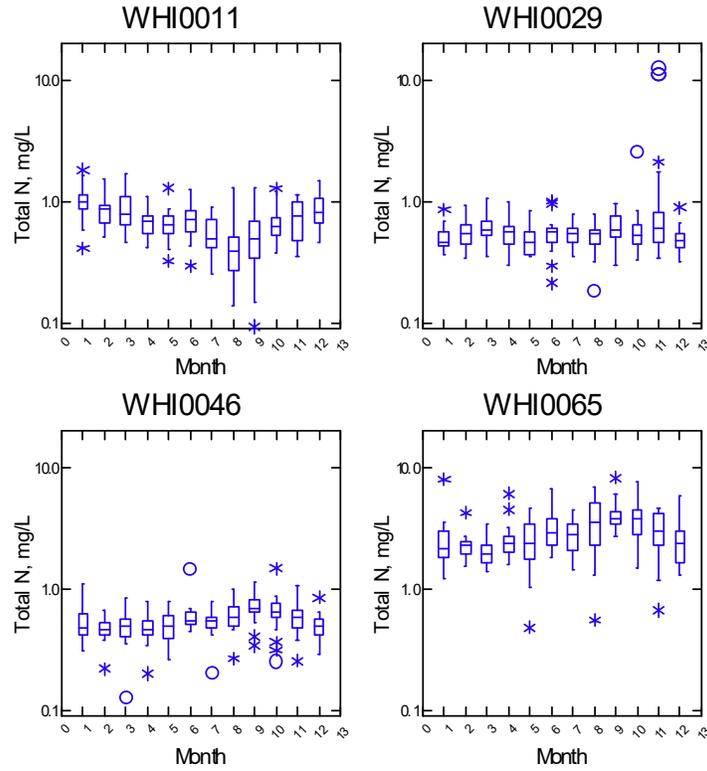


Figure B.11. Total nitrogen concentrations from 1993-2017 at long term water quality stations.

# ADEQ Long Term Stations, 2000-2017



## USGS Long Term Stations, 2000-2017

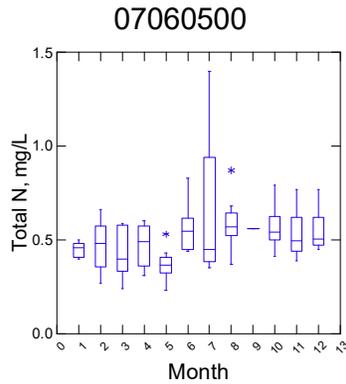


Figure B.12. Total nitrogen from some long-term stations show seasonal patterns in data from 2000-2017.

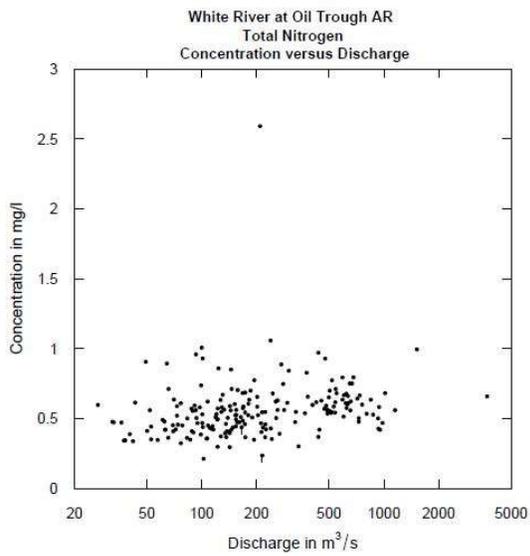
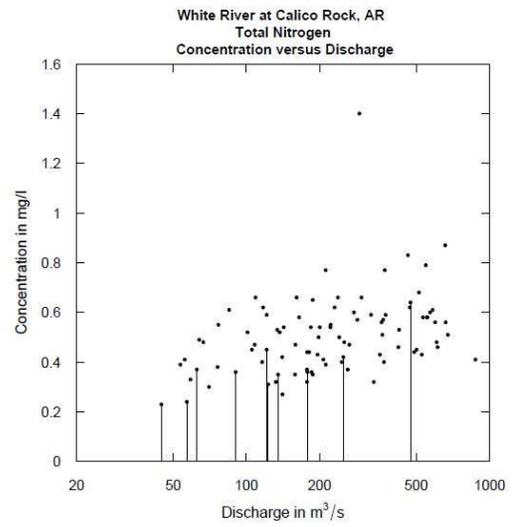
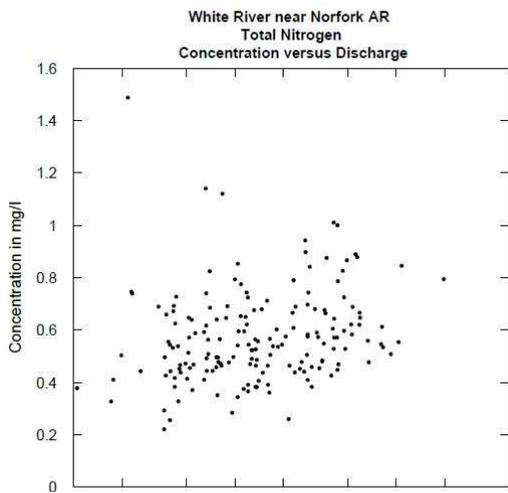


Figure B.13. Total nitrogen concentrations versus flow at long term stations associated with flow gages.

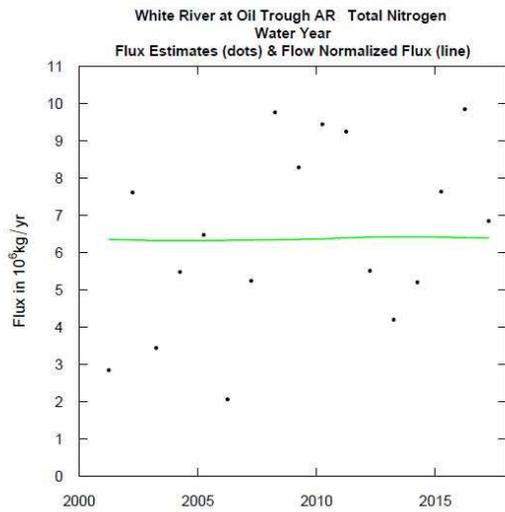
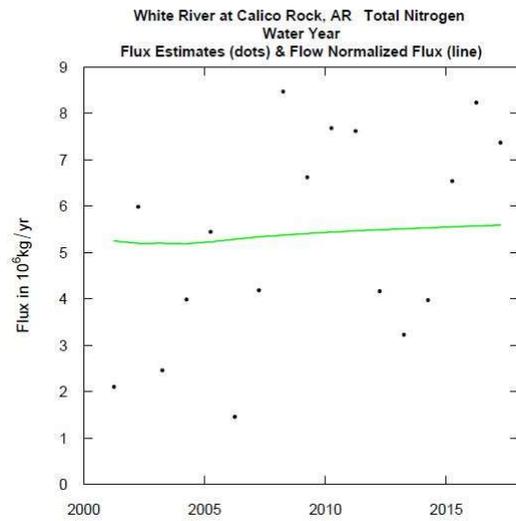
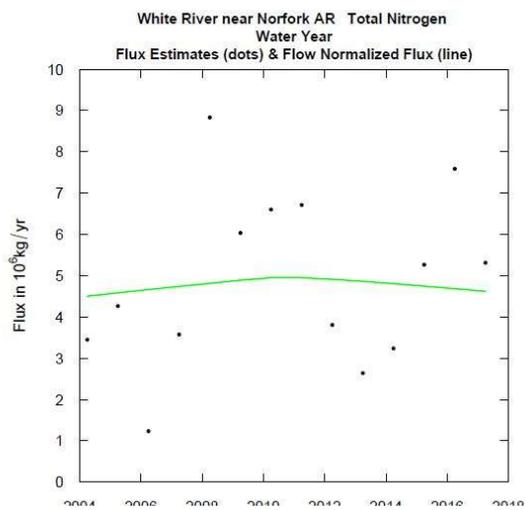


Figure B.14. WRTBS estimates of annual average total nitrogen flux at long term stations associated with flow gages.

## B.5. Total Phosphorus

Figure B.15 shows graphs of the available total phosphorus data for the period 1993-2017 for the selected water quality stations (all figures referenced in this subsection are located at end of this subsection). The total phosphorus data from the USGS stations is heavily censored, with around two-thirds of the data reported as less than detection; 65 of the 96 measurements at station 07060500, and 118 of the 186 measurements at station 07060710. In addition, the detection limits for total phosphorus have varied over time. Similarly, at ADEQ station WHI0046, 96 of the 291 measurements are reported as less than detection, and it appears that there was a change in the detection limit during the period 2004-2012. This makes the total phosphorus data from these stations unsuitable for trend analysis. Therefore, only total phosphorus data from three of the ADEQ monitoring stations, WHI0011, WHI0029, and WHI0065, are evaluated for trends. Total phosphorus data from these stations appear to exhibit changes over time.

Total phosphorus data may exhibit seasonal patterns, depending on the sources. Figure 16 shows box plots of total phosphorus by month. These plots suggest that total phosphorus exhibits seasonal patterns at some stations. For example, at station WHI0065 (Hicks Creek) total phosphorus appears to usually be higher during the period August through October, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.13. Total phosphorus measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.13. Normality test results for total phosphorus data from long term stations for the period 1993-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.663	0.00	21.18	<0.01	Not normal
WHI0029	0.167	0.00	71.07	<0.01	Not normal
WHI0065	0.894	0.00	9.67	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in total phosphorus concentrations for the period 1993-2017. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 5. The test results are summarized in Table B.14. No trends are indicated by this test.

Table B.14. Results of Seasonal Mann-Kendall test of total phosphorus data for 1993-2017, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	-92	-0.69	0.65	No
WHI0029	White R	-196	-1.42	0.32	No
WHI0065	Hicks Cr	-1	0.00	1.0	No

Total phosphorus can also be affected flow. Only one of the stations being analyzed for trends has daily flow measurements available nearby, WHI0029, White River at Oil Trough. Figure 17 shows a graph of total phosphorus data from this station versus flow. There is no readily apparent relationship between total phosphorus and flow at this station.

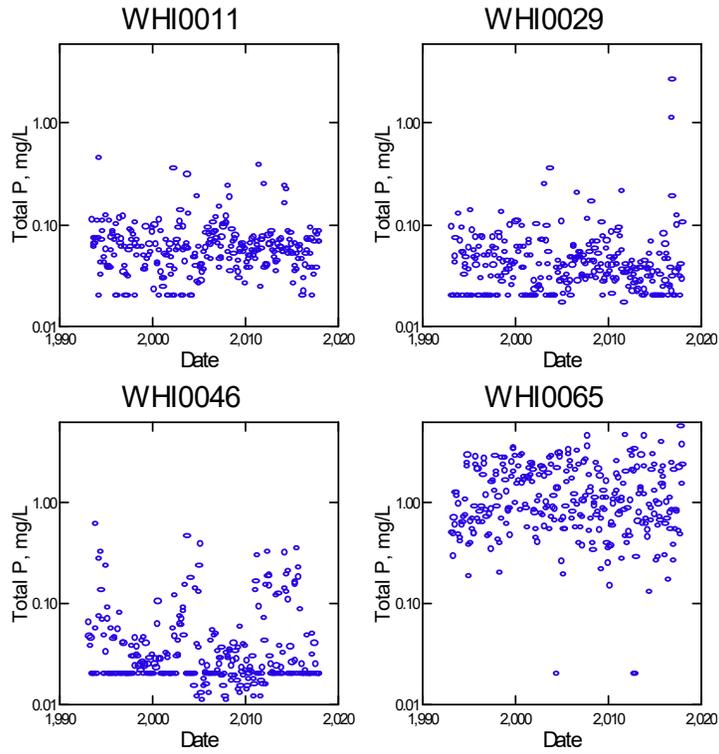
The WRTDS trend analysis (Hirsch, Moyer and Archfield 2010) was applied to the total phosphorus data from station WHI0029. Figure 18 shows WRTDS estimates of annual average total phosphorus flux (or export) for this station. The WRTDS results suggest that total phosphorus flux at this station has been declining since sometime between 2005 and 2010. However, the current total phosphorus flux appears greater than at the beginning of the analysis period.

The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.15 lists the flux bias statistics associated with the WRTDS analyses of total nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015).

Table B.15. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

Station ID	Stream	Flux Bias Statistic
WHI0046	White R	0.0232

### ADEQ Long Term Stations, 1993-2017



### USGS Long Term Stations, 1993-2017

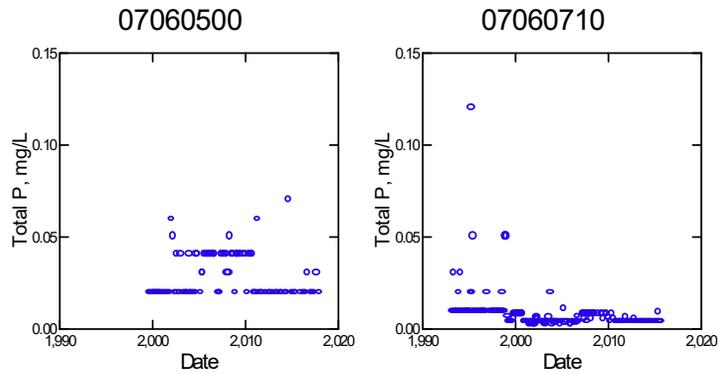


Figure B.15. Total phosphorus concentrations from 1993-2017 at long term water quality stations.

# ADEQ Long Term Stations, 1993-2017

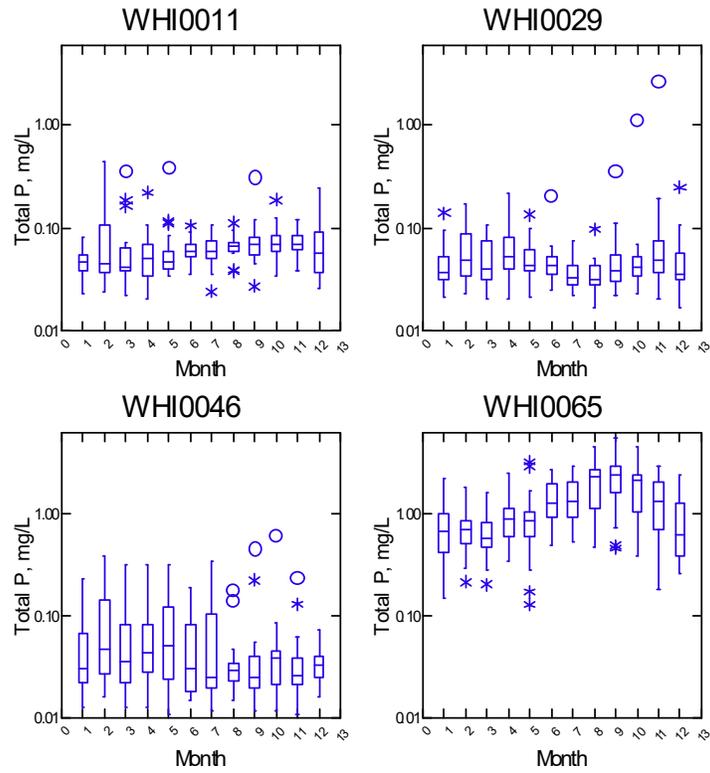


Figure B.16. Total phosphorus from some long-term stations show seasonal patterns in data from 1993-2017.

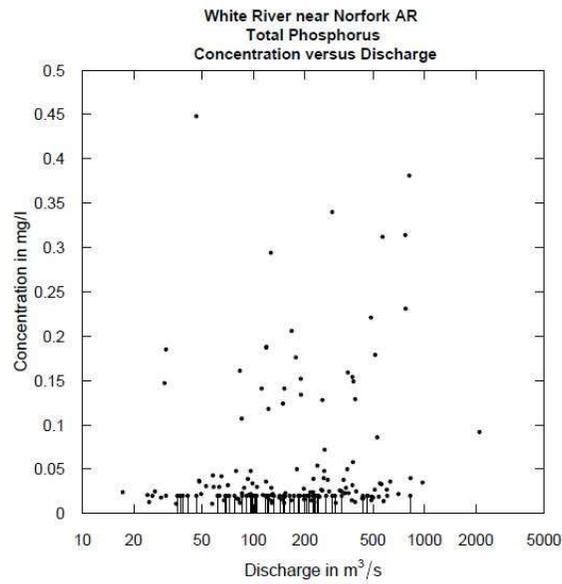


Figure B.17. Total phosphorus concentrations versus flow at White River near Norfolk (WHI0046).

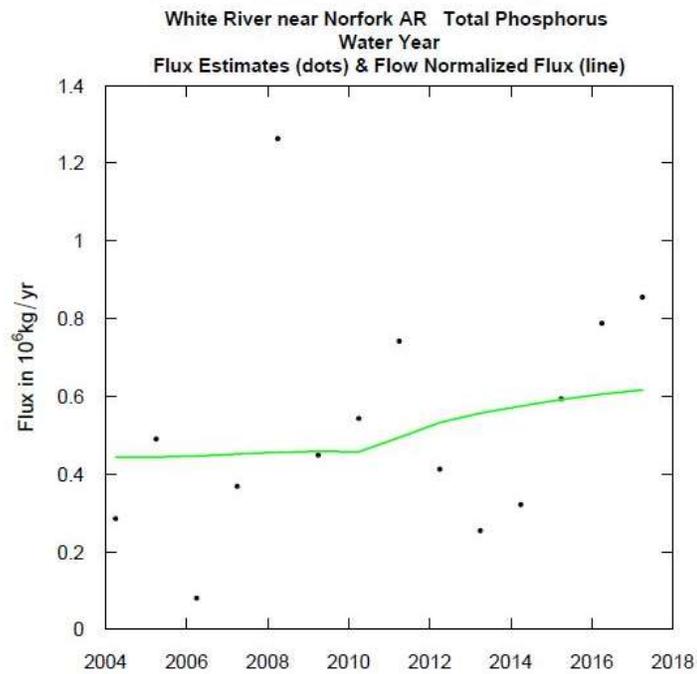


Figure B.18. WRTDS estimates of annual average total phosphorus flux at White River near Norfolk long term station (WHI0046).

## B.6. Fecal Coliforms

Figure B.19 shows graphs of the available fecal coliform data for the long-term water quality stations for the period 1993-2017. Note that this is USGS parameter code 31625. The only water quality station with fecal coliform measurements from the entire period 1993-2017 is the USGS station on the White River at Calico Rock (07060500). The fecal coliform data record for the USGS station on the North Sylamore Creek (07060710) ends in 2012. The fecal coliform data records for the ADEQ stations end in 1999. Only the fecal coliform data from USGS station 07060500 (White River at Calico Rock) is suitable for trend analysis.

Fecal coliform data may exhibit seasonal patterns. Figure B.20 shows a box plot of fecal coliform measurements from USGS station 07060500 by month. This plot appears to show a seasonal pattern in the data that may need to be accounted for in trend analysis.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.16. The fecal coliform measurements from station 07060500 are not normally distributed, so non-parametric trend analysis is used.

Table B.16. Normality test results for fecal coliform data from White River at Calico Rock (07060500) for the period 1993-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
07060500	0.631	0.00	13.17	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in fecal coliform measurements for the period 1993-2017. The USGS program for the Kendall family of tests was used to run the statistical test. In the data record, fecal coliform measurements were collected 7 to 4 times a year. Therefore, the program was set up with four seasons. Each season included data from three months. Based on the box plot in Figure B.20, data from different months were grouped into seasons as follows; June-August, September-November, December-February, and March-May. The program input and output are included as Attachment 6. The test results are summarized in Table B.17. No trends are indicated by this test.

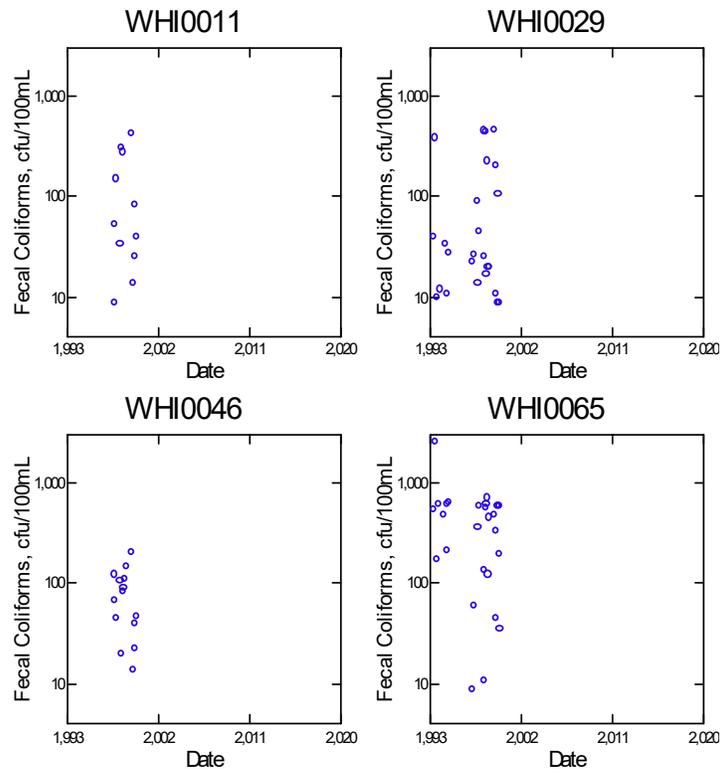
Table B.17. Results of Seasonal Mann-Kendall test of fecal coliform data for 1993-2017, assuming 4 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
07060500	White River	48	0.627	0.55	No
07060500 (2000-2017)	White River	-41	-0.895	0.35	No

Fecal coliforms can be related to flow. Figure B.21 shows a graph of fecal coliform data from this station versus flow. It appears that there may be a relationship between flow and fecal coliform levels.

The WRTDS trend analysis was also applied to these data. Figure B.22 shows WRTDS estimates of annual fecal coliform levels for this station. The WRTDS results indicate that fecal coliform levels in the White River at Calico Rock have been declining since sometime after 2000. We re-evaluated the fecal coliform data from 2000-2017 using the Seasonal Mann-Kendall test (see Table B.17). The declining trend shown during this period in the WRTDS results did not give a statistically significant result to the Mann-Kendall test.

## ADEQ Long Term Stations, 1993-2017



## USGS Long Term Stations, 1993-2017

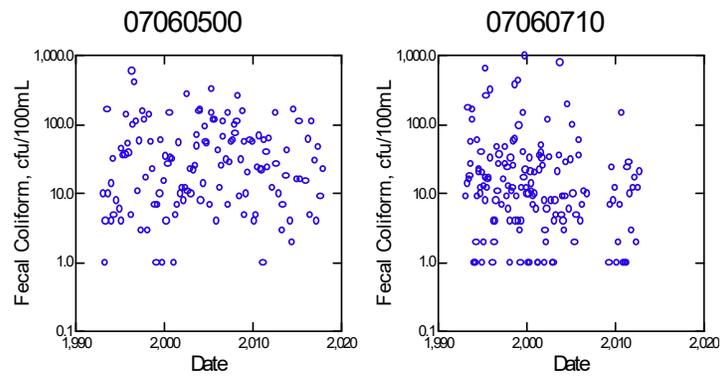


Figure B.19. Fecal coliform concentrations from 1993-2017 at long term water quality stations.

USGS Station 07060500, 1993-2017

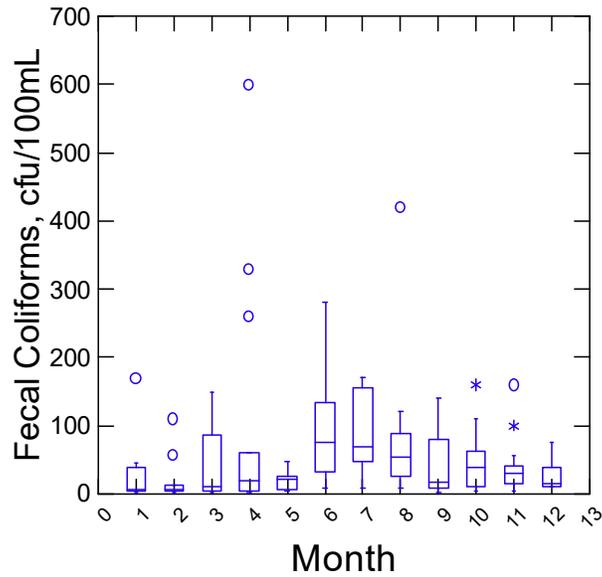


Figure B.20. Fecal coliform data from USGS station 07060500, White River at Calico Rock, 1993-2017, show seasonal pattern.

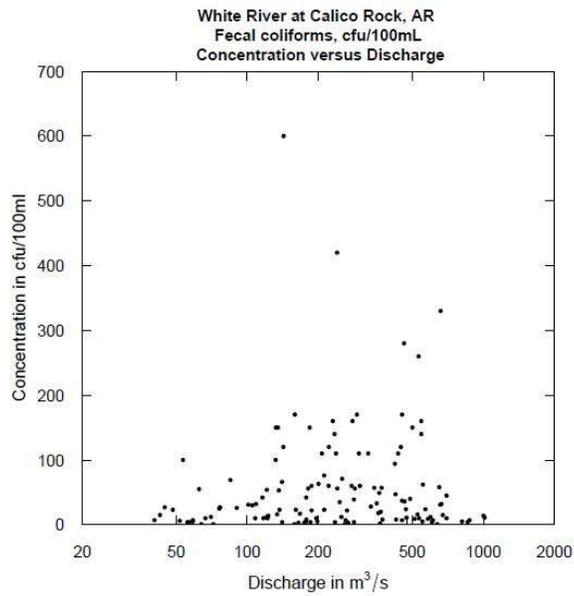


Figure B.21. 1993-2017 fecal coliform concentrations versus flow at White River at Calico Rock (07060500).

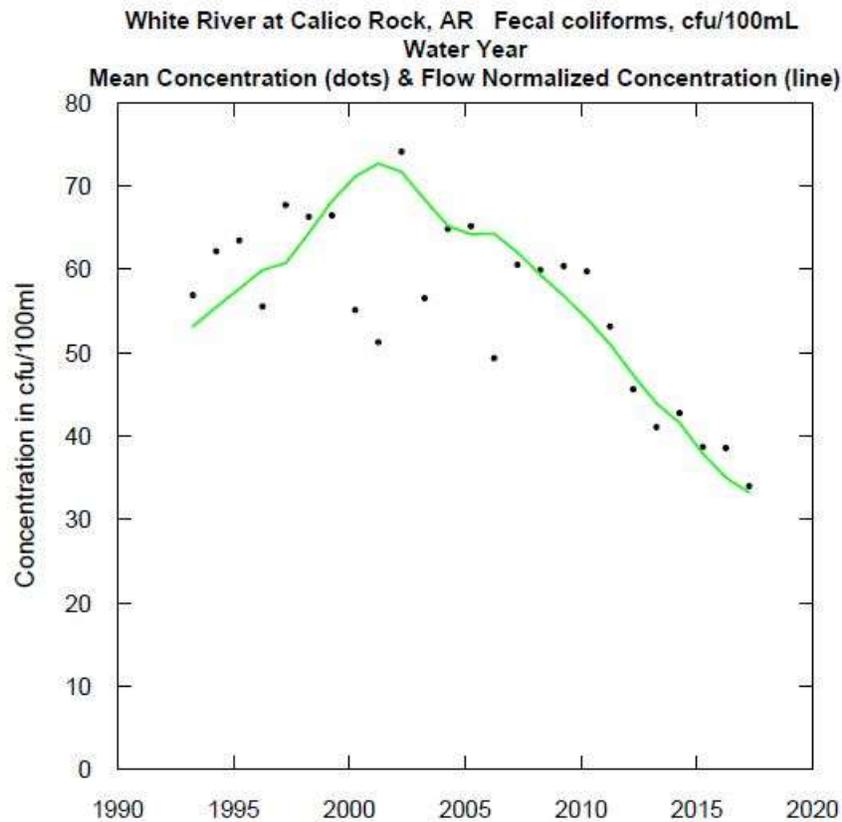


Figure B.22. WRTDS estimates of annual average fecal coliform concentration at White River at Calico Rock (07060500).

## B.7. REFERENCES

- Helsel, Dennis R, David K Mueller, and James R Slack. 2006. Computer Program for the Kendall Family of Trend Tests. Scientific Investigations Report 2005-5275, US Geological Survey. Accessed 2018. <https://pubs.usgs.gov/sir/2005/5275/>.
- Hirsch, Robert M, and Laura A De Cicco. 2015. User Guide to Exploration and Graphics for RivEr Trends (EGRET) and dataRetrieval: R Packages for Hydrologic Data. Techniques and Methods 4-A10, USGS.
- Hirsch, Robert, Douglas Moyer, and Stacey Archfield. 2010. "Weighted regressions on time, discharge, and season (WRTDS), with an application to Chesapeake Bay River inputs." *Journal of the Americal Water Resources Association* 46 (5): 857-880.

# **ATTACHMENT 1**

---

**Dissolved Oxygen Seasonal Mann-Kendall Input and Output**

2 0 DO WHI0011 1993-2017

1993 5 9.1  
1993 7 6.8  
1993 8 7.3  
1993 9 7.9  
1993 10 9.4  
1993 11 11.8  
1993 12 11.1  
1994 1 10.8  
1994 2 10.4  
1994 3 11.1  
1994 5 10  
1994 6 12  
1994 8 6.4  
1994 10 8.2  
1995 3 11.1  
1995 4 9.4  
1995 5 9.1  
1995 6 9.4  
1995 7 7.8  
1995 8 8.2  
1995 9 7  
1995 10 7.4  
1995 11 9.1  
1996 2 12.8  
1996 3 10.9  
1996 4 11.2  
1996 5 8.1  
1996 7 7.7  
1996 8 8.5  
1996 9 8.3  
1996 10 9.1  
1996 11 11.6  
1996 12 12.1  
1997 2 10.4  
1997 3 10.2  
1997 4 11.8  
1997 8 10.7  
1997 10 9.5  
1998 1 13.3  
1998 3 12.03  
1998 4 6.65  
1998 5 10.6  
1998 10 11  
1998 12 12  
1999 1 12  
1999 2 11.8  
1999 3 11  
1999 4 7.88  
1999 5 11.8  
1999 7 9.5  
1999 8 4.9  
1999 9 7.7

1999 10 6.2  
1999 11 10.8  
2000 1 11.56  
2000 2 7.88  
2000 3 8.21  
2000 4 7.1  
2000 5 6.6  
2000 6 9.12  
2000 8 7.75  
2000 8 6.91  
2000 9 6.38  
2000 10 6.27  
2000 11 8.91  
2000 12 10.48  
2001 2 7.65  
2001 3 8.94  
2001 4 6.79  
2001 5 6.72  
2001 6 5.09  
2001 7 5.13  
2001 8 6.57  
2001 9 6.42  
2001 10 5.91  
2001 11 6.07  
2001 12 7.84  
2002 1 8.45  
2002 2 7.99  
2002 3 7.02  
2002 4 7.46  
2002 5 7.37  
2002 6 5.81  
2002 7 5.42  
2002 8 4.39  
2002 10 6.56  
2002 12 9.68  
2003 3 13.5  
2003 4 11.3  
2003 4 7.78  
2003 5 9.49  
2003 6 7.24  
2003 7 6.04  
2003 8 8.33  
2003 9 9.21  
2003 10 8.74  
2003 11 8.84  
2003 12 9.62  
2004 1 12.2  
2004 2 9.35  
2004 6 7.72  
2004 7 10.2  
2004 8 8.25  
2004 9 9.58  
2004 10 8.16  
2004 11 10.4

2004 12 11.5  
2005 1 12.3  
2005 2 12.1  
2005 3 13.8  
2005 4 11.1  
2005 5 12  
2005 5 9.96  
2005 7 8.98  
2005 8 8.81  
2005 9 7.63  
2005 10 8.92  
2005 11 9.4  
2005 12 12  
2006 1 13.8  
2006 3 11.7  
2006 4 15.1  
2006 5 9.91  
2006 6 12.8  
2006 7 8.41  
2006 8 7.86  
2006 9 9.93  
2006 10 10.2  
2006 11 9.91  
2006 12 11.8  
2007 1 14.1  
2007 2 12.5  
2007 3 11.7  
2007 4 11.8  
2007 5 9.89  
2007 6 9.91  
2007 7 7.96  
2007 8 6.15  
2007 9 9.91  
2007 10 9.14  
2007 11 12  
2007 12 12  
2008 1 10.9  
2008 2 11.8  
2008 3 9.98  
2008 4 9.89  
2008 5 9.89  
2008 6 7.44  
2008 7 7.76  
2008 8 7.09  
2008 9 8.66  
2008 10 8.61  
2008 11 12.1  
2008 12 12.3  
2009 1 13.2  
2009 2 13.6  
2009 3 9.95  
2009 4 12.1  
2009 5 10.5  
2009 6 8.83

2009 8 7.36  
2009 9 9.12  
2009 10 10.3  
2009 11 10.9  
2009 12 12  
2010 1 14.2  
2010 2 14.8  
2010 3 11.6  
2010 4 11  
2010 5 11.1  
2010 6 9.94  
2010 7 9.17  
2010 8 8.4  
2010 9 7.46  
2010 10 8  
2010 11 8.92  
2010 12 11.9  
2011 1 13.6  
2011 2 15.1  
2011 3 12.8  
2011 4 9.46  
2011 5 9.92  
2011 6 8.28  
2011 7 7.65  
2011 8 8.77  
2011 9 9.26  
2011 10 9.47  
2011 11 11.1  
2011 12 10.7  
2012 1 12  
2012 2 11.9  
2012 3 10.3  
2012 4 8.33  
2012 5 6.52  
2012 6 8.73  
2012 7 8.38  
2012 8 7.53  
2012 9 7.41  
2012 10 9.96  
2012 11 8.72  
2012 12 8.05  
2013 1 12.8  
2013 2 14  
2013 3 12.1  
2013 4 11.7  
2013 5 11.7  
2013 6 9.85  
2013 7 9.08  
2013 8 7.47  
2013 9 7.78  
2013 12 10.4  
2014 1 13.3  
2014 2 13  
2014 3 11.4

2014 4 9.48  
2014 5 10.1  
2014 6 7.6  
2014 7 7.99  
2014 8 10.1  
2014 9 6.07  
2014 10 6.94  
2014 11 8.67  
2014 12 8.27  
2015 1 11.7  
2015 2 11.5  
2015 3 11.6  
2015 4 10.1  
2015 5 10.7  
2015 6 10.5  
2015 7 9.96  
2015 8 7.42  
2015 9 7.73  
2015 10 7.59  
2015 11 8.47  
2016 1 11.2  
2016 2 10.4  
2016 3 9.3  
2016 4 10.3  
2016 5 9.04  
2016 6 7.62  
2016 7 7.67  
2016 8 7.73  
2016 9 6.8  
2016 10 9.22  
2016 11 10.3  
2016 12 11.2  
2017 1 11.9  
2017 2 11  
2017 3 9.8  
2017 4 8.19  
2017 5 9.61  
2017 6 9.37  
2017 7 7.24  
2017 8 7.78  
2017 9 7.43  
2017 10 8.88  
2017 11 9.83  
2017 12 8.22

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: O WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.050

$$S = 129.$$

$$z = 1.086$$

$$p = 0.2774$$

$$p = 0.5946 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 9.259 + 0.1625E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO WHI0011 2004-2017

2004 1 12.2  
2004 2 9.35  
2004 6 7.72  
2004 7 10.2  
2004 8 8.25  
2004 9 9.58  
2004 10 8.16  
2004 11 10.4  
2004 12 11.5  
2005 1 12.3  
2005 2 12.1  
2005 3 13.8  
2005 4 11.1  
2005 5 12  
2005 5 9.96  
2005 7 8.98  
2005 8 8.81  
2005 9 7.63  
2005 10 8.92  
2005 11 9.4  
2005 12 12  
2006 1 13.8  
2006 3 11.7  
2006 4 15.1  
2006 5 9.91  
2006 6 12.8  
2006 7 8.41  
2006 8 7.86  
2006 9 9.93  
2006 10 10.2  
2006 11 9.91  
2006 12 11.8  
2007 1 14.1  
2007 2 12.5  
2007 3 11.7  
2007 4 11.8  
2007 5 9.89  
2007 6 9.91  
2007 7 7.96  
2007 8 6.15  
2007 9 9.91  
2007 10 9.14  
2007 11 12  
2007 12 12  
2008 1 10.9  
2008 2 11.8  
2008 3 9.98  
2008 4 9.89  
2008 5 9.89  
2008 6 7.44  
2008 7 7.76  
2008 8 7.09

2008 9 8.66  
2008 10 8.61  
2008 11 12.1  
2008 12 12.3  
2009 1 13.2  
2009 2 13.6  
2009 3 9.95  
2009 4 12.1  
2009 5 10.5  
2009 6 8.83  
2009 8 7.36  
2009 9 9.12  
2009 10 10.3  
2009 11 10.9  
2009 12 12  
2010 1 14.2  
2010 2 14.8  
2010 3 11.6  
2010 4 11  
2010 5 11.1  
2010 6 9.94  
2010 7 9.17  
2010 8 8.4  
2010 9 7.46  
2010 10 8  
2010 11 8.92  
2010 12 11.9  
2011 1 13.6  
2011 2 15.1  
2011 3 12.8  
2011 4 9.46  
2011 5 9.92  
2011 6 8.28  
2011 7 7.65  
2011 8 8.77  
2011 9 9.26  
2011 10 9.47  
2011 11 11.1  
2011 12 10.7  
2012 1 12  
2012 2 11.9  
2012 3 10.3  
2012 4 8.33  
2012 5 6.52  
2012 6 8.73  
2012 7 8.38  
2012 8 7.53  
2012 9 7.41  
2012 10 9.96  
2012 11 8.72  
2012 12 8.05  
2013 1 12.8  
2013 2 14  
2013 3 12.1

2013 4 11.7  
2013 5 11.7  
2013 6 9.85  
2013 7 9.08  
2013 8 7.47  
2013 9 7.78  
2013 12 10.4  
2014 1 13.3  
2014 2 13  
2014 3 11.4  
2014 4 9.48  
2014 5 10.1  
2014 6 7.6  
2014 7 7.99  
2014 8 10.1  
2014 9 6.07  
2014 10 6.94  
2014 11 8.67  
2014 12 8.27  
2015 1 11.7  
2015 2 11.5  
2015 3 11.6  
2015 4 10.1  
2015 5 10.7  
2015 6 10.5  
2015 7 9.96  
2015 8 7.42  
2015 9 7.73  
2015 10 7.59  
2015 11 8.47  
2016 1 11.2  
2016 2 10.4  
2016 3 9.3  
2016 4 10.3  
2016 5 9.04  
2016 6 7.62  
2016 7 7.67  
2016 8 7.73  
2016 9 6.8  
2016 10 9.22  
2016 11 10.3  
2016 12 11.2  
2017 1 11.9  
2017 2 11  
2017 3 9.8  
2017 4 8.19  
2017 5 9.61  
2017 6 9.37  
2017 7 7.24  
2017 8 7.78  
2017 9 7.43  
2017 10 8.88  
2017 11 9.83  
2017 12 8.22



Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO WHI0011 2004-2017

The record is 15 complete water years with 12 seasons per year beginning in water year 2004.

The tau correlation coefficient is -0.249

S = -243.

z = -4.143

p = 0.0000

p = 0.0196 adjusted for correlation among seasons  
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 10.64 + -0.9778E-01 * \text{Time}$$

where Time = Year (as a decimal) - 2003.75  
(beginning of first water year)

2 0 DO WHI0029 1993-2017

1993 1 10.3  
1993 2 11.1  
1993 3 11.1  
1993 4 8.9  
1993 5 10  
1993 6 9.1  
1993 7 8.3  
1993 8 9.2  
1993 9 10.2  
1993 10 10.2  
1993 11 11.8  
1993 12 11  
1994 1 10.6  
1994 2 10.3  
1994 3 10.1  
1994 5 10.4  
1994 6 10  
1994 8 8.5  
1994 10 10.2  
1995 3 9.9  
1995 4 9.5  
1995 5 7.3  
1995 6 8.1  
1995 7 7.6  
1995 8 8.7  
1995 9 8.2  
1995 10 9.2  
1995 11 10.4  
1996 2 11.7  
1996 3 10.8  
1996 4 10.9  
1996 5 8.6  
1996 7 8.1  
1996 8 9.8  
1996 9 9.6  
1996 10 8.9  
1996 11 10.6  
1996 12 12.3  
1997 2 10.1  
1997 3 10.5  
1997 4 9.9  
1997 7 9.8  
1997 8 12.1  
1997 9 12.2  
1997 10 10.8  
1998 3 10  
1998 4 10.2  
1998 5 9.6  
1998 6 9  
1998 7 9.6  
1998 8 9.3  
1998 9 8.9

1998 10 11.7  
1998 11 10  
1998 12 11.4  
1999 1 11.2  
1999 2 10.7  
1999 3 10.4  
1999 4 9.3  
1999 5 8.1  
1999 6 10.4  
1999 7 10.5  
1999 8 9.5  
1999 9 8.7  
1999 11 9.5  
2000 1 12.45  
2000 2 7.92  
2000 3 8.05  
2000 4 8.24  
2000 6 7.9  
2000 8 7.58  
2000 8 7.23  
2000 9 7.98  
2000 10 7.92  
2000 11 9.22  
2000 12 10.66  
2001 2 8.12  
2001 3 8.35  
2001 4 7.08  
2001 5 6  
2001 6 5.7  
2001 7 5.93  
2001 8 7.3  
2001 9 6.46  
2001 10 7.79  
2001 11 7.59  
2001 12 7.7  
2002 1 8.9  
2002 2 8.31  
2002 3 7.63  
2002 5 6.75  
2002 6 5.56  
2002 7 7.01  
2002 8 6.78  
2002 10 5.97  
2002 12 11.6  
2003 3 12.6  
2003 4 11  
2003 4 9.1  
2003 5 7.64  
2003 6 8.69  
2003 7 8.36  
2003 8 9.02  
2003 9 8.26  
2003 10 9.28  
2003 11 9.28

2003 12 10.9  
2004 1 11.5  
2004 2 9.26  
2004 6 9.16  
2004 7 8.84  
2004 8 9.49  
2004 9 8.67  
2004 10 9.4  
2004 12 11.1  
2005 1 12.6  
2005 2 11.2  
2005 3 10.8  
2005 4 10.6  
2005 5 9.11  
2005 7 8.53  
2005 8 8.89  
2005 9 8.03  
2005 10 9.8  
2005 11 10.6  
2005 12 11.8  
2006 1 14.6  
2006 3 11  
2006 4 9.53  
2006 5 10.2  
2006 6 9.4  
2006 7 9.86  
2006 8 9.67  
2006 9 9.75  
2006 10 9.95  
2006 11 10.8  
2006 12 9.95  
2007 1 13.2  
2007 2 9.9  
2007 3 12.3  
2007 4 12.5  
2007 5 9.81  
2007 6 9.46  
2007 7 10.2  
2007 8 10.1  
2007 9 7.55  
2007 10 8.51  
2007 11 10.8  
2007 12 12.8  
2008 1 14  
2008 2 11.9  
2008 3 11.8  
2008 4 10.2  
2008 5 10.1  
2008 6 10.5  
2008 7 10.1  
2008 8 10.4  
2008 9 7.84  
2008 10 10  
2008 11 10.4

2008 12 12.8  
2009 1 13.1  
2009 2 14.9  
2009 3 10.4  
2009 4 12.7  
2009 5 10.4  
2009 6 9.47  
2009 8 9.56  
2009 9 8.47  
2009 10 8.7  
2009 11 9.66  
2009 12 12  
2010 1 13  
2010 2 12.3  
2010 3 11.2  
2010 4 10  
2010 5 10.4  
2010 6 10.6  
2010 7 10.4  
2010 8 10.1  
2010 9 8.36  
2010 10 10  
2010 10 9.1  
2010 11 10.8  
2010 11 11.7  
2011 1 13.2  
2011 2 11.7  
2011 3 9.85  
2011 4 8.53  
2011 5 9.54  
2011 6 9.3  
2011 7 9.91  
2011 8 10.4  
2011 9 9.46  
2011 11 10.1  
2011 12 11.5  
2012 1 9.77  
2012 2 11.9  
2012 3 9.78  
2012 4 10.9  
2012 5 8.78  
2012 6 8.98  
2012 7 8.1  
2012 8 8.53  
2012 9 8.89  
2012 10 9.07  
2012 11 10.7  
2012 12 10.8  
2013 1 12  
2013 2 12.7  
2013 3 11.2  
2013 4 10.4  
2013 5 9.92  
2013 6 10.3

2013 7 9.02  
2013 8 9.9  
2013 9 9.66  
2013 10 10.5  
2013 11 11.2  
2013 12 11.8  
2014 1 12.6  
2014 2 11.7  
2014 3 11.9  
2014 4 10.8  
2014 5 10.6  
2014 6 10  
2014 7 9.8  
2014 8 9.55  
2014 9 9.97  
2014 10 10.3  
2014 11 12.3  
2014 12 11.8  
2015 1 11.8  
2015 2 9.76  
2015 3 10.1  
2015 4 9.25  
2015 5 11  
2015 6 8.02  
2015 7 8.53  
2015 8 10.3  
2015 9 9.91  
2015 10 9.24  
2015 11 9.27  
2015 11 10.6  
2015 12 9.74  
2016 1 12.2  
2016 2 11.9  
2016 3 7.98  
2016 4 9.88  
2016 5 9.21  
2016 6 9.07  
2016 7 9.25  
2016 8 4.05  
2016 9 8.48  
2016 11 8.62  
2016 11 8.12  
2016 11 7.69  
2016 12 12.7  
2017 1 13.1  
2017 2 12.1  
2017 3 11.5  
2017 4 10  
2017 5 8.62  
2017 6 8.48  
2017 7 6.94  
2017 8 9.21  
2017 9 8.88  
2017 10 8.88

2017 11 8.28  
2017 12 11.9

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.128

$$S = 354.$$

$$z = 2.872$$

$$p = 0.0041$$

$$p = 0.1623 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 9.499 + 0.3087E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO WHI0029 2004-2017

2004 1 11.5  
2004 2 9.26  
2004 6 9.16  
2004 7 8.84  
2004 8 9.49  
2004 9 8.67  
2004 10 9.4  
2004 12 11.1  
2005 1 12.6  
2005 2 11.2  
2005 3 10.8  
2005 4 10.6  
2005 5 9.11  
2005 7 8.53  
2005 8 8.89  
2005 9 8.03  
2005 10 9.8  
2005 11 10.6  
2005 12 11.8  
2006 1 14.6  
2006 3 11  
2006 4 9.53  
2006 5 10.2  
2006 6 9.4  
2006 7 9.86  
2006 8 9.67  
2006 9 9.75  
2006 10 9.95  
2006 11 10.8  
2006 12 9.95  
2007 1 13.2  
2007 2 9.9  
2007 3 12.3  
2007 4 12.5  
2007 5 9.81  
2007 6 9.46  
2007 7 10.2  
2007 8 10.1  
2007 9 7.55  
2007 10 8.51  
2007 11 10.8  
2007 12 12.8  
2008 1 14  
2008 2 11.9  
2008 3 11.8  
2008 4 10.2  
2008 5 10.1  
2008 6 10.5  
2008 7 10.1  
2008 8 10.4  
2008 9 7.84  
2008 10 10

2008 11 10.4  
2008 12 12.8  
2009 1 13.1  
2009 2 14.9  
2009 3 10.4  
2009 4 12.7  
2009 5 10.4  
2009 6 9.47  
2009 8 9.56  
2009 9 8.47  
2009 10 8.7  
2009 11 9.66  
2009 12 12  
2010 1 13  
2010 2 12.3  
2010 3 11.2  
2010 4 10  
2010 5 10.4  
2010 6 10.6  
2010 7 10.4  
2010 8 10.1  
2010 9 8.36  
2010 10 10  
2010 10 9.1  
2010 11 10.8  
2010 11 11.7  
2011 1 13.2  
2011 2 11.7  
2011 3 9.85  
2011 4 8.53  
2011 5 9.54  
2011 6 9.3  
2011 7 9.91  
2011 8 10.4  
2011 9 9.46  
2011 11 10.1  
2011 12 11.5  
2012 1 9.77  
2012 2 11.9  
2012 3 9.78  
2012 4 10.9  
2012 5 8.78  
2012 6 8.98  
2012 7 8.1  
2012 8 8.53  
2012 9 8.89  
2012 10 9.07  
2012 11 10.7  
2012 12 10.8  
2013 1 12  
2013 2 12.7  
2013 3 11.2  
2013 4 10.4  
2013 5 9.92

2013 6 10.3  
2013 7 9.02  
2013 8 9.9  
2013 9 9.66  
2013 10 10.5  
2013 11 11.2  
2013 12 11.8  
2014 1 12.6  
2014 2 11.7  
2014 3 11.9  
2014 4 10.8  
2014 5 10.6  
2014 6 10  
2014 7 9.8  
2014 8 9.55  
2014 9 9.97  
2014 10 10.3  
2014 11 12.3  
2014 12 11.8  
2015 1 11.8  
2015 2 9.76  
2015 3 10.1  
2015 4 9.25  
2015 5 11  
2015 6 8.02  
2015 7 8.53  
2015 8 10.3  
2015 9 9.91  
2015 10 9.24  
2015 11 9.27  
2015 11 10.6  
2015 12 9.74  
2016 1 12.2  
2016 2 11.9  
2016 3 7.98  
2016 4 9.88  
2016 5 9.21  
2016 6 9.07  
2016 7 9.25  
2016 8 4.05  
2016 9 8.48  
2016 11 8.62  
2016 11 8.12  
2016 11 7.69  
2016 12 12.7  
2017 1 13.1  
2017 2 12.1  
2017 3 11.5  
2017 4 10  
2017 5 8.62  
2017 6 8.48  
2017 7 6.94  
2017 8 9.21  
2017 9 8.88

2017 10 8.88  
2017 11 8.28  
2017 12 11.9

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO WHI0029 2004-2017

The record is 15 complete water years with 12 seasons per year beginning in water year 2004.

The tau correlation coefficient is -0.057

$$S = -55.$$

$$z = -0.934$$

$$p = 0.3504$$

$$p = 0.5510 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 10.20 + -0.2000E-01 * \text{Time}$$

where Time = Year (as a decimal) - 2003.75  
(beginning of first water year)

2 0 DO WHI0046 1993-2017

1993 1 11.5  
1993 2 11.4  
1993 3 10.5  
1993 4 9.7  
1993 5 9.4  
1993 6 8.5  
1993 7 8.3  
1993 8 9.1  
1993 9 10  
1993 10 8.2  
1993 11 9.8  
1993 12 11.7  
1994 1 10  
1994 2 11.9  
1994 3 10.2  
1994 4 9.5  
1994 5 9.6  
1994 6 9.7  
1994 7 8.6  
1994 8 8.9  
1994 9 8.1  
1994 10 8.3  
1994 11 10.3  
1995 1 11.1  
1995 2 10  
1995 3 11.2  
1995 4 10.6  
1995 5 9  
1995 6 8.1  
1995 7 9.5  
1995 8 8  
1995 9 7.6  
1995 10 7.9  
1995 10 8.3  
1995 11 11.5  
1996 1 12.3  
1996 2 9.8  
1996 3 12.2  
1996 4 12  
1996 5 11.1  
1996 6 10.8  
1996 7 11.6  
1996 8 11.5  
1996 9 10.8  
1996 10 12.1  
1996 11 8.5  
1996 12 8.6  
1997 1 14.8  
1997 2 11.6  
1997 3 10.9  
1997 4 10.6  
1997 5 10.8

1997 6 9.9  
1997 8 12.6  
1997 9 9.2  
1997 10 9.1  
1997 11 10.2  
1997 12 12.2  
1998 1 10.2  
1998 2 11.1  
1998 4 10.8  
1998 5 10.8  
1998 6 11  
1998 7 10.3  
1998 8 8.4  
1998 9 7.7  
1998 10 9.6  
1998 11 11  
1998 12 10.7  
1999 1 13  
1999 2 11.4  
1999 3 10.4  
1999 4 10.2  
1999 5 9.9  
1999 7 11.06  
1999 8 7.75  
1999 9 8.03  
1999 10 9.1  
1999 11 9  
1999 11 12.6  
2000 1 12.1  
2000 2 12.9  
2000 3 10.1  
2000 4 8.9  
2000 5 8.8  
2000 6 7.8  
2000 7 8.7  
2000 8 9.5  
2000 9 9.82  
2000 10 10.7  
2000 10 11.6  
2000 12 10.2  
2001 1 12.2  
2001 2 11.7  
2001 3 12.5  
2001 4 10.1  
2001 5 9.5  
2001 6 9.1  
2001 7 11.8  
2001 8 10.6  
2001 9 9.5  
2001 10 10.6  
2001 11 10.2  
2001 12 9.9  
2002 1 12.1  
2002 2 11.5

2002 3 12.9  
2002 4 11  
2002 5 10.8  
2002 6 9.9  
2002 7 9.3  
2002 8 7.8  
2002 10 7.76  
2002 11 11.5  
2002 12 10.1  
2003 1 11.5  
2003 2 12.4  
2003 3 12.6  
2003 4 10.4  
2003 5 10.6  
2003 6 10.9  
2003 7 11  
2003 8 10  
2003 9 9.48  
2003 10 9.69  
2003 12 10.9  
2004 1 13.7  
2004 2 12.9  
2004 3 11.2  
2004 4 11.5  
2004 5 10.6  
2004 6 10.9  
2004 7 8.85  
2004 8 9.39  
2004 9 9.47  
2004 10 9.18  
2004 11 8.72  
2004 12 8.46  
2005 1 9.87  
2005 2 12.1  
2005 3 12.2  
2005 4 11  
2005 5 10  
2005 6 8.05  
2005 7 9.2  
2005 8 10.3  
2005 9 9.74  
2005 10 9.67  
2005 11 11.9  
2005 12 12.9  
2006 1 13.1  
2006 2 13  
2006 2 13.7  
2006 4 9.52  
2006 5 8.58  
2006 6 10.4  
2006 7 9.68  
2006 8 10.5  
2006 9 10.6  
2006 10 8.98

2006 11 10.7  
2006 12 11  
2007 1 13.5  
2007 2 13  
2007 3 11.1  
2007 4 11.7  
2007 5 10  
2007 6 10.9  
2007 7 10.9  
2007 8 10.2  
2007 9 11.6  
2007 10 9.84  
2007 11 12.9  
2007 12 11.5  
2008 1 9.87  
2008 2 14.8  
2008 3 11.6  
2008 4 10.1  
2008 5 10.7  
2008 6 9.86  
2008 7 8.77  
2008 8 9.76  
2008 9 7.22  
2008 10 6.75  
2008 11 7.63  
2008 12 9.63  
2009 1 12.2  
2009 2 11.9  
2009 3 10.7  
2009 4 9.85  
2009 5 9.49  
2009 6 9.26  
2009 7 8.53  
2009 8 8.28  
2009 9 9.45  
2009 10 10.1  
2009 11 10.5  
2009 12 7.48  
2010 1 10.3  
2010 2 11.6  
2010 3 11.6  
2010 4 10.2  
2010 5 10.1  
2010 6 11.9  
2010 7 8.33  
2010 8 8.23  
2010 9 9.92  
2010 10 10  
2010 11 9.58  
2010 12 9.58  
2011 1 13.1  
2011 2 13.2  
2011 3 13.4  
2011 4 10.5

2011 5 9.94  
2011 6 8.56  
2011 7 9.81  
2011 8 10.3  
2011 9 8.9  
2011 10 10.6  
2011 11 12  
2011 12 10.3  
2012 1 10.4  
2012 2 12.1  
2012 3 9.97  
2012 4 8.87  
2012 5 9.54  
2012 6 11.3  
2012 7 9.25  
2012 8 9.77  
2012 9 10.2  
2012 10 12.3  
2012 11 10.4  
2012 12 9.66  
2013 1 12.8  
2013 2 11.5  
2013 3 13.1  
2013 4 10.4  
2013 5 13.4  
2013 6 12.7  
2013 7 11.2  
2013 8 8.31  
2013 9 9.08  
2013 12 11.5  
2014 1 10.6  
2014 2 13.7  
2014 3 11.6  
2014 4 10.2  
2014 5 12.1  
2014 6 10.9  
2014 7 10.9  
2014 8 12.7  
2014 9 10.2  
2014 10 9.11  
2014 11 11.6  
2014 12 8.73  
2015 1 11.9  
2015 2 12.6  
2015 3 11  
2015 4 11.9  
2015 5 13.1  
2015 6 11.3  
2015 7 11.2  
2015 8 9.89  
2015 9 8.89  
2015 10 7.5  
2015 11 9.03  
2016 1 11.1

2016 2 10.9  
2016 3 10.9  
2016 4 11.2  
2016 5 8.89  
2016 6 10  
2016 7 9.26  
2016 8 7.48  
2016 9 7.83  
2016 10 9.83  
2016 11 10.5  
2016 12 11.5  
2017 1 11.9  
2017 2 13.9  
2017 3 10.4  
2017 4 9.77  
2017 5 10.1  
2017 6 9.25  
2017 7 8.93  
2017 8 8.34  
2017 9 7.9  
2017 10 8.82  
2017 11 10.1  
2017 12 8.36

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.065

$$S = 215.$$

$$z = 1.537$$

$$p = 0.1244$$

$$p = 0.3358 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 10.11 + 0.1429E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO WHI0065 1993-2017

1993 1 13.2  
1993 2 12.3  
1993 3 12.4  
1993 4 10.2  
1993 5 7.9  
1993 6 7.1  
1993 7 5.8  
1993 8 9.3  
1993 9 9.8  
1993 10 9  
1993 11 10.5  
1993 12 11.2  
1994 1 12.3  
1994 2 11.8  
1994 3 10.8  
1994 4 10.3  
1994 5 10.4  
1994 6 9  
1994 7 7.2  
1994 8 8.2  
1994 9 8.3  
1994 10 7.7  
1994 11 9.2  
1995 1 13.8  
1995 2 11.2  
1995 3 10.6  
1995 4 12.4  
1995 5 10.9  
1995 6 8.7  
1995 7 8.7  
1995 8 7.2  
1995 9 7.3  
1995 10 8.3  
1995 10 10.2  
1995 11 12.2  
1996 1 12.2  
1996 2 14.4  
1996 3 12.8  
1996 4 12.7  
1996 5 10.1  
1996 6 11.4  
1996 7 7.5  
1996 8 8.3  
1996 9 10.8  
1996 10 9.8  
1996 11 10.1  
1996 12 10.5  
1997 1 15.3  
1997 2 12.5  
1997 3 12.1  
1997 4 12.4  
1997 5 9.8

1997 6 10.9  
1997 8 8.8  
1997 9 7.4  
1997 10 7.4  
1997 11 12.2  
1997 12 12.9  
1998 1 11.8  
1998 2 11.4  
1998 4 12.9  
1998 5 9.9  
1998 6 10.4  
1998 7 9.8  
1998 8 8.3  
1998 9 6.9  
1998 10 10.4  
1998 11 12.2  
1998 12 12.2  
1999 1 12  
1999 2 11.7  
1999 3 11.7  
1999 4 10.2  
1999 5 9.6  
1999 7 7.08  
1999 8 7.04  
1999 9 7.42  
1999 10 7.8  
1999 11 9.2  
1999 11 12.2  
2000 1 13.1  
2000 2 13.3  
2000 3 11.2  
2000 4 12.8  
2000 5 11.5  
2000 6 10.8  
2000 7 9.2  
2000 8 9.5  
2000 9 10.05  
2000 10 10.2  
2000 10 10.8  
2000 12 12.1  
2001 1 12.9  
2001 2 12.4  
2001 3 13.2  
2001 4 13.3  
2001 5 10.2  
2001 6 8.9  
2001 7 10.4  
2001 8 11.2  
2001 9 9.1  
2001 10 10.1  
2001 11 12.8  
2001 12 11.1  
2002 1 13.5  
2002 2 12.4

2002 3 13.1  
2002 4 13.3  
2002 5 10.2  
2002 6 9.1  
2002 7 9.7  
2002 8 6.7  
2002 10 9.16  
2002 11 11.2  
2002 12 13.2  
2003 1 13.5  
2003 2 13.2  
2003 3 13.7  
2003 4 12.3  
2003 5 10.9  
2003 6 10.9  
2003 7 6.96  
2003 8 9.9  
2003 9 9.52  
2003 10 9.06  
2003 12 11.6  
2004 1 13.1  
2004 2 14  
2004 3 13  
2004 4 13.1  
2004 5 11.5  
2004 6 10.3  
2004 7 8.59  
2004 8 9.69  
2004 9 8.67  
2004 10 9.62  
2004 11 9.48  
2004 12 10.3  
2005 1 10.7  
2005 2 13.1  
2005 3 13  
2005 4 12.9  
2005 5 11.2  
2005 6 8.5  
2005 7 8.46  
2005 8 9.96  
2005 9 9.36  
2005 10 9.98  
2005 11 11.4  
2005 12 14.1  
2006 1 12.9  
2006 2 14  
2006 2 13.3  
2006 4 13.4  
2006 5 9.38  
2006 6 9.38  
2006 7 7.41  
2006 8 8.14  
2006 9 9.12  
2006 10 9.02

2006 11 12.5  
2006 12 14.4  
2007 1 13.9  
2007 2 13.7  
2007 3 13.9  
2007 4 12.5  
2007 5 14.9  
2007 6 11.5  
2007 7 8.94  
2007 8 8.14  
2007 9 10.1  
2007 10 9.23  
2007 11 14  
2007 12 11.5  
2008 1 10.7  
2008 2 15.3  
2008 3 14.9  
2008 4 10.8  
2008 5 9.9  
2008 6 8.72  
2008 7 7.32  
2008 8 9.05  
2008 9 7.73  
2008 10 8.89  
2008 11 11.3  
2008 12 10.2  
2009 1 15  
2009 2 12.8  
2009 3 12.7  
2009 4 8.65  
2009 5 10.6  
2009 6 8.44  
2009 7 8.42  
2009 8 7.68  
2009 9 8.98  
2009 10 10.4  
2009 11 11.2  
2009 12 10.2  
2010 1 13.8  
2010 2 16.1  
2010 3 14  
2010 4 11  
2010 5 8.91  
2010 6 8.86  
2010 7 7.66  
2010 8 7.89  
2010 9 9.55  
2010 10 11  
2010 11 10.9  
2010 12 16.6  
2011 1 14.8  
2011 2 15.5  
2011 3 14.6  
2011 4 11.2

2011 5 9.17  
2011 6 9.37  
2011 7 8.47  
2011 8 10.2  
2011 9 10.8  
2011 10 11.3  
2011 11 12.6  
2011 12 11.7  
2012 1 12.2  
2012 2 16.2  
2012 3 11  
2012 4 8.24  
2012 5 8.02  
2012 6 9.54  
2012 7 8.88  
2012 8 8.24  
2012 9 8.58  
2012 10 11.1  
2012 11 8.56  
2012 12 9.37  
2013 1 16.5  
2013 2 15.4  
2013 3 16.2  
2013 4 12.5  
2013 5 13.3  
2013 6 11.4  
2013 7 9.63  
2013 8 7.86  
2013 9 9.61  
2013 12 15.2  
2014 1 15  
2014 2 18.6  
2014 3 12  
2014 4 13.1  
2014 5 12.3  
2014 6 8.64  
2014 7 8.03  
2014 8 10.6  
2014 9 8.21  
2014 10 8.59  
2014 11 11.2  
2014 12 7.78  
2015 1 13.9  
2015 2 17.1  
2015 3 12.3  
2015 4 12.1  
2015 5 11.8  
2015 6 10.3  
2015 7 9.27  
2015 8 8.95  
2015 8 8.15  
2015 9 7.56  
2015 10 9.84  
2015 11 9.98

2015 11 9.07  
2016 1 12.3  
2016 2 12.2  
2016 3 11  
2016 4 12.8  
2016 5 8.93  
2016 6 8  
2016 7 8.56  
2016 8 7.71  
2016 9 8.4  
2016 10 10.8  
2016 11 9.91  
2016 12 14.1  
2017 1 16  
2017 2 13.7  
2017 3 12.9  
2017 4 9.15  
2017 5 10.1  
2017 6 9.06  
2017 7 8.28  
2017 8 6.85  
2017 9 8.02  
2017 10 10.2  
2017 11 12.3  
2017 12 7.21

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.105

$$S = 346.$$

$$z = 2.476$$

$$p = 0.0133$$

$$p = 0.0944 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 10.19 + 0.3174E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO 07060500 1993-2017

1993 1. 12.00  
1993 3. 13.20  
1993 4. 9.100  
1993 6. 8.100  
1993 8. 8.200  
1993 11 9.900  
1993 12 10.20  
1994 3. 10.60  
1994 4. 11.00  
1994 6. 8.700  
1994 6. 8.700  
1994 6. 8.600  
1994 6. 8.600  
1994 6. 8.700  
1994 6. 8.700  
1994 6. 8.800  
1994 6. 8.800  
1994 6. 8.900  
1994 6. 8.900  
1994 7. 9.800  
1994 8. 10.90  
1994 10 4.500  
1995 1. 10.20  
1995 2. 11.70  
1995 4. 10.90  
1995 7. 9.900  
1995 9. 8.500  
1995 9. 7.700  
1995 9. 7.500  
1995 9. 7.400  
1995 9. 7.400  
1995 9. 7.600  
1995 9. 7.500  
1995 9. 7.700  
1995 9. 7.700  
1995 9. 7.800  
1995 9. 7.600  
1995 10 8.600  
1995 11 10.70  
1996 2. 9.300  
1996 2. 11.30  
1996 2. 10.80  
1996 2. 10.60  
1996 2. 10.60  
1996 2. 10.50  
1996 2. 10.60  
1996 2. 10.60  
1996 2. 10.70  
1996 2. 10.70  
1996 2. 10.70  
1996 4. 9.900  
1996 6. 8.600

1996 8. 9.800  
1996 10 7.300  
1996 12 9.500  
1997 2. 11.20  
1997 4. 11.00  
1997 7. 8.400  
1997 8. 7.900  
1997 11 11.20  
1998 1. 14.20  
1998 3. 12.40  
1998 4. 9.300  
1998 6. 9.200  
1998 6. 9.200  
1998 6. 9.000  
1998 6. 9.100  
1998 6. 9.100  
1998 6. 9.000  
1998 6. 9.100  
1998 6. 9.200  
1998 6. 9.200  
1998 6. 9.300  
1998 6. 9.300  
1998 8. 8.800  
1998 11 10.50  
1999 1. 11.80  
1999 3. 10.70  
1999 6. 10.40  
1999 7. 8.200  
1999 9. 7.600  
1999 11 8.200  
2000 1. 10.00  
2000 3. 10.60  
2000 5. 7.900  
2000 7. 9.300  
2000 8. 8.300  
2000 11 12.10  
2001 1. 12.90  
2001 3. 11.60  
2001 5. 10.10  
2001 8. 9.400  
2001 10 9.300  
2001 12 10.00  
2002 2. 13.30  
2002 4. 11.60  
2002 6. 8.100  
2002 8. 9.900  
2002 8. 9.700  
2002 8. 9.400  
2002 8. 9.400  
2002 8. 9.400  
2002 8. 9.400  
2002 8. 9.300  
2002 8. 9.300  
2002 8. 9.300

2002 8. 9.200  
2002 8. 9.300  
2002 10 10.20  
2002 12 6.500  
2003 3. 11.90  
2003 3. 11.30  
2003 3. 11.50  
2003 3. 11.60  
2003 3. 11.50  
2003 3. 11.70  
2003 3. 11.50  
2003 3. 11.50  
2003 3. 11.30  
2003 3. 11.20  
2003 3. 11.10  
2003 5. 8.800  
2003 7. 9.800  
2003 7. 10.00  
2003 7. 9.800  
2003 7. 9.800  
2003 7. 9.800  
2003 7. 9.700  
2003 7. 9.700  
2003 7. 9.700  
2003 7. 9.700  
2003 7. 9.600  
2003 7. 9.700  
2003 8. 9.300  
2003 11 8.300  
2003 11 8.200  
2003 11 8.200  
2003 11 8.100  
2003 11 8.100  
2003 11 8.200  
2003 11 8.200  
2003 11 8.100  
2003 11 8.100  
2003 11 8.000  
2003 11 8.200  
2004 1. 11.90  
2004 1. 11.90  
2004 1. 13.20  
2004 1. 11.80  
2004 1. 11.70  
2004 1. 11.60  
2004 1. 11.50  
2004 1. 11.60  
2004 1. 11.60  
2004 1. 11.60  
2004 1. 11.70  
2004 1. 11.80  
2004 2. 10.60  
2004 4. 9.600  
2004 6. 8.800  
2004 8. 9.200

2004 8. 9.200  
2004 8. 9.400  
2004 8. 9.300  
2004 8. 9.200  
2004 8. 9.200  
2004 8. 9.300  
2004 8. 9.200  
2004 8. 9.200  
2004 8. 9.200  
2004 8. 9.200  
2004 10 9.000  
2004 10 9.100  
2004 10 10.00  
2004 10 9.100  
2004 10 8.900  
2004 10 9.700  
2004 10 9.300  
2004 10 9.200  
2004 10 9.400  
2004 10 9.300  
2004 10 9.300  
2005 1. 8.800  
2005 3. 11.00  
2005 4. 10.00  
2005 6. 9.600  
2005 8. 9.300  
2005 10 9.500  
2006 1. 10.80  
2006 3. 10.00  
2006 5. 9.000  
2006 7. 8.700  
2006 8. 8.400  
2006 11 8.100  
2007 1. 11.20  
2007 3. 11.60  
2007 4. 11.40  
2007 6. 10.70  
2007 8. 8.100  
2007 11 10.60  
2007 12 10.30  
2008 2. 10.00  
2008 4. 10.80  
2008 6. 10.20  
2008 8. 8.600  
2008 10 7.700  
2008 12 10.20  
2009 1. 11.90  
2009 3. 12.30  
2009 4. 11.00  
2009 8. 8.300  
2009 11 10.30  
2010 2. 11.80  
2010 3. 11.20  
2010 3. 11.40

2010 3. 11.40  
2010 3. 11.20  
2010 3. 10.90  
2010 3. 10.20  
2010 3. 9.300  
2010 3. 11.60  
2010 6. 10.40  
2010 8. 8.500  
2010 10 9.200  
2010 12 10.30  
2011 2. 12.10  
2011 4. 9.500  
2011 6. 10.50  
2011 8. 8.900  
2011 10 8.500  
2012 2. 12.10  
2012 6. 10.00  
2012 8. 9.700  
2012 11 10.20  
2013 3. 12.60  
2013 5. 9.900  
2013 9. 9.800  
2013 11 10.20  
2014 3. 11.40  
2014 4. 12.10  
2014 7. 10.60  
2014 11 9.800  
2015 3. 11.50  
2015 5. 12.30  
2015 12 9.200  
2016 3. 11.10  
2016 5. 11.70  
2016 8. 8.600  
2016 11 10.60  
2017 2. 9.500  
2017 5. 9.500  
2017 8. 8.100  
2017 11 9.700

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.034

$$S = 28.$$

$$z = 0.489$$

$$p = 0.6247$$

$$p = 0.6481 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 9.916 + 0.6458E-02 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO 07060710 1993-2017

1993 1. 10.90  
1993 3. 12.20  
1993 4. 9.000  
1993 5. 9.100  
1993 6. 6.800  
1993 7. 8.800  
1993 8. 6.600  
1993 9. 6.800  
1993 12 11.50  
1993 12 12.00  
1994 1. 12.20  
1994 2. 12.90  
1994 3. 10.80  
1994 4. 9.900  
1994 5. 10.70  
1994 6. 10.00  
1994 6. 7.300  
1994 6. 7.500  
1994 6. 8.500  
1994 6. 9.000  
1994 6. 9.000  
1994 6. 8.700  
1994 6. 8.900  
1994 6. 9.000  
1994 6. 9.000  
1994 6. 9.000  
1994 7. 8.000  
1994 8. 5.200  
1994 8. 5.600  
1994 10 8.900  
1994 11 9.600  
1994 12 10.80  
1995 1. 8.000  
1995 2. 12.80  
1995 3. 10.20  
1995 3. 8.700  
1995 4. 8.800  
1995 5. 7.200  
1995 6. 8.100  
1995 7. 8.200  
1995 8. 12.30  
1995 10 9.600  
1995 11 9.300  
1996 1. 12.00  
1996 1. 12.10  
1996 1. 10.20  
1996 1. 7.800  
1996 1. 6.900  
1996 1. 11.40  
1996 1. 12.10  
1996 1. 12.60  
1996 1. 12.80

1996 1. 12.90  
1996 1. 13.30  
1996 2. 11.30  
1996 4. 11.30  
1996 5. 9.800  
1996 6. 6.700  
1996 7. 6.800  
1996 8. 7.400  
1996 9. 10.50  
1996 10 7.400  
1997 2. 10.20  
1997 4. 10.20  
1997 5. 10.50  
1997 6. 9.100  
1997 7. 8.900  
1997 8. 9.700  
1997 9. 9.000  
1997 10 10.40  
1997 11 8.200  
1997 12 12.60  
1998 1. 10.80  
1998 2. 14.00  
1998 3. 11.50  
1998 4. 9.800  
1998 5. 8.500  
1998 6. 7.200  
1998 7. 7.300  
1998 8. 6.900  
1998 9. 10.40  
1998 10 10.40  
1998 11 11.00  
1998 12 9.500  
1999 1. 9.800  
1999 2. 12.20  
1999 3. 8.900  
1999 4. 10.30  
1999 5. 10.50  
1999 6. 7.200  
1999 7. 6.600  
1999 8. 4.600  
1999 9. 5.400  
1999 10 8.300  
1999 11 12.00  
1999 12 12.20  
2000 1. 10.20  
2000 2. 10.10  
2000 3. 11.20  
2000 4. 10.50  
2000 5. 7.300  
2000 6. 9.600  
2000 7. 8.400  
2000 8. 9.500  
2000 9. 5.900  
2000 10 9.600

2000 11 10.30  
2000 12 8.200  
2001 2. 9.400  
2001 3. 10.80  
2001 4. 10.20  
2001 5. 7.000  
2001 6. 7.200  
2001 7. 5.500  
2001 8. 6.300  
2001 9. 7.200  
2001 11 10.20  
2001 12 10.40  
2002 1. 13.20  
2002 2. 12.70  
2002 3. 10.70  
2002 5. 9.400  
2002 7. 6.300  
2002 9. 9.500  
2002 11 11.20  
2002 12 12.20  
2003 1. 13.70  
2003 2. 10.80  
2003 3. 12.10  
2003 5. 10.90  
2003 7. 8.800  
2003 9. 8.200  
2003 11 9.200  
2003 12 10.50  
2004 1. 11.70  
2004 2. 13.20  
2004 3. 9.700  
2004 3. 10.00  
2004 5. 7.100  
2004 7. 6.000  
2004 8. 9.600  
2004 11 11.90  
2005 1. 9.500  
2005 3. 11.80  
2005 5. 11.70  
2005 7. 6.900  
2005 9. 9.200  
2005 11 10.90  
2006 1. 13.00  
2006 3. 12.00  
2006 5. 9.700  
2006 6. 9.200  
2006 7. 7.500  
2006 9. 10.60  
2007 2. 13.00  
2007 3. 10.00  
2007 5. 10.20  
2007 5. 9.900  
2007 6. 8.000  
2007 7. 8.600

2007 8. 6.800  
2007 9. 8.400  
2007 10 9.100  
2007 12 12.10  
2008 1. 15.50  
2008 2. 10.30  
2008 3. 11.90  
2008 5. 9.900  
2008 6. 8.200  
2008 9. 9.200  
2009 3. 11.20  
2009 4. 10.10  
2009 6. 8.900  
2009 8. 7.400  
2009 11 10.70  
2010 2. 12.70  
2010 3. 10.40  
2010 6. 10.10  
2010 8. 10.50  
2010 10 11.10  
2010 12 12.80  
2011 2. 12.90  
2011 4. 10.80  
2011 6. 9.800  
2011 8. 10.10  
2011 10 13.30  
2011 12 11.60  
2012 2. 12.90  
2012 4. 10.80  
2012 6. 11.30  
2012 8. 6.100  
2012 11 11.10  
2013 1. 13.60  
2013 3. 11.90  
2013 5. 9.200  
2013 7. 10.00  
2013 9. 10.10  
2013 11 14.00  
2014 1. 15.20  
2014 3. 11.40  
2014 4. 11.60  
2014 5. 10.60  
2014 7. 10.70  
2014 9. 8.400  
2014 11 10.50  
2015 1. 12.50  
2015 3. 11.60  
2015 5. 9.900  
2015 7. 9.700  
2015 8. 10.20  
2015 10 9.400  
2015 11 11.90  
2015 12 12.30  
2016 1. 12.60

2016 1. 13.40  
2016 2. 12.40  
2016 2. 11.60  
2016 3. 11.60  
2016 4. 11.40  
2016 4. 9.800  
2016 5. 9.900  
2016 5. 10.20  
2016 7. 9.400  
2016 7. 7.400  
2016 8. 9.000  
2016 9. 8.300  
2016 10 9.700  
2016 10 10.20  
2016 11 11.20  
2016 11 11.60  
2016 12 13.30  
2017 3. 10.00  
2017 3. 11.70  
2017 4. 10.60  
2017 5. 9.700  
2017 5. 10.70  
2017 6. 9.600  
2017 6. 9.400  
2017 7. 10.20  
2017 8. 10.30  
2017 9. 9.500  
2017 10 9.800  
2017 10 11.00  
2017 11 10.40

# **ATTACHMENT 2**

---

**Dissolved Oxygen Saturation Seasonal Mann-Kendall Input and Output**

2 0 DO saturation WHI0011 1993-2017

1993 5. 94.11  
1993 7. 83.82  
1993 8. 91.64  
1993 9. 95.61  
1993 10 99.24  
1993 11 109.4  
1993 12 96.01  
1994 1. 100.1  
1994 2. 89.95  
1994 3. 105.3  
1994 5. 112.1  
1994 6. 145.2  
1994 8. 77.45  
1994 10 83.03  
1995 5. 98.06  
1995 6. 97.21  
1995 7. 94.40  
1995 8. 101.0  
1995 9. 78.50  
1995 10 76.53  
1996 2. 110.7  
1996 3. 94.28  
1996 4. 106.2  
1996 5. 92.62  
1996 7. 93.19  
1996 9. 93.07  
1996 10 98.06  
1996 11 107.6  
1996 12 102.1  
1997 2. 94.28  
1997 3. 96.76  
1997 4. 119.4  
1997 8. 131.9  
1997 10 96.20  
1998 1. 117.8  
1998 3. 98.37  
1998 4. 66.62  
1998 5. 114.6  
1998 10 113.7  
1998 12 106.2  
1999 1. 103.7  
1999 2. 104.5  
1999 4. 75.25  
1999 5. 130.5  
1999 7. 119.2  
1999 8. 59.30  
1999 9. 88.04  
1999 10 69.52  
1999 11 109.3  
2000 1. 92.87  
2000 2. 74.75  
2000 3. 76.15

2000 4. 73.42  
2000 5. 75.47  
2000 6. 104.2  
2000 8. 93.79  
2000 8. 86.74  
2000 9. 71.54  
2000 10 67.56  
2000 11 88.31  
2000 12 79.96  
2001 2. 64.59  
2001 3. 82.92  
2001 4. 65.85  
2001 5. 72.41  
2001 6. 60.46  
2001 7. 63.24  
2001 8. 82.47  
2001 9. 70.58  
2001 10 59.84  
2001 11 58.87  
2001 12 71.07  
2002 1. 66.17  
2002 2. 69.11  
2002 3. 65.11  
2002 4. 80.38  
2002 5. 77.81  
2002 6. 69.01  
2002 7. 66.81  
2002 8. 53.13  
2002 10 70.69  
2002 12 89.79  
2003 3. 119.5  
2003 4. 114.4  
2003 4. 82.14  
2003 5. 102.2  
2003 6. 84.39  
2003 7. 73.10  
2003 8. 98.95  
2003 9. 111.4  
2003 10 95.71  
2003 11 97.19  
2003 12 89.23  
2004 1. 100.5  
2004 2. 80.87  
2004 6. 91.70  
2004 7. 121.1  
2004 8. 96.16  
2004 9. 111.6  
2004 10 87.93  
2004 11 98.66  
2004 12 104.2  
2005 1. 106.3  
2005 2. 114.7  
2005 3. 128.0  
2005 4. 110.0

2005 5. 124.1  
2005 5. 113.8  
2005 7. 110.7  
2005 8. 110.5  
2005 9. 89.95  
2005 10 88.22  
2005 11 85.81  
2005 12 111.8  
2006 1. 117.9  
2006 3. 109.7  
2006 4. 172.6  
2006 5. 115.5  
2006 6. 154.9  
2006 7. 101.7  
2006 8. 99.56  
2006 9. 112.4  
2006 10 105.4  
2006 11 97.17  
2006 12 110.6  
2007 1. 117.6  
2007 2. 102.9  
2007 3. 115.9  
2007 4. 115.7  
2007 5. 108.7  
2007 6. 113.3  
2007 7. 92.78  
2007 8. 77.20  
2007 9. 115.5  
2007 10 93.54  
2007 11 120.2  
2007 12 112.5  
2008 1. 103.4  
2008 2. 96.00  
2008 3. 94.67  
2008 4. 96.97  
2008 5. 102.2  
2008 6. 86.72  
2008 7. 93.05  
2008 8. 84.22  
2008 9. 96.16  
2008 10 96.55  
2008 11 113.5  
2008 12 105.1  
2009 1. 110.0  
2009 2. 119.0  
2009 3. 100.7  
2009 4. 114.7  
2009 5. 107.4  
2009 6. 102.9  
2009 8. 91.56  
2009 9. 96.29  
2009 10 106.5  
2009 11 103.4  
2009 12 106.2

2010 1. 119.8  
2010 2. 132.6  
2010 3. 108.8  
2010 4. 110.2  
2010 5. 114.7  
2010 6. 116.9  
2010 7. 115.1  
2010 8. 109.2  
2010 9. 88.62  
2010 10 84.64  
2010 11 83.11  
2010 12 99.25  
2011 1. 117.0  
2011 2. 125.9  
2011 3. 117.1  
2011 4. 93.36  
2011 5. 92.43  
2011 6. 97.62  
2011 7. 89.34  
2011 8. 109.3  
2011 9. 107.9  
2011 10 103.0  
2011 11 114.5  
2011 12 94.55  
2012 1. 106.7  
2012 2. 103.1  
2012 3. 99.02  
2012 4. 85.78  
2012 5. 73.40  
2012 6. 100.4  
2012 7. 102.3  
2012 8. 96.57  
2012 9. 85.71  
2012 10 104.5  
2012 11 85.50  
2012 12 79.96  
2013 1. 108.0  
2013 2. 123.1  
2013 3. 107.9  
2013 4. 110.5  
2013 5. 117.4  
2013 6. 104.8  
2013 7. 110.9  
2013 8. 84.92  
2013 9. 89.82  
2013 12 97.78  
2014 1. 101.2  
2014 2. 112.7  
2014 3. 105.2  
2014 4. 92.95  
2014 5. 107.0  
2014 6. 88.92  
2014 7. 92.60  
2014 8. 122.0

2014 9. 68.20  
2014 10 74.63  
2014 11 84.09  
2014 12 77.75  
2015 1. 99.51  
2015 2. 101.3  
2015 3. 114.7  
2015 4. 99.46  
2015 5. 115.0  
2015 6. 109.4  
2015 7. 126.8  
2015 8. 91.63  
2015 9. 72.19  
2015 10 81.29  
2015 11 82.33  
2016 1. 96.41  
2016 2. 99.76  
2016 3. 90.00  
2016 4. 100.7  
2016 5. 92.71  
2016 6. 91.54  
2016 7. 94.03  
2016 8. 87.19  
2016 9. 80.17  
2016 10 101.3  
2016 11 96.62  
2016 12 102.2  
2017 1. 106.1  
2017 2. 107.1  
2017 3. 84.16  
2017 4. 86.11  
2017 5. 100.2  
2017 6. 104.8  
2017 7. 92.69  
2017 8. 95.21  
2017 9. 91.09  
2017 10 88.02  
2017 11 95.55  
2017 12 80.77

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.048

$$S = 121.$$

$$z = 1.049$$

$$p = 0.2941$$

$$p = 0.6128 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 95.99 + 0.1487 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO saturation WHI0011 2004-2017

2004 1. 100.5  
2004 2. 80.87  
2004 6. 91.70  
2004 7. 121.1  
2004 8. 96.16  
2004 9. 111.6  
2004 10 87.93  
2004 11 98.66  
2004 12 104.2  
2005 1. 106.3  
2005 2. 114.7  
2005 3. 128.0  
2005 4. 110.0  
2005 5. 124.1  
2005 5. 113.8  
2005 7. 110.7  
2005 8. 110.5  
2005 9. 89.95  
2005 10 88.22  
2005 11 85.81  
2005 12 111.8  
2006 1. 117.9  
2006 3. 109.7  
2006 4. 172.6  
2006 5. 115.5  
2006 6. 154.9  
2006 7. 101.7  
2006 8. 99.56  
2006 9. 112.4  
2006 10 105.4  
2006 11 97.17  
2006 12 110.6  
2007 1. 117.6  
2007 2. 102.9  
2007 3. 115.9  
2007 4. 115.7  
2007 5. 108.7  
2007 6. 113.3  
2007 7. 92.78  
2007 8. 77.20  
2007 9. 115.5  
2007 10 93.54  
2007 11 120.2  
2007 12 112.5  
2008 1. 103.4  
2008 2. 96.00  
2008 3. 94.67  
2008 4. 96.97  
2008 5. 102.2  
2008 6. 86.72  
2008 7. 93.05  
2008 8. 84.22

2008 9. 96.16  
2008 10 96.55  
2008 11 113.5  
2008 12 105.1  
2009 1. 110.0  
2009 2. 119.0  
2009 3. 100.7  
2009 4. 114.7  
2009 5. 107.4  
2009 6. 102.9  
2009 8. 91.56  
2009 9. 96.29  
2009 10 106.5  
2009 11 103.4  
2009 12 106.2  
2010 1. 119.8  
2010 2. 132.6  
2010 3. 108.8  
2010 4. 110.2  
2010 5. 114.7  
2010 6. 116.9  
2010 7. 115.1  
2010 8. 109.2  
2010 9. 88.62  
2010 10 84.64  
2010 11 83.11  
2010 12 99.25  
2011 1. 117.0  
2011 2. 125.9  
2011 3. 117.1  
2011 4. 93.36  
2011 5. 92.43  
2011 6. 97.62  
2011 7. 89.34  
2011 8. 109.3  
2011 9. 107.9  
2011 10 103.0  
2011 11 114.5  
2011 12 94.55  
2012 1. 106.7  
2012 2. 103.1  
2012 3. 99.02  
2012 4. 85.78  
2012 5. 73.40  
2012 6. 100.4  
2012 7. 102.3  
2012 8. 96.57  
2012 9. 85.71  
2012 10 104.5  
2012 11 85.50  
2012 12 79.96  
2013 1. 108.0  
2013 2. 123.1  
2013 3. 107.9

2013 4. 110.5  
2013 5. 117.4  
2013 6. 104.8  
2013 7. 110.9  
2013 8. 84.92  
2013 9. 89.82  
2013 12 97.78  
2014 1. 101.2  
2014 2. 112.7  
2014 3. 105.2  
2014 4. 92.95  
2014 5. 107.0  
2014 6. 88.92  
2014 7. 92.60  
2014 8. 122.0  
2014 9. 68.20  
2014 10 74.63  
2014 11 84.09  
2014 12 77.75  
2015 1. 99.51  
2015 2. 101.3  
2015 3. 114.7  
2015 4. 99.46  
2015 5. 115.0  
2015 6. 109.4  
2015 7. 126.8  
2015 8. 91.63  
2015 9. 72.19  
2015 10 81.29  
2015 11 82.33  
2016 1. 96.41  
2016 2. 99.76  
2016 3. 90.00  
2016 4. 100.7  
2016 5. 92.71  
2016 6. 91.54  
2016 7. 94.03  
2016 8. 87.19  
2016 9. 80.17  
2016 10 101.3  
2016 11 96.62  
2016 12 102.2  
2017 1. 106.1  
2017 2. 107.1  
2017 3. 84.16  
2017 4. 86.11  
2017 5. 100.2  
2017 6. 104.8  
2017 7. 92.69  
2017 8. 95.21  
2017 9. 91.09  
2017 10 88.02  
2017 11 95.55  
2017 12 80.77



Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0011 2004-2017

The record is 15 complete water years with 12 seasons per year beginning in water year 2004.

The tau correlation coefficient is -0.261

$$S = -254.$$

$$z = -4.327$$

$$p = 0.0000$$

$$p = 0.0138 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 109.9 + -1.144 * \text{Time}$$

where Time = Year (as a decimal) - 2003.75  
(beginning of first water year)

2 0 DO saturation WHI0029 1993-2017

1993 1. 84.85  
1993 2. 93.72  
1993 3. 96.01  
1993 4. 88.21  
1993 5. 101.2  
1993 6. 96.08  
1993 7. 93.07  
1993 8. 105.2  
1993 9. 125.7  
1993 10 103.2  
1993 11 111.9  
1993 12 97.43  
1994 1. 91.68  
1994 2. 91.23  
1994 3. 97.96  
1994 5. 112.0  
1994 6. 107.7  
1994 8. 93.45  
1994 10 105.4  
1995 5. 83.47  
1995 6. 89.05  
1995 7. 81.89  
1995 8. 95.65  
1995 9. 88.36  
1995 10 101.1  
1996 2. 103.6  
1996 3. 102.4  
1996 4. 103.4  
1996 5. 96.44  
1996 7. 94.41  
1996 9. 111.9  
1996 10 101.7  
1996 11 96.10  
1996 12 103.8  
1997 2. 87.36  
1997 3. 93.00  
1997 4. 96.02  
1997 7. 109.9  
1997 8. 138.3  
1997 9. 126.1  
1997 10 107.0  
1998 3. 84.43  
1998 4. 96.76  
1998 5. 105.5  
1998 6. 95.02  
1998 7. 127.0  
1998 8. 112.5  
1998 9. 101.7  
1998 10 126.0  
1998 11 90.66  
1998 12 100.9  
1999 1. 96.87

1999 4. 92.18  
1999 5. 90.83  
1999 6. 114.3  
1999 7. 120.0  
1999 8. 108.6  
1999 9. 97.56  
1999 11 98.24  
2000 1. 102.5  
2000 2. 76.81  
2000 3. 78.07  
2000 4. 90.59  
2000 6. 97.38  
2000 8. 88.35  
2000 8. 85.88  
2000 9. 91.25  
2000 10 85.34  
2000 11 95.35  
2000 12 83.48  
2001 2. 68.56  
2001 3. 75.70  
2001 4. 74.75  
2001 5. 71.27  
2001 6. 72.84  
2001 7. 69.12  
2001 8. 83.47  
2001 9. 71.02  
2001 10 75.55  
2001 11 75.23  
2001 12 69.80  
2002 1. 67.91  
2002 2. 71.88  
2002 3. 70.77  
2002 5. 72.73  
2002 6. 64.81  
2002 7. 74.01  
2002 8. 71.58  
2002 10 63.03  
2002 12 102.7  
2003 3. 111.6  
2003 4. 111.3  
2003 4. 100.0  
2003 5. 83.99  
2003 6. 101.2  
2003 7. 95.59  
2003 8. 103.1  
2003 9. 99.97  
2003 10 103.8  
2003 11 97.98  
2003 12 98.82  
2004 1. 97.10  
2004 2. 80.09  
2004 6. 104.7  
2004 7. 101.0  
2004 8. 112.7

2004 9. 95.32  
2004 10 99.24  
2004 12 98.31  
2005 1. 116.8  
2005 2. 103.8  
2005 3. 102.4  
2005 4. 105.0  
2005 5. 112.3  
2005 7. 101.3  
2005 8. 109.5  
2005 9. 93.60  
2005 10 97.34  
2005 11 95.43  
2005 12 101.8  
2006 1. 126.8  
2006 3. 105.5  
2006 4. 111.0  
2006 5. 122.0  
2006 6. 114.8  
2006 7. 120.4  
2006 8. 114.8  
2006 9. 112.5  
2006 10 100.7  
2006 11 105.8  
2006 12 94.39  
2007 1. 111.4  
2007 2. 82.57  
2007 3. 121.9  
2007 4. 123.9  
2007 5. 118.7  
2007 6. 113.4  
2007 7. 109.9  
2007 8. 122.2  
2007 9. 91.37  
2007 10 85.26  
2007 11 110.5  
2007 12 117.3  
2008 1. 115.3  
2008 2. 96.82  
2008 3. 109.4  
2008 4. 101.1  
2008 5. 102.2  
2008 6. 110.8  
2008 7. 108.8  
2008 8. 109.8  
2008 9. 90.51  
2008 10 108.8  
2008 11 103.0  
2008 12 105.4  
2009 1. 114.6  
2009 2. 125.8  
2009 3. 105.3  
2009 4. 117.8  
2009 5. 105.3

2009 6. 110.3  
2009 8. 115.7  
2009 9. 94.05  
2009 10 88.10  
2009 11 95.75  
2009 12 113.8  
2010 1. 107.1  
2010 2. 103.8  
2010 3. 108.6  
2010 4. 103.4  
2010 5. 107.5  
2010 6. 111.9  
2010 7. 128.2  
2010 8. 124.5  
2010 9. 97.44  
2010 10 107.7  
2010 10 90.98  
2010 11 102.4  
2010 11 102.4  
2011 1. 112.8  
2011 2. 96.39  
2011 3. 101.8  
2011 4. 97.54  
2011 5. 106.9  
2011 6. 106.3  
2011 7. 108.0  
2011 8. 116.6  
2011 9. 99.06  
2011 11 99.68  
2011 12 99.71  
2012 1. 86.13  
2012 2. 110.1  
2012 3. 101.7  
2012 4. 109.9  
2012 5. 101.7  
2012 6. 110.7  
2012 7. 101.6  
2012 8. 104.3  
2012 9. 114.8  
2012 10 98.92  
2012 11 100.6  
2012 12 97.46  
2013 1. 109.0  
2013 2. 110.1  
2013 3. 106.2  
2013 4. 108.6  
2013 5. 107.7  
2013 6. 123.7  
2013 7. 112.0  
2013 8. 108.4  
2013 9. 107.0  
2013 10 103.4  
2013 11 109.3  
2013 12 104.2

2014 1. 97.41  
2014 2. 103.1  
2014 3. 98.76  
2014 4. 102.0  
2014 5. 124.0  
2014 6. 113.9  
2014 7. 115.5  
2014 8. 110.4  
2014 9. 113.1  
2014 10 117.0  
2014 12 105.2  
2015 1. 98.18  
2015 2. 81.40  
2015 3. 97.31  
2015 4. 89.32  
2015 5. 109.9  
2015 6. 98.14  
2015 7. 103.4  
2015 8. 110.9  
2015 9. 104.4  
2015 10 95.16  
2015 11 93.87  
2015 11 98.54  
2015 12 95.29  
2016 1. 106.7  
2016 2. 114.6  
2016 3. 78.92  
2016 4. 108.6  
2016 5. 97.24  
2016 6. 107.1  
2016 7. 108.2  
2016 8. 52.68  
2016 9. 97.71  
2016 11 111.3  
2016 11 104.8  
2016 11 99.32  
2016 11 106.4  
2016 11 100.2  
2016 11 94.97  
2016 11 102.5  
2016 11 96.64  
2016 11 91.52  
2016 12 109.3  
2017 1. 116.5  
2017 2. 115.3  
2017 3. 100.9  
2017 4. 106.4  
2017 5. 95.15  
2017 6. 97.34  
2017 7. 81.05  
2017 8. 98.44  
2017 9. 96.66  
2017 10 97.04  
2017 11 85.09

2017 12 106.6

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.148

$$S = 386.$$

$$z = 3.257$$

$$p = 0.0011$$

$$p = 0.0970 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 97.27 + 0.3450 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO saturation WHI0029 2004-2017

2004 1. 97.10  
2004 2. 80.09  
2004 6. 104.7  
2004 7. 101.0  
2004 8. 112.7  
2004 9. 95.32  
2004 10 99.24  
2004 12 98.31  
2005 1. 116.8  
2005 2. 103.8  
2005 3. 102.4  
2005 4. 105.0  
2005 5. 112.3  
2005 7. 101.3  
2005 8. 109.5  
2005 9. 93.60  
2005 10 97.34  
2005 11 95.43  
2005 12 101.8  
2006 1. 126.8  
2006 3. 105.5  
2006 4. 111.0  
2006 5. 122.0  
2006 6. 114.8  
2006 7. 120.4  
2006 8. 114.8  
2006 9. 112.5  
2006 10 100.7  
2006 11 105.8  
2006 12 94.39  
2007 1. 111.4  
2007 2. 82.57  
2007 3. 121.9  
2007 4. 123.9  
2007 5. 118.7  
2007 6. 113.4  
2007 7. 109.9  
2007 8. 122.2  
2007 9. 91.37  
2007 10 85.26  
2007 11 110.5  
2007 12 117.3  
2008 1. 115.3  
2008 2. 96.82  
2008 3. 109.4  
2008 4. 101.1  
2008 5. 102.2  
2008 6. 110.8  
2008 7. 108.8  
2008 8. 109.8  
2008 9. 90.51  
2008 10 108.8

2008 11 103.0  
2008 12 105.4  
2009 1. 114.6  
2009 2. 125.8  
2009 3. 105.3  
2009 4. 117.8  
2009 5. 105.3  
2009 6. 110.3  
2009 8. 115.7  
2009 9. 94.05  
2009 10 88.10  
2009 11 95.75  
2009 12 113.8  
2010 1. 107.1  
2010 2. 103.8  
2010 3. 108.6  
2010 4. 103.4  
2010 5. 107.5  
2010 6. 111.9  
2010 7. 128.2  
2010 8. 124.5  
2010 9. 97.44  
2010 10 107.7  
2010 10 90.98  
2010 11 102.4  
2010 11 102.4  
2011 1. 112.8  
2011 2. 96.39  
2011 3. 101.8  
2011 4. 97.54  
2011 5. 106.9  
2011 6. 106.3  
2011 7. 108.0  
2011 8. 116.6  
2011 9. 99.06  
2011 11 99.68  
2011 12 99.71  
2012 1. 86.13  
2012 2. 110.1  
2012 3. 101.7  
2012 4. 109.9  
2012 5. 101.7  
2012 6. 110.7  
2012 7. 101.6  
2012 8. 104.3  
2012 9. 114.8  
2012 10 98.92  
2012 11 100.6  
2012 12 97.46  
2013 1. 109.0  
2013 2. 110.1  
2013 3. 106.2  
2013 4. 108.6  
2013 5. 107.7

2013 6. 123.7  
2013 7. 112.0  
2013 8. 108.4  
2013 9. 107.0  
2013 10 103.4  
2013 11 109.3  
2013 12 104.2  
2014 1. 97.41  
2014 2. 103.1  
2014 3. 98.76  
2014 4. 102.0  
2014 5. 124.0  
2014 6. 113.9  
2014 7. 115.5  
2014 8. 110.4  
2014 9. 113.1  
2014 10 117.0  
2014 12 105.2  
2015 1. 98.18  
2015 2. 81.40  
2015 3. 97.31  
2015 4. 89.32  
2015 5. 109.9  
2015 6. 98.14  
2015 7. 103.4  
2015 8. 110.9  
2015 9. 104.4  
2015 10 95.16  
2015 11 93.87  
2015 11 98.54  
2015 12 95.29  
2016 1. 106.7  
2016 2. 114.6  
2016 3. 78.92  
2016 4. 108.6  
2016 5. 97.24  
2016 6. 107.1  
2016 7. 108.2  
2016 8. 52.68  
2016 9. 97.71  
2016 11 111.3  
2016 11 104.8  
2016 11 99.32  
2016 11 106.4  
2016 11 100.2  
2016 11 94.97  
2016 11 102.5  
2016 11 96.64  
2016 11 91.52  
2016 12 109.3  
2017 1. 116.5  
2017 2. 115.3  
2017 3. 100.9  
2017 4. 106.4

2017 5. 95.15  
2017 6. 97.34  
2017 7. 81.05  
2017 8. 98.44  
2017 9. 96.66  
2017 10 97.04  
2017 11 85.09  
2017 12 106.6

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0029 2004-2017

The record is 15 complete water years with 12 seasons per year beginning in water year 2004.

The tau correlation coefficient is -0.116

$$S = -110.$$

$$z = -1.896$$

$$p = 0.0579$$

$$p = 0.1441 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 108.1 + -0.3709 * \text{Time}$$

where Time = Year (as a decimal) - 2003.75  
(beginning of first water year)

2 0 DO saturation WHI0046 1993-2017

1993 1. 94.74  
1993 2. 89.28  
1993 3. 88.65  
1993 4. 92.02  
1993 5. 89.17  
1993 6. 84.25  
1993 7. 82.27  
1993 8. 98.06  
1993 9. 105.5  
1993 10 83.03  
1993 11 92.97  
1993 12 103.6  
1994 1. 80.34  
1994 2. 102.9  
1994 3. 90.34  
1994 4. 92.14  
1994 5. 101.3  
1994 6. 102.4  
1994 7. 87.08  
1994 8. 101.7  
1994 9. 82.02  
1994 10 84.05  
1994 11 102.0  
1995 1. 93.72  
1995 2. 84.43  
1995 3. 101.5  
1995 5. 95.02  
1995 6. 89.05  
1995 7. 102.3  
1995 8. 86.20  
1995 9. 81.89  
1995 10 83.41  
1995 10 82.27  
1995 11 99.47  
1996 1. 98.82  
1996 2. 78.73  
1996 3. 110.6  
1996 4. 111.3  
1996 5. 112.4  
1996 6. 104.7  
1996 7. 119.9  
1996 8. 113.9  
1996 9. 118.7  
1996 10 117.3  
1996 11 82.44  
1996 12 81.58  
1997 1. 112.9  
1997 2. 100.3  
1997 3. 92.03  
1997 4. 100.5  
1997 5. 104.7  
1997 6. 106.6

1997 8. 124.8  
1997 9. 99.13  
1997 10 90.20  
1997 11 90.34  
1997 12 93.09  
1998 1. 81.95  
1998 2. 91.44  
1998 4. 102.4  
1998 5. 109.3  
1998 6. 104.3  
1998 7. 106.5  
1998 8. 86.87  
1998 9. 79.63  
1998 10 101.3  
1998 11 106.6  
1998 12 92.55  
1999 1. 104.4  
1999 2. 98.60  
1999 3. 94.28  
1999 4. 96.76  
1999 5. 102.3  
1999 7. 119.1  
1999 8. 78.48  
1999 9. 81.31  
1999 10 92.15  
1999 11 91.13  
1999 11 114.2  
2000 1. 102.1  
2000 2. 114.2  
2000 3. 95.81  
2000 4. 93.97  
2000 5. 112.4  
2000 6. 90.92  
2000 7. 95.65  
2000 8. 102.3  
2000 9. 112.2  
2000 10 115.3  
2000 10 132.6  
2000 12 84.03  
2001 1. 100.5  
2001 2. 101.2  
2001 3. 113.3  
2001 4. 100.1  
2001 5. 106.5  
2001 6. 108.1  
2001 7. 116.9  
2001 8. 111.9  
2001 9. 106.5  
2001 10 102.8  
2001 11 101.1  
2001 12 93.92  
2002 1. 104.6  
2002 2. 94.74  
2002 3. 108.9

2002 4. 113.7  
2002 5. 114.0  
2002 6. 108.8  
2002 7. 96.18  
2002 8. 78.98  
2002 10 83.62  
2002 11 109.0  
2002 12 89.46  
2003 1. 97.10  
2003 2. 102.1  
2003 3. 108.9  
2003 4. 100.8  
2003 5. 114.2  
2003 6. 112.7  
2003 7. 109.0  
2003 8. 99.12  
2003 9. 104.2  
2003 10 100.2  
2003 12 98.82  
2004 1. 115.6  
2004 2. 101.0  
2004 3. 101.5  
2004 4. 109.0  
2004 5. 116.5  
2004 6. 105.7  
2004 7. 95.36  
2004 8. 101.1  
2004 9. 102.0  
2004 10 94.93  
2004 11 90.18  
2004 12 78.47  
2005 1. 93.63  
2005 2. 102.1  
2005 3. 103.0  
2005 4. 106.6  
2005 5. 116.5  
2005 6. 92.05  
2005 7. 109.2  
2005 8. 104.3  
2005 9. 107.0  
2005 10 102.1  
2005 11 130.8  
2005 12 106.2  
2006 1. 110.6  
2006 2. 107.1  
2006 2. 127.0  
2006 4. 100.5  
2006 5. 90.59  
2006 6. 105.3  
2006 7. 108.5  
2006 8. 110.8  
2006 9. 109.6  
2006 10 87.09  
2006 11 103.7

2006 12 99.72  
2007 1. 111.2  
2007 2. 107.1  
2007 3. 105.3  
2007 4. 115.9  
2007 5. 112.1  
2007 6. 122.2  
2007 7. 106.8  
2007 8. 102.1  
2007 9. 119.9  
2007 10 99.64  
2007 11 114.2  
2007 12 104.2  
2008 1. 91.55  
2008 2. 134.1  
2008 3. 100.3  
2008 4. 89.46  
2008 5. 108.3  
2008 6. 95.63  
2008 7. 92.59  
2008 8. 98.83  
2008 9. 79.38  
2008 10 68.35  
2008 11 74.00  
2008 12 81.31  
2009 1. 95.54  
2009 2. 110.3  
2009 3. 101.5  
2009 4. 97.63  
2009 5. 98.14  
2009 6. 95.76  
2009 7. 90.06  
2009 8. 87.42  
2009 9. 97.73  
2009 10 100.1  
2009 11 97.39  
2009 12 69.38  
2010 1. 91.23  
2010 2. 88.51  
2010 3. 90.84  
2010 4. 96.76  
2010 5. 93.68  
2010 6. 115.4  
2010 7. 95.25  
2010 8. 88.68  
2010 9. 102.5  
2010 10 99.33  
2010 11 90.68  
2010 12 90.47  
2011 1. 109.2  
2011 2. 106.3  
2011 3. 119.2  
2011 4. 98.94  
2011 5. 91.99

2011 6. 79.76  
2011 7. 91.41  
2011 8. 110.5  
2011 9. 91.46  
2011 10 112.6  
2011 11 124.6  
2011 12 91.01  
2012 1. 90.17  
2012 2. 103.6  
2012 3. 95.64  
2012 4. 81.34  
2012 5. 103.2  
2012 6. 112.4  
2012 7. 108.8  
2012 8. 113.0  
2012 9. 112.5  
2012 10 121.9  
2012 11 97.56  
2012 12 92.66  
2013 1. 108.8  
2013 2. 99.47  
2013 3. 113.0  
2013 4. 97.12  
2013 5. 125.7  
2013 6. 119.1  
2013 7. 113.1  
2013 8. 91.54  
2013 9. 93.31  
2013 12 105.2  
2014 1. 86.89  
2014 2. 115.3  
2014 3. 103.7  
2014 4. 100.8  
2014 5. 124.0  
2014 6. 115.0  
2014 7. 105.4  
2014 8. 128.3  
2014 9. 99.36  
2014 10 95.00  
2014 11 108.0  
2014 12 79.69  
2015 1. 99.25  
2015 2. 114.7  
2015 3. 104.5  
2015 4. 107.6  
2015 5. 118.2  
2015 6. 107.6  
2015 7. 126.8  
2015 8. 97.18  
2015 9. 88.69  
2015 10 77.56  
2015 11 87.19  
2016 1. 94.18  
2016 2. 97.00

2016 3. 100.4  
2016 4. 106.9  
2016 5. 91.36  
2016 6. 102.7  
2016 7. 96.56  
2016 8. 86.85  
2016 9. 78.61  
2016 10 99.96  
2016 11 95.41  
2016 12 104.7  
2017 1. 108.1  
2017 2. 127.1  
2017 3. 92.11  
2017 4. 96.21  
2017 5. 103.5  
2017 6. 98.26  
2017 7. 96.42  
2017 8. 89.32  
2017 9. 89.63  
2017 10 87.99  
2017 11 95.81  
2017 12 80.90

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.076

$$S = 248.$$

$$z = 1.781$$

$$p = 0.0749$$

$$p = 0.2996 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 98.11 + 0.1803 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO saturation WHI0065 1993-2017

1993 1. 98.07  
1993 2. 91.39  
1993 3. 109.8  
1993 4. 101.1  
1993 5. 83.41  
1993 6. 81.18  
1993 7. 70.19  
1993 8. 120.9  
1993 9. 107.7  
1993 10 93.07  
1993 11 97.39  
1993 12 94.56  
1994 1. 93.85  
1994 2. 109.4  
1994 3. 109.3  
1994 4. 106.5  
1994 5. 114.3  
1994 6. 110.9  
1994 7. 88.76  
1994 8. 101.0  
1994 9. 91.25  
1994 10 84.65  
1994 11 89.23  
1995 1. 113.6  
1995 2. 92.27  
1995 3. 105.0  
1995 5. 124.6  
1995 6. 95.65  
1995 7. 109.2  
1995 8. 93.65  
1995 9. 86.71  
1995 10 93.07  
1995 10 101.1  
1995 11 100.5  
1996 1. 95.54  
1996 2. 106.9  
1996 3. 129.6  
1996 4. 117.8  
1996 5. 111.0  
1996 6. 125.3  
1996 7. 94.15  
1996 8. 96.75  
1996 9. 123.4  
1996 10 101.3  
1996 11 100.1  
1996 12 97.39  
1997 1. 119.8  
1997 2. 113.3  
1997 3. 112.2  
1997 4. 130.9  
1997 5. 105.6  
1997 6. 119.8

1997 8. 106.5  
1997 9. 79.74  
1997 10 74.93  
1997 11 100.5  
1997 12 98.43  
1998 1. 94.80  
1998 2. 93.91  
1998 4. 133.4  
1998 5. 108.8  
1998 6. 116.6  
1998 7. 123.0  
1998 8. 100.4  
1998 9. 80.43  
1998 10 105.3  
1998 11 115.7  
1998 12 105.5  
1999 1. 96.41  
1999 2. 106.0  
1999 3. 110.9  
1999 4. 98.93  
1999 5. 105.5  
1999 7. 88.87  
1999 8. 82.06  
1999 9. 78.34  
1999 10 78.98  
1999 11 97.13  
1999 11 108.0  
2000 1. 110.6  
2000 2. 112.3  
2000 3. 111.0  
2000 4. 129.6  
2000 5. 105.4  
2000 6. 130.7  
2000 7. 111.3  
2000 8. 119.2  
2000 9. 114.9  
2000 10 109.9  
2000 10 123.4  
2000 12 92.32  
2001 1. 103.6  
2001 2. 107.2  
2001 3. 130.8  
2001 4. 155.0  
2001 5. 118.8  
2001 6. 105.7  
2001 7. 132.9  
2001 8. 140.5  
2001 9. 104.0  
2001 10 104.4  
2001 11 135.1  
2001 12 107.6  
2002 1. 111.2  
2002 2. 102.1  
2002 3. 116.0

2002 4. 140.4  
2002 5. 114.3  
2002 6. 106.0  
2002 7. 130.6  
2002 8. 81.09  
2002 10 104.7  
2002 11 106.2  
2002 12 108.7  
2003 1. 108.4  
2003 2. 108.7  
2003 3. 124.2  
2003 4. 127.2  
2003 5. 127.0  
2003 6. 131.9  
2003 7. 85.80  
2003 8. 126.5  
2003 9. 108.8  
2003 10 95.65  
2003 12 102.7  
2004 1. 110.6  
2004 2. 104.0  
2004 3. 123.3  
2004 4. 132.6  
2004 5. 131.5  
2004 6. 124.6  
2004 7. 107.8  
2004 8. 117.2  
2004 9. 101.0  
2004 10 101.5  
2004 11 98.04  
2004 12 95.54  
2005 1. 99.25  
2005 2. 105.2  
2005 3. 115.1  
2005 4. 132.0  
2005 5. 133.0  
2005 6. 100.9  
2005 7. 106.2  
2005 8. 122.7  
2005 9. 113.2  
2005 10 118.5  
2005 11 125.3  
2005 12 113.2  
2006 1. 106.2  
2006 2. 115.3  
2006 2. 128.9  
2006 4. 135.6  
2006 5. 103.1  
2006 6. 107.2  
2006 7. 91.34  
2006 8. 104.0  
2006 9. 100.2  
2006 10 91.34  
2006 11 123.9

2006 12 130.5  
2007 1. 114.5  
2007 2. 110.0  
2007 3. 137.7  
2007 4. 140.1  
2007 5. 173.6  
2007 6. 144.3  
2007 7. 106.2  
2007 8. 104.0  
2007 9. 115.7  
2007 10 97.45  
2007 11 118.2  
2007 12 104.2  
2008 1. 106.0  
2008 2. 138.7  
2008 3. 131.9  
2008 4. 102.4  
2008 5. 113.2  
2008 6. 105.5  
2008 7. 93.55  
2008 8. 107.5  
2008 9. 88.39  
2008 10 97.74  
2008 11 95.41  
2008 12 92.47  
2009 1. 114.4  
2009 2. 118.7  
2009 3. 131.3  
2009 4. 95.10  
2009 5. 111.9  
2009 6. 100.2  
2009 7. 103.8  
2009 8. 96.41  
2009 9. 100.7  
2009 10 105.3  
2009 11 101.5  
2009 12 86.12  
2010 1. 122.2  
2010 2. 119.6  
2010 3. 112.4  
2010 4. 118.5  
2010 5. 90.22  
2010 6. 111.2  
2010 7. 97.89  
2010 8. 99.04  
2010 9. 102.9  
2010 10 113.9  
2010 11 97.90  
2010 12 130.6  
2011 1. 120.1  
2011 2. 122.9  
2011 3. 134.8  
2011 4. 118.9  
2011 5. 87.77

2011 6. 114.4  
2011 7. 105.1  
2011 8. 130.1  
2011 9. 125.4  
2011 10 120.7  
2011 11 125.7  
2011 12 98.54  
2012 1. 103.2  
2012 2. 139.1  
2012 3. 113.2  
2012 4. 87.89  
2012 5. 89.76  
2012 6. 113.1  
2012 7. 110.4  
2012 8. 77.12  
2012 9. 97.16  
2012 10 110.7  
2012 11 80.12  
2012 12 90.88  
2013 1. 131.5  
2013 2. 137.3  
2013 3. 146.5  
2013 4. 114.8  
2013 5. 140.7  
2013 6. 130.6  
2013 7. 122.4  
2013 8. 96.71  
2013 9. 108.6  
2013 12 136.8  
2014 1. 104.3  
2014 2. 161.6  
2014 3. 112.5  
2014 4. 142.8  
2014 5. 139.5  
2014 6. 104.7  
2014 7. 95.57  
2014 8. 131.1  
2014 9. 91.16  
2014 10 91.25  
2014 11 105.0  
2014 12 67.45  
2015 1. 110.8  
2015 2. 147.9  
2015 3. 130.4  
2015 4. 122.0  
2015 5. 131.5  
2015 6. 112.5  
2015 7. 121.0  
2015 8. 112.7  
2015 8. 89.42  
2015 9. 83.61  
2015 10 101.1  
2015 11 99.99  
2015 11 83.56

2016 1. 100.8  
2016 2. 118.0  
2016 3. 109.0  
2016 4. 130.9  
2016 5. 90.43  
2016 6. 98.62  
2016 7. 105.1  
2016 8. 93.31  
2016 9. 99.78  
2016 10 116.1  
2016 11 89.84  
2016 12 123.4  
2017 1. 140.3  
2017 2. 136.6  
2017 3. 112.1  
2017 4. 98.20  
2017 5. 111.7  
2017 6. 108.2  
2017 7. 107.7  
2017 8. 83.52  
2017 9. 100.6  
2017 10 96.55  
2017 11 114.3  
2017 12 68.24

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.126

$$S = 413.$$

$$z = 2.970$$

$$p = 0.0030$$

$$p = 0.0446 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 102.5 + 0.4000 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO saturation 07060500 1993-2017

1993 1. 95.  
1993 3. 114  
1993 4. 81.  
1993 6. 82.  
1993 8. 95.  
1993 11 88.  
1993 12 88.  
1994 3. 90.  
1994 4. 93.  
1994 6. 84.  
1994 6. 83.  
1994 6. 82.  
1994 6. 81.  
1994 6. 82.  
1994 6. 82.  
1994 6. 84.  
1994 6. 83.  
1994 6. 84.  
1994 6. 85.  
1994 7. 96.  
1994 8. 110  
1994 10 43.  
1995 1. 86.  
1995 2. 104  
1995 4. 99.  
1995 7. 95.  
1995 9. 88.  
1995 9. 79.  
1995 9. 77.  
1995 9. 76.  
1995 9. 76.  
1995 9. 77.  
1995 9. 77.  
1995 9. 79.  
1995 9. 80.  
1995 9. 81.  
1995 9. 80.  
1995 10 85.  
1995 11 102  
1996 2. 86.  
1996 2. 109  
1996 2. 104  
1996 2. 100  
1996 2. 98.  
1996 2. 97.  
1996 2. 97.  
1996 2. 97.  
1996 2. 98.  
1996 2. 98.  
1996 2. 99.  
1996 4. 100  
1996 6. 89.

1996 8. 110  
1996 10 70.  
1996 12 86.  
1997 2. 91.  
1997 4. 101  
1997 7. 82.  
1997 8. 75.  
1997 11 97.  
1998 1. 116  
1998 3. 100  
1998 4. 85.  
1998 6. 89.  
1998 6. 89.  
1998 6. 87.  
1998 6. 88.  
1998 6. 88.  
1998 6. 87.  
1998 6. 88.  
1998 6. 89.  
1998 6. 88.  
1998 6. 90.  
1998 6. 90.  
1998 8. 98.  
1998 11 97.  
1999 1. 99.  
1999 3. 95.  
1999 6. 101  
1999 7. 81.  
1999 9. 79.  
1999 11 82.  
2000 1. 90.  
2000 3. 93.  
2000 5. 91.  
2000 7. 99.  
2000 8. 81.  
2000 11 109  
2001 1. 101  
2001 3. 99.  
2001 5. 105  
2001 8. 108  
2001 10 90.  
2001 12 93.  
2002 2. 113  
2002 4. 107  
2002 6. 89.  
2002 8. 94.  
2002 8. 93.  
2002 8. 90.  
2002 8. 89.  
2002 8. 89.  
2002 8. 89.  
2002 8. 89.  
2002 8. 88.  
2002 8. 88.

2002 8. 88.  
2002 8. 88.  
2002 10 101  
2002 12 60.  
2003 3. 107  
2003 3. 101  
2003 3. 103  
2003 3. 103  
2003 3. 102  
2003 3. 103  
2003 3. 102  
2003 3. 102  
2003 3. 100  
2003 3. 99.  
2003 3. 97.  
2003 5. 87.  
2003 7. 92.  
2003 7. 94.  
2003 7. 91.  
2003 7. 92.  
2003 7. 92.  
2003 7. 91.  
2003 7. 91.  
2003 7. 91.  
2003 7. 91.  
2003 7. 91.  
2003 7. 91.  
2003 8. 86.  
2003 11 80.  
2003 11 79.  
2003 11 79.  
2003 11 78.  
2003 11 78.  
2003 11 79.  
2003 11 78.  
2003 11 78.  
2003 11 77.  
2003 11 77.  
2003 11 78.  
2004 1. 92.  
2004 1. 93.  
2004 1. 103  
2004 1. 93.  
2004 1. 93.  
2004 1. 92.  
2004 1. 91.  
2004 1. 92.  
2004 1. 92.  
2004 1. 92.  
2004 1. 92.  
2004 1. 93.  
2004 2. 84.  
2004 4. 95.  
2004 6. 85.  
2004 8. 94.

2004 8. 94.  
2004 8. 95.  
2004 8. 94.  
2004 8. 93.  
2004 8. 93.  
2004 8. 93.  
2004 8. 92.  
2004 8. 93.  
2004 8. 92.  
2004 8. 93.  
2004 10 90.  
2004 10 91.  
2004 10 100  
2004 10 91.  
2004 10 89.  
2004 10 97.  
2004 10 93.  
2004 10 92.  
2004 10 94.  
2004 10 93.  
2004 10 93.  
2005 1. 76.  
2005 3. 99.  
2005 4. 91.  
2005 6. 101  
2005 8. 93.  
2005 10 90.  
2006 1. 90.  
2006 3. 92.  
2006 5. 91.  
2006 7. 88.  
2006 8. 82.  
2006 11 78.  
2007 1. 93.  
2007 3. 109  
2007 4. 101  
2007 6. 103  
2007 8. 79.  
2007 11 92.  
2007 12 87.  
2008 2. 83.  
2008 4. 100  
2008 6. 96.  
2008 8. 85.  
2008 10 78.  
2008 12 92.  
2009 1. 102  
2009 3. 100  
2009 4. 104  
2009 8. 90.  
2009 11 100  
2010 2. 94.  
2010 3. 102  
2010 3. 102

2010 3. 101  
2010 3. 99.  
2010 3. 96.  
2010 3. 90.  
2010 3. 82.  
2010 3. 103  
2010 6. 96.  
2010 8. 87.  
2010 10 93.  
2010 12 91.  
2011 2. 103  
2011 4. 97.  
2011 6. 100  
2011 8. 90.  
2011 10 90.  
2012 2. 102  
2012 6. 109  
2012 8. 113  
2012 11 97.  
2013 3. 105  
2013 5. 96.  
2013 9. 96.  
2013 11 94.  
2014 3. 102  
2014 4. 113  
2014 7. 104  
2014 11 92.  
2015 3. 98.  
2015 5. 108  
2015 12 87.  
2016 3. 97.  
2016 5. 119  
2016 8. 95.  
2016 11 102  
2017 2. 92.  
2017 5. 97.  
2017 8. 82.  
2017 11 95.

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.119

$$S = 97.$$

$$z = 1.742$$

$$p = 0.0815$$

$$p = 0.1330 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 90.25 + 0.2500 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DO saturation 07060710 1993-2017

1993 1. 88.  
1993 3. 105  
1993 4. 81.  
1993 5. 87.  
1993 6. 78.  
1993 7. 107  
1993 8. 77.  
1993 9. 76.  
1993 12 94.  
1993 12 102  
1994 1. 100  
1994 2. 111  
1994 3. 101  
1994 4. 93.  
1994 5. 108  
1994 6. 129  
1994 6. 91.  
1994 6. 96.  
1994 6. 111  
1994 6. 116  
1994 6. 115  
1994 6. 111  
1994 6. 114  
1994 6. 115  
1994 6. 115  
1994 6. 115  
1994 7. 95.  
1994 8. 58.  
1994 8. 65.  
1994 10 97.  
1994 11 94.  
1994 12 102  
1995 1. 63.  
1995 2. 98.  
1995 3. 90.  
1995 3. 88.  
1995 4. 95.  
1995 5. 71.  
1995 6. 94.  
1995 7. 96.  
1995 8. 155  
1995 10 97.  
1995 11 92.  
1996 1. 98.  
1996 1. 91.  
1996 1. 77.  
1996 1. 59.  
1996 1. 52.  
1996 1. 86.  
1996 1. 91.  
1996 1. 95.  
1996 1. 97.

1996 1. 97.  
1996 1. 100  
1996 2. 102  
1996 4. 109  
1996 5. 100  
1996 6. 79.  
1996 7. 82.  
1996 8. 89.  
1996 9. 117  
1996 10 75.  
1997 2. 90.  
1997 4. 96.  
1997 5. 114  
1997 6. 107  
1997 7. 116  
1997 8. 121  
1997 9. 96.  
1997 10 106  
1997 11 67.  
1997 12 98.  
1998 1. 89.  
1998 2. 115  
1998 3. 99.  
1998 4. 99.  
1998 5. 91.  
1998 6. 83.  
1998 7. 90.  
1998 8. 82.  
1998 9. 128  
1998 10 105  
1998 11 103  
1998 12 93.  
1999 1. 82.  
1999 2. 108  
1999 3. 87.  
1999 4. 99.  
1999 5. 117  
1999 6. 84.  
1999 7. 79.  
1999 8. 55.  
1999 9. 63.  
1999 10 83.  
1999 11 115  
1999 12 102  
2000 1. 77.  
2000 2. 92.  
2000 3. 109  
2000 4. 99.  
2000 5. 83.  
2000 6. 111  
2000 7. 105  
2000 8. 122  
2000 9. 69.  
2000 10 87.

2000 11 97.  
2000 12 58.  
2001 2. 85.  
2001 3. 96.  
2001 4. 90.  
2001 5. 73.  
2001 6. 81.  
2001 7. 66.  
2001 8. 73.  
2001 9. 77.  
2001 11 83.  
2001 12 92.  
2002 1. 105  
2002 2. 104  
2002 3. 92.  
2002 5. 97.  
2002 7. 75.  
2002 9. 115  
2002 11 88.  
2002 12 97.  
2003 1. 104  
2003 2. 89.  
2003 3. 102  
2003 5. 107  
2003 7. 103  
2003 9. 92.  
2003 11 86.  
2003 12 90.  
2004 1. 94.  
2004 2. 112  
2004 3. 103  
2004 3. 91.  
2004 5. 74.  
2004 7. 69.  
2004 8. 119  
2004 11 112  
2005 1. 88.  
2005 3. 96.  
2005 5. 116  
2005 7. 82.  
2005 9. 103  
2005 11 113  
2006 1. 129  
2006 3. 102  
2006 5. 99.  
2006 6. 119  
2006 7. 91.  
2006 9. 126  
2007 2. 102  
2007 3. 97.  
2007 5. 106  
2007 5. 112  
2007 6. 91.  
2007 7. 100

2007 8. 84.  
2007 9. 93.  
2007 10 84.  
2007 12 100  
2008 1. 110  
2008 2. 84.  
2008 3. 106  
2008 5. 106  
2008 6. 94.  
2008 9. 99.  
2009 3. 104  
2009 4. 103  
2009 6. 102  
2009 8. 81.  
2009 11 101  
2010 2. 105  
2010 3. 96.  
2010 6. 129  
2010 8. 128  
2010 10 115  
2010 12 99.  
2011 2. 118  
2011 4. 101  
2011 6. 124  
2011 8. 134  
2011 10 144  
2011 12 104  
2012 2. 108  
2012 4. 116  
2012 6. 138  
2012 8. 73.  
2012 11 105  
2013 1. 105  
2013 3. 102  
2013 5. 93.  
2013 7. 134  
2013 9. 130  
2013 11 118  
2014 1. 105  
2014 3. 100  
2014 4. 120  
2014 5. 104  
2014 7. 137  
2014 9. 85.  
2014 11 103  
2015 1. 103  
2015 3. 100  
2015 5. 106  
2015 7. 109  
2015 8. 117  
2015 10 93.  
2015 11 109  
2015 12 102  
2016 1. 97.

2016 1. 109  
2016 2. 107  
2016 2. 105  
2016 3. 107  
2016 4. 110  
2016 4. 103  
2016 5. 101  
2016 5. 112  
2016 7. 115  
2016 7. 90.  
2016 8. 100  
2016 9. 96.  
2016 10 109  
2016 10 110  
2016 11 110  
2016 11 108  
2016 12 111  
2017 3. 101  
2017 3. 100  
2017 4. 105  
2017 5. 102  
2017 5. 113  
2017 6. 114  
2017 6. 114  
2017 7. 128  
2017 8. 126  
2017 9. 104  
2017 10 110  
2017 10 105  
2017 11 98.

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DO saturation 07060710 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.254

$$S = 440.$$

$$z = 4.948$$

$$p = 0.0000$$

$$p = 0.0019 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 92.06 + 0.6111 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

# **ATTACHMENT 3**

---

**Dissolved Inorganic Nitrogen Seasonal Mann-Kendall Input and Output**

2 0 NOx WHI0011 1993-2017

1993 5.0 0.428  
1993 7.0 0.629  
1993 8.0 0.354  
1993 9.0 0.288  
1993 10. 0.652  
1993 11. 0.840  
1993 12. 0.619  
1994 1.0 0.641  
1994 2.0 0.377  
1994 4.0 0.379  
1994 5.0 0.419  
1994 6.0 0.580  
1994 7.0 0.603  
1994 8.0 0.439  
1994 9.0 0.339  
1994 10. 0.491  
1994 11. 0.722  
1994 12. 0.694  
1995 1.0 0.671  
1995 2.0 0.618  
1995 3.0 0.395  
1995 4.0 0.554  
1995 5.0 0.417  
1995 6.0 0.459  
1995 7.0 0.582  
1995 8.0 0.042  
1995 9.0 0.380  
1995 10. 0.393  
1995 11. 0.485  
1995 12. 1.101  
1996 1.0 0.803  
1996 2.0 0.555  
1996 3.0 0.475  
1996 4.0 0.681  
1996 5.0 0.760  
1996 6.0 0.610  
1996 7.0 0.485  
1996 8.0 0.435  
1996 9.0 0.714  
1996 10. 0.997  
1996 11. 0.879  
1996 12. 0.650  
1997 1.0 0.540  
1997 2.0 0.645  
1997 3.0 0.546  
1997 4.0 0.146  
1997 5.0 0.532  
1997 6.0 0.436  
1997 7.0 0.317  
1997 8.0 0.402  
1997 9.0 0.375  
1997 10. 0.441

1997 11. 0.543  
1997 12. 0.980  
1998 1.0 0.815  
1998 2.0 0.647  
1998 3.0 0.394  
1998 4.0 0.136  
1998 5.0 0.120  
1998 10. 0.971  
1998 12. 0.800  
1999 1.0 0.233  
1999 2.0 0.726  
1999 3.0 0.519  
1999 4.0 0.320  
1999 5.0 0.112  
1999 7.0 0.305  
1999 8.0 0.287  
1999 9.0 0.256  
1999 10. 0.418  
1999 11. 0.390  
1999 12. 1.546  
2000 1.0 0.765  
2000 2.0 0.939  
2000 3.0 0.381  
2000 4.0 0.430  
2000 5.0 1.159  
2000 6.0 1.107  
2000 8.0 0.330  
2000 8.0 0.138  
2000 9.0 0.036  
2000 10. 0.290  
2000 11. 1.135  
2000 12. 1.463  
2001 1.0 1.540  
2001 2.0 1.392  
2001 3.0 0.703  
2001 4.0 0.670  
2001 5.0 0.655  
2001 6.0 0.417  
2001 7.0 0.190  
2001 8.0 0.062  
2001 9.0 0.233  
2001 10. 0.470  
2001 11. 0.475  
2001 12. 1.065  
2002 1.0 1.302  
2002 2.0 0.879  
2002 3.0 0.406  
2002 4.0 0.390  
2002 5.0 0.526  
2002 6.0 0.646  
2002 7.0 0.487  
2002 8.0 0.245  
2002 9.0 0.291  
2002 10. 0.383

2002 11. 0.662  
2002 12. 0.772  
2003 1.0 0.300  
2003 3.0 0.819  
2003 4.0 0.468  
2003 4.0 0.581  
2003 5.0 0.618  
2003 6.0 0.551  
2003 7.0 0.725  
2003 8.0 0.633  
2003 9.0 0.522  
2003 10. 0.707  
2003 11. 0.694  
2003 12. 0.996  
2004 1.0 0.879  
2004 2.0 0.633  
2004 3.0 0.662  
2004 5.0 0.472  
2004 6.0 0.457  
2004 7.0 0.313  
2004 8.0 0.284  
2004 9.0 0.150  
2004 10. 1.050  
2004 11. 0.825  
2004 12. 0.975  
2005 1.0 0.896  
2005 2.0 0.601  
2005 3.0 0.427  
2005 4.0 0.389  
2005 5.0 0.293  
2005 5.0 0.550  
2005 7.0 0.242  
2005 8.0 0.128  
2005 9.0 0.714  
2005 10. 0.316  
2005 11. 0.913  
2005 12. 0.587  
2006 1.0 0.882  
2006 2.0 0.419  
2006 3.0 0.490  
2006 4.0 0.278  
2006 5.0 0.595  
2006 6.0 0.230  
2006 7.0 0.139  
2006 8.0 0.000  
2006 9.0 0.086  
2006 10. 0.971  
2006 11. 0.877  
2006 12. 0.894  
2007 1.0 0.843  
2007 2.0 0.659  
2007 3.0 0.627  
2007 4.0 0.343  
2007 5.0 0.157

2007 6.0 0.164  
2007 7.0 0.446  
2007 8.0 0.227  
2007 9.0 0.642  
2007 10. 0.438  
2007 11. 0.306  
2007 12. 0.508  
2008 1.0 0.875  
2008 2.0 0.604  
2008 3.0 0.528  
2008 4.0 0.639  
2008 5.0 0.394  
2008 6.0 0.387  
2008 7.0 0.278  
2008 8.0 0.282  
2008 9.0 0.935  
2008 10. 0.553  
2008 11. 0.583  
2009 1.0 0.609  
2009 2.0 0.696  
2009 3.0 0.343  
2009 4.0 0.415  
2009 5.0 0.502  
2009 6.0 0.497  
2009 7.0 0.396  
2009 8.0 0.290  
2009 9.0 0.897  
2009 10. 0.814  
2009 11. 0.611  
2009 12. 0.427  
2010 1.0 0.672  
2010 2.0 0.462  
2010 3.0 0.605  
2010 4.0 0.609  
2010 5.0 0.575  
2010 6.0 0.526  
2010 7.0 0.272  
2010 8.0 0.271  
2010 9.0 0.166  
2010 10. 0.443  
2010 11. 0.309  
2010 12. 0.535  
2011 1.0 0.464  
2011 2.0 0.738  
2011 3.0 1.010  
2011 4.0 0.632  
2011 5.0 0.412  
2011 6.0 0.324  
2011 7.0 0.423  
2011 8.0 0.257  
2011 9.0 0.248  
2011 10. 0.320  
2011 11. 0.324  
2011 12. 0.831

2012 1.0 0.779  
2012 2.0 0.836  
2012 3.0 0.616  
2012 4.0 0.431  
2012 5.0 0.407  
2012 6.0 0.364  
2012 7.0 0.138  
2012 8.0 0.051  
2012 9.0 0.204  
2012 10. 0.392  
2012 11. 0.240  
2012 12. 0.384  
2013 1.0 1.300  
2013 2.0 0.871  
2013 3.0 1.200  
2013 4.0 0.409  
2013 5.0 0.405  
2013 6.0 0.964  
2013 7.0 0.368  
2013 8.0 0.780  
2013 9.0 0.483  
2013 10. 0.644  
2013 11. 0.596  
2013 12. 0.610  
2014 1.0 1.200  
2014 2.0 0.696  
2014 3.0 0.847  
2014 4.0 0.706  
2014 5.0 0.713  
2014 6.0 0.560  
2014 7.0 0.568  
2014 8.0 0.462  
2014 9.0 0.316  
2014 10. 0.503  
2014 11. 0.434  
2014 12. 0.572  
2015 1.0 1.380  
2015 2.0 0.647  
2015 3.0 0.516  
2015 4.0 0.532  
2015 5.0 0.469  
2015 6.0 0.601  
2015 7.0 0.417  
2015 8.0 0.372  
2015 9.0 0.338  
2015 10. 0.348  
2015 11. 0.664  
2016 1.0 1.050  
2016 2.0 0.518  
2016 3.0 0.382  
2016 4.0 0.355  
2016 5.0 0.632  
2016 6.0 0.598  
2016 7.0 0.508

2016 8.0 0.974  
2016 9.0 0.564  
2016 10. 0.642  
2016 11. 0.734  
2016 12. 0.755  
2017 1.0 0.727  
2017 2.0 0.511  
2017 3.0 0.811  
2017 4.0 0.555  
2017 6.0 0.580  
2017 7.0 0.421  
2017 8.0 0.432  
2017 9.0 0.265  
2017 10. 0.388  
2017 11. 0.391  
2017 12. 0.359

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: NOx WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is -0.004

$$S = -12.$$

$$z = -0.081$$

$$p = 0.9351$$

$$p = 0.9436 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.5242 + -0.1667E-03 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DNOx WHI0029 1993-2017

1993 1.0 0.324  
1993 2.0 0.315  
1993 3.0 0.327  
1993 4.0 0.326  
1993 5.0 0.288  
1993 6.0 0.293  
1993 7.0 0.377  
1993 8.0 0.365  
1993 9.0 0.248  
1993 10. 0.275  
1993 11. 0.276  
1993 12. 0.265  
1994 1.0 0.266  
1994 2.0 0.190  
1994 4.0 0.300  
1994 5.0 0.328  
1994 6.0 0.437  
1994 7.0 0.477  
1994 8.0 0.431  
1994 9.0 0.398  
1994 10. 0.376  
1994 11. 0.511  
1994 12. 0.275  
1995 1.0 0.462  
1995 2.0 0.245  
1995 3.0 0.189  
1995 4.0 0.241  
1995 5.0 0.260  
1995 6.0 0.277  
1995 7.0 0.314  
1995 8.0 0.190  
1995 9.0 0.415  
1995 10. 0.291  
1995 11. 0.086  
1995 12. 0.283  
1996 1.0 0.345  
1996 2.0 0.149  
1996 3.0 0.257  
1996 4.0 0.249  
1996 5.0 0.238  
1996 6.0 0.406  
1996 7.0 0.309  
1996 8.0 0.218  
1996 9.0 0.166  
1996 10. 0.262  
1996 11. 0.404  
1996 12. 0.238  
1997 1.0 0.438  
1997 2.0 0.295  
1997 3.0 0.276  
1997 4.0 0.185  
1997 5.0 0.336

1997 6.0 0.276  
1997 7.0 0.392  
1997 8.0 0.342  
1997 9.0 0.435  
1997 10. 0.391  
1997 11. 0.222  
1997 12. 0.216  
1998 1.0 0.387  
1998 2.0 0.290  
1998 3.0 0.269  
1998 4.0 0.242  
1998 5.0 0.270  
1998 6.0 0.045  
1998 7.0 0.295  
1998 8.0 0.329  
1998 9.0 0.438  
1998 10. 0.246  
1998 11. 0.166  
1998 12. 0.143  
1999 1.0 0.396  
1999 2.0 0.179  
1999 3.0 0.246  
1999 4.0 0.255  
1999 5.0 0.290  
1999 6.0 0.315  
1999 7.0 0.354  
1999 8.0 0.388  
1999 9.0 0.288  
1999 10. 0.365  
1999 11. 0.135  
1999 12. 0.474  
2000 1.0 0.190  
2000 2.0 0.299  
2000 3.0 0.128  
2000 4.0 0.046  
2000 6.0 0.631  
2000 8.0 0.150  
2000 8.0 0.153  
2000 9.0 0.111  
2000 10. 0.000  
2000 11. 0.135  
2000 12. 0.230  
2001 1.0 0.110  
2001 2.0 0.180  
2001 3.0 0.217  
2001 4.0 0.060  
2001 5.0 0.143  
2001 6.0 0.028  
2001 7.0 0.120  
2001 8.0 0.185  
2001 9.0 0.149  
2001 10. 0.180  
2001 11. 0.182  
2001 12. 0.360

2002 1.0 0.494  
2002 2.0 0.284  
2002 3.0 0.295  
2002 5.0 0.244  
2002 6.0 0.439  
2002 7.0 0.314  
2002 8.0 0.400  
2002 9.0 0.457  
2002 10. 0.352  
2002 11. 0.427  
2002 12. 0.280  
2003 3.0 0.396  
2003 4.0 0.264  
2003 4.0 0.169  
2003 5.0 0.387  
2003 6.0 0.234  
2003 7.0 0.264  
2003 8.0 0.294  
2003 9.0 0.307  
2003 10. 0.267  
2003 11. 0.262  
2003 12. 0.252  
2004 1.0 0.226  
2004 2.0 0.194  
2004 3.0 0.296  
2004 5.0 0.371  
2004 6.0 0.229  
2004 7.0 0.401  
2004 8.0 0.259  
2004 9.0 0.298  
2004 10. 0.332  
2004 11. 0.383  
2004 12. 0.265  
2005 1.0 0.259  
2005 2.0 0.298  
2005 3.0 0.464  
2005 4.0 0.280  
2005 5.0 0.212  
2005 7.0 0.283  
2005 8.0 0.333  
2005 9.0 0.411  
2005 10. 0.356  
2005 11. 0.212  
2005 12. 0.260  
2006 1.0 0.083  
2006 2.0 0.121  
2006 3.0 0.127  
2006 4.0 0.098  
2006 5.0 0.171  
2006 6.0 0.067  
2006 7.0 0.131  
2006 8.0 0.189  
2006 9.0 0.101  
2006 10. 0.138

2006 11. 0.394  
2006 12. 0.461  
2007 1.0 0.197  
2007 2.0 0.667  
2007 3.0 0.229  
2007 4.0 0.139  
2007 5.0 0.092  
2007 6.0 0.079  
2007 7.0 0.250  
2007 8.0 0.195  
2007 9.0 0.355  
2007 10. 0.205  
2007 11. 0.218  
2007 12. 0.198  
2008 1.0 0.183  
2008 2.0 0.384  
2008 3.0 0.235  
2008 4.0 0.358  
2008 5.0 0.313  
2008 6.0 0.310  
2008 7.0 0.442  
2008 8.0 0.580  
2008 9.0 0.571  
2008 10. 0.550  
2008 11. 0.304  
2009 1.0 0.274  
2009 2.0 0.322  
2009 3.0 0.352  
2009 4.0 0.238  
2009 5.0 0.251  
2009 6.0 0.221  
2009 7.0 0.375  
2009 8.0 0.309  
2009 9.0 0.537  
2009 10. 0.444  
2009 11. 0.425  
2009 12. 0.249  
2010 1.0 0.290  
2010 2.0 0.311  
2010 3.0 0.300  
2010 4.0 0.366  
2010 5.0 0.229  
2010 6.0 0.345  
2010 7.0 0.371  
2010 8.0 0.372  
2010 9.0 0.622  
2010 10. 0.424  
2010 10. 0.236  
2010 11. 0.207  
2010 11. 0.347  
2011 1.0 0.189  
2011 2.0 0.352  
2011 3.0 0.278  
2011 4.0 0.249

2011 5.0 0.470  
2011 6.0 0.380  
2011 7.0 0.347  
2011 8.0 0.371  
2011 9.0 0.453  
2011 11. 0.229  
2011 12. 0.430  
2012 1.0 0.549  
2012 2.0 0.251  
2012 3.0 0.500  
2012 4.0 0.331  
2012 5.0 0.497  
2012 6.0 0.257  
2012 7.0 0.231  
2012 8.0 0.210  
2012 9.0 0.224  
2012 10. 0.224  
2012 11. 0.161  
2012 12. 0.157  
2013 1.0 0.375  
2013 2.0 0.326  
2013 3.0 0.360  
2013 4.0 0.212  
2013 5.0 0.118  
2013 6.0 0.220  
2013 7.0 0.296  
2013 8.0 0.319  
2013 9.0 0.349  
2013 10. 0.297  
2013 11. 0.227  
2013 12. 0.257  
2014 1.0 0.400  
2014 2.0 0.217  
2014 3.0 0.329  
2014 4.0 0.234  
2014 5.0 0.155  
2014 6.0 0.338  
2014 7.0 0.239  
2014 8.0 0.270  
2014 9.0 0.258  
2014 10. 0.332  
2014 11. 0.228  
2014 12. 0.216  
2015 1.0 0.267  
2015 2.0 0.242  
2015 3.0 0.566  
2015 4.0 0.135  
2015 5.0 0.172  
2015 6.0 0.321  
2015 7.0 0.336  
2015 8.0 0.358  
2015 9.0 0.412  
2015 10. 0.398  
2015 11. 0.446

2015 11. 0.392  
2015 12. 0.329  
2016 1.0 0.317  
2016 2.0 0.314  
2016 3.0 0.206  
2016 4.0 0.306  
2016 5.0 0.303  
2016 6.0 0.278  
2016 7.0 0.297  
2016 8.0 0.330  
2016 9.0 0.414  
2016 10. 1.600  
2016 11. 0.000  
2016 11. 10.80  
2016 11. 0.369  
2016 12. 0.243  
2017 1.0 0.221  
2017 2.0 0.230  
2017 3.0 0.224  
2017 4.0 0.158  
2017 5.0 0.117  
2017 6.0 0.300  
2017 7.0 0.215  
2017 8.0 0.356  
2017 9.0 0.375  
2017 10. 0.282  
2017 11. 0.244  
2017 12. 0.113

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNO<sub>x</sub> WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.003

$$S = 10.$$

$$z = 0.064$$

$$p = 0.9489$$

$$p = 0.9704 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.2813 + 0.5159E-04 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DNOx WHI0046 1993-2017

1993 1.0 0.240  
1993 2.0 0.289  
1993 3.0 0.210  
1993 4.0 0.183  
1993 5.0 0.260  
1993 6.0 0.366  
1993 7.0 0.442  
1993 8.0 0.405  
1993 9.0 0.322  
1993 11. 0.336  
1993 12. 0.230  
1994 1.0 0.173  
1994 3.0 0.280  
1994 4.0 0.242  
1994 5.0 0.202  
1994 6.0 0.411  
1994 7.0 0.504  
1994 8.0 0.280  
1994 9.0 0.494  
1994 10. 0.581  
1994 11. 0.400  
1994 12. 0.343  
1995 1.0 0.381  
1995 2.0 0.282  
1995 3.0 0.237  
1995 4.0 0.075  
1995 5.0 0.175  
1995 6.0 0.214  
1995 7.0 0.334  
1995 8.0 0.401  
1995 9.0 0.406  
1995 10. 0.327  
1995 10. 0.239  
1995 11. 0.081  
1996 1.0 0.205  
1996 2.0 0.224  
1996 3.0 0.265  
1996 4.0 0.097  
1996 5.0 0.276  
1996 6.0 0.279  
1996 7.0 0.381  
1996 8.0 0.281  
1996 9.0 0.202  
1996 10. 0.455  
1996 11. 0.292  
1996 12. 0.258  
1997 1.0 0.191  
1997 2.0 0.408  
1997 3.0 0.270  
1997 4.0 0.126  
1997 5.0 0.359  
1997 6.0 0.122

1997 7.0 0.459  
1997 8.0 0.439  
1997 9.0 0.212  
1997 10. 0.431  
1997 11. 0.229  
1997 12. 0.229  
1998 1.0 0.455  
1998 2.0 0.172  
1998 3.0 0.286  
1998 4.0 0.242  
1998 5.0 0.224  
1998 6.0 0.340  
1998 7.0 0.365  
1998 8.0 0.438  
1998 9.0 0.481  
1998 10. 0.184  
1998 11. 0.146  
1998 12. 0.497  
1999 1.0 0.484  
1999 2.0 0.332  
1999 3.0 0.188  
1999 4.0 0.263  
1999 5.0 0.298  
1999 6.0 0.330  
1999 7.0 0.400  
1999 8.0 0.483  
1999 9.0 0.464  
1999 10. 0.435  
1999 11. 0.336  
1999 11. 0.173  
2000 1.0 0.336  
2000 2.0 0.132  
2000 3.0 0.041  
2000 4.0 0.000  
2000 5.0 0.034  
2000 6.0 0.333  
2000 7.0 0.203  
2000 8.0 0.216  
2000 9.0 0.158  
2000 10. 0.060  
2000 10. 0.000  
2001 1.0 0.080  
2001 2.0 0.244  
2001 3.0 0.180  
2001 5.0 0.125  
2001 6.0 0.077  
2001 7.0 0.170  
2001 8.0 0.208  
2001 9.0 0.204  
2001 10. 0.238  
2001 11. 0.265  
2001 12. 0.271  
2002 1.0 0.369  
2002 2.0 0.399

2002 3.0 0.232  
2002 4.0 0.400  
2002 5.0 0.240  
2002 6.0 0.241  
2002 7.0 0.349  
2002 8.0 0.399  
2002 9.0 0.492  
2002 10. 0.465  
2002 11. 0.324  
2002 12. 0.202  
2003 1.0 0.333  
2003 2.0 0.204  
2003 3.0 0.219  
2003 4.0 0.066  
2003 5.0 0.121  
2003 6.0 0.194  
2003 7.0 0.290  
2003 8.0 0.317  
2003 9.0 0.255  
2003 10. 0.217  
2003 12. 0.228  
2004 1.0 0.144  
2004 2.0 0.152  
2004 3.0 0.237  
2004 4.0 0.132  
2004 5.0 0.217  
2004 6.0 0.233  
2004 7.0 0.232  
2004 8.0 0.328  
2004 9.0 0.297  
2004 10. 0.337  
2004 11. 0.371  
2004 12. 0.301  
2005 1.0 0.438  
2005 2.0 0.265  
2005 3.0 0.233  
2005 4.0 0.283  
2005 5.0 0.215  
2005 6.0 0.317  
2005 7.0 0.234  
2005 8.0 0.392  
2005 9.0 0.333  
2005 10. 0.414  
2005 11. 0.221  
2005 12. 0.232  
2006 1.0 0.101  
2006 2.0 0.176  
2006 2.0 0.053  
2006 4.0 0.069  
2006 5.0 0.343  
2006 6.0 0.163  
2006 7.0 0.099  
2006 8.0 0.170  
2006 9.0 0.199

2006 10. 0.189  
2006 11. 0.489  
2006 12. 0.428  
2007 1.0 0.426  
2007 2.0 0.209  
2007 3.0 0.127  
2007 4.0 0.200  
2007 5.0 0.078  
2007 6.0 0.081  
2007 7.0 0.217  
2007 8.0 0.255  
2007 9.0 0.866  
2007 10. 0.295  
2007 11. 0.261  
2007 12. 0.205  
2008 1.0 0.196  
2008 2.0 0.138  
2008 3.0 0.403  
2008 4.0 0.304  
2008 5.0 0.432  
2008 6.0 0.341  
2008 7.0 0.457  
2008 8.0 0.657  
2008 9.0 0.600  
2008 10. 0.588  
2008 11. 0.290  
2008 12. 0.307  
2009 1.0 0.233  
2009 2.0 0.273  
2009 3.0 0.217  
2009 4.0 0.177  
2009 5.0 0.389  
2009 6.0 0.239  
2009 7.0 0.440  
2009 8.0 0.409  
2009 9.0 0.394  
2009 10. 0.490  
2009 11. 0.330  
2009 12. 0.247  
2010 1.0 0.344  
2010 2.0 0.408  
2010 3.0 0.297  
2010 4.0 0.461  
2010 5.0 0.371  
2010 6.0 0.392  
2010 7.0 0.398  
2010 8.0 0.495  
2010 9.0 0.471  
2010 10. 0.526  
2010 11. 0.364  
2010 12. 0.262  
2011 1.0 0.228  
2011 2.0 0.207  
2011 3.0 0.353

2011 4.0 0.211  
2011 5.0 0.407  
2011 6.0 0.316  
2011 7.0 0.258  
2011 8.0 0.503  
2011 9.0 0.501  
2011 10. 0.407  
2011 11. 0.155  
2011 12. 0.566  
2012 1.0 0.328  
2012 2.0 0.501  
2012 3.0 0.325  
2012 4.0 0.338  
2012 5.0 0.243  
2012 6.0 0.398  
2012 7.0 0.285  
2012 8.0 0.272  
2012 9.0 0.275  
2012 10. 0.374  
2012 11. 0.357  
2012 12. 0.180  
2013 1.0 0.084  
2013 2.0 0.241  
2013 3.0 0.181  
2013 4.0 0.215  
2013 5.0 0.115  
2013 6.0 0.179  
2013 7.0 0.215  
2013 8.0 0.600  
2013 9.0 0.385  
2013 10. 0.344  
2013 11. 0.347  
2013 12. 0.237  
2014 1.0 0.261  
2014 2.0 0.219  
2014 3.0 0.494  
2014 4.0 0.273  
2014 5.0 0.172  
2014 6.0 0.214  
2014 7.0 0.272  
2014 8.0 0.273  
2014 9.0 0.326  
2014 10. 0.309  
2014 11. 0.309  
2014 12. 0.229  
2015 1.0 0.477  
2015 2.0 0.184  
2015 3.0 0.440  
2015 4.0 0.207  
2015 5.0 0.191  
2015 6.0 0.291  
2015 7.0 0.305  
2015 8.0 0.397  
2015 9.0 0.473

2015 10. 0.533  
2015 11. 0.324  
2016 1.0 0.713  
2016 2.0 0.337  
2016 3.0 0.300  
2016 4.0 0.262  
2016 5.0 0.262  
2016 6.0 0.400  
2016 7.0 0.389  
2016 8.0 0.318  
2016 9.0 0.468  
2016 10. 0.517  
2016 11. 0.268  
2016 12. 0.193  
2017 1.0 0.162  
2017 2.0 0.150  
2017 3.0 0.260  
2017 4.0 0.182  
2017 6.0 0.229  
2017 7.0 0.231  
2017 8.0 0.376  
2017 9.0 0.344  
2017 10. 0.136  
2017 11. 0.069  
2017 12. 0.109

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNOx WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.022

$$S = 75.$$

$$z = 0.526$$

$$p = 0.5991$$

$$p = 0.7749 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.2672 + 0.6000E-03 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DNOx WHI0065 1993-2017

1993 1.0 2.290  
1993 2.0 1.590  
1993 3.0 1.840  
1993 4.0 1.650  
1993 5.0 2.990  
1993 6.0 6.770  
1993 7.0 6.860  
1993 8.0 4.680  
1993 9.0 2.400  
1993 11. 2.300  
1993 12. 2.360  
1994 1.0 2.990  
1994 3.0 2.320  
1994 4.0 0.994  
1994 5.0 3.560  
1994 6.0 6.090  
1994 7.0 3.930  
1994 8.0 12.50  
1994 9.0 14.60  
1994 10. 14.20  
1994 11. 0.967  
1994 12. 2.510  
1995 1.0 2.435  
1995 2.0 4.270  
1995 3.0 2.802  
1995 4.0 2.807  
1995 5.0 2.277  
1995 6.0 2.155  
1995 7.0 0.173  
1995 8.0 13.50  
1995 9.0 13.70  
1995 10. 4.290  
1995 10. 10.10  
1995 11. 11.40  
1996 1.0 3.219  
1996 2.0 4.060  
1996 3.0 8.720  
1996 4.0 2.151  
1996 5.0 2.623  
1996 6.0 10.30  
1996 7.0 15.50  
1996 8.0 15.70  
1996 9.0 5.440  
1996 10. 7.410  
1996 11. 4.520  
1996 12. 2.481  
1997 1.0 2.570  
1997 2.0 2.504  
1997 3.0 1.954  
1997 4.0 2.981  
1997 5.0 5.950  
1997 6.0 10.40

1997 8.0 6.638  
1997 9.0 9.310  
1997 10. 9.504  
1997 11. 9.810  
1997 12. 5.421  
1998 1.0 3.070  
1998 2.0 5.959  
1998 3.0 1.592  
1998 4.0 2.466  
1998 5.0 3.802  
1998 6.0 12.80  
1998 7.0 13.54  
1998 8.0 4.266  
1998 9.0 5.310  
1998 10. 4.381  
1998 11. 4.680  
1998 12. 3.080  
1999 1.0 2.150  
1999 2.0 2.340  
1999 3.0 1.968  
1999 4.0 1.610  
1999 5.0 2.240  
1999 6.0 2.780  
1999 7.0 3.840  
1999 8.0 2.730  
1999 9.0 4.290  
1999 10. 4.460  
1999 11. 1.110  
1999 11. 4.430  
2000 1.0 2.590  
2000 2.0 3.060  
2000 3.0 3.220  
2000 4.0 3.690  
2000 5.0 3.645  
2000 6.0 1.849  
2000 7.0 2.767  
2000 8.0 3.431  
2000 9.0 3.810  
2000 10. 2.370  
2000 10. 2.240  
2001 1.0 1.830  
2001 2.0 1.812  
2001 3.0 1.223  
2001 5.0 2.878  
2001 6.0 3.897  
2001 7.0 2.980  
2001 8.0 3.254  
2001 9.0 3.104  
2001 10. 4.001  
2001 11. 3.937  
2001 12. 2.794  
2002 1.0 2.047  
2002 2.0 2.479  
2002 3.0 2.011

2002 4.0 1.510  
2002 5.0 2.140  
2002 6.0 2.233  
2002 7.0 2.672  
2002 8.0 1.502  
2002 9.0 2.857  
2002 10. 3.410  
2002 11. 1.540  
2002 12. 3.550  
2003 1.0 2.330  
2003 2.0 2.540  
2003 3.0 1.960  
2003 4.0 1.940  
2003 5.0 2.180  
2003 6.0 3.150  
2003 7.0 1.340  
2003 8.0 3.860  
2003 9.0 3.490  
2003 10. 1.200  
2003 11. 3.850  
2003 12. 2.260  
2004 1.0 2.260  
2004 2.0 1.850  
2004 3.0 1.630  
2004 4.0 2.320  
2004 5.0 0.883  
2004 6.0 3.430  
2004 7.0 1.810  
2004 8.0 4.400  
2004 9.0 3.840  
2004 10. 4.200  
2004 11. 1.500  
2004 12. 0.940  
2005 1.0 0.556  
2005 2.0 1.990  
2005 3.0 1.690  
2005 4.0 2.160  
2005 5.0 2.620  
2005 6.0 3.300  
2005 7.0 2.660  
2005 8.0 4.420  
2005 9.0 4.370  
2005 10. 3.800  
2005 11. 4.220  
2005 12. 2.970  
2006 1.0 1.330  
2006 2.0 2.120  
2006 2.0 2.260  
2006 4.0 2.180  
2006 5.0 1.570  
2006 6.0 3.150  
2006 7.0 1.560  
2006 8.0 4.540  
2006 9.0 3.190

2006 10. 1.110  
2006 11. 1.990  
2006 12. 1.350  
2007 1.0 1.790  
2007 2.0 2.050  
2007 3.0 2.010  
2007 4.0 4.590  
2007 5.0 2.340  
2007 6.0 6.080  
2007 7.0 2.160  
2007 8.0 6.290  
2007 9.0 5.250  
2007 10. 2.360  
2007 11. 3.620  
2007 12. 2.020  
2008 1.0 1.300  
2008 2.0 3.670  
2008 3.0 1.920  
2008 4.0 1.950  
2008 5.0 2.880  
2008 6.0 2.230  
2008 7.0 2.450  
2008 8.0 4.930  
2008 9.0 2.090  
2008 10. 1.260  
2008 11. 3.180  
2008 12. 1.140  
2009 1.0 2.300  
2009 2.0 1.180  
2009 3.0 1.610  
2009 4.0 1.980  
2009 5.0 1.510  
2009 6.0 2.300  
2009 7.0 1.750  
2009 8.0 1.810  
2009 9.0 3.010  
2009 10. 1.550  
2009 11. 1.120  
2009 12. 2.030  
2010 1.0 1.350  
2010 2.0 1.280  
2010 3.0 1.200  
2010 4.0 1.470  
2010 5.0 1.290  
2010 6.0 2.410  
2010 7.0 1.250  
2010 8.0 2.670  
2010 9.0 3.380  
2010 10. 3.010  
2010 11. 2.820  
2010 12. 3.760  
2011 1.0 2.350  
2011 2.0 1.500  
2011 3.0 1.510

2011 4.0 2.470  
2011 5.0 1.490  
2011 6.0 2.290  
2011 7.0 2.160  
2011 8.0 2.810  
2011 9.0 3.250  
2011 10. 7.300  
2011 11. 3.070  
2011 12. 0.900  
2012 1.0 1.710  
2012 2.0 2.270  
2012 3.0 1.030  
2012 4.0 1.620  
2012 5.0 3.160  
2012 6.0 3.370  
2012 7.0 2.550  
2012 8.0 0.431  
2012 9.0 2.350  
2012 10. 6.600  
2012 11. 0.416  
2012 12. 0.720  
2013 1.0 2.600  
2013 2.0 1.990  
2013 3.0 2.160  
2013 4.0 2.290  
2013 5.0 4.070  
2013 6.0 2.200  
2013 7.0 2.320  
2013 8.0 1.930  
2013 9.0 3.850  
2013 10. 3.590  
2013 11. 2.400  
2013 12. 1.850  
2014 1.0 1.620  
2014 2.0 1.150  
2014 3.0 0.994  
2014 4.0 1.430  
2014 5.0 0.229  
2014 6.0 1.190  
2014 7.0 0.988  
2014 8.0 2.230  
2014 9.0 2.580  
2014 10. 3.240  
2014 11. 1.810  
2014 12. 2.320  
2015 1.0 1.380  
2015 2.0 1.330  
2015 3.0 1.210  
2015 4.0 0.998  
2015 5.0 1.350  
2015 6.0 1.760  
2015 7.0 1.590  
2015 8.0 1.930  
2015 8.0 0.643

2015 9.0 2.180  
2015 10. 2.400  
2015 11. 2.220  
2015 11. 2.000  
2016 1.0 1.640  
2016 2.0 1.770  
2016 3.0 1.470  
2016 4.0 1.530  
2016 5.0 0.589  
2016 6.0 1.400  
2016 7.0 2.360  
2016 8.0 1.100  
2016 9.0 2.700  
2016 10. 4.080  
2016 11. 0.669  
2016 12. 1.700  
2017 1.0 7.050  
2017 2.0 1.010  
2017 3.0 2.290  
2017 4.0 1.940  
2017 6.0 1.960  
2017 7.0 4.300  
2017 8.0 0.754  
2017 9.0 3.850  
2017 10. 6.450  
2017 11. 3.740  
2017 12. 4.730

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNO<sub>x</sub> WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is -0.353

$$S = -1181.$$

$$z = -8.385$$

$$p = 0.0000$$

$$p = 0.0001 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 3.414 + -0.8106E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DNOx WHI0065 1999-2017

1999 1.0 2.150  
1999 2.0 2.340  
1999 3.0 1.968  
1999 4.0 1.610  
1999 5.0 2.240  
1999 6.0 2.780  
1999 7.0 3.840  
1999 8.0 2.730  
1999 9.0 4.290  
1999 10. 4.460  
1999 11. 1.110  
1999 11. 4.430  
2000 1.0 2.590  
2000 2.0 3.060  
2000 3.0 3.220  
2000 4.0 3.690  
2000 5.0 3.645  
2000 6.0 1.849  
2000 7.0 2.767  
2000 8.0 3.431  
2000 9.0 3.810  
2000 10. 2.370  
2000 10. 2.240  
2001 1.0 1.830  
2001 2.0 1.812  
2001 3.0 1.223  
2001 5.0 2.878  
2001 6.0 3.897  
2001 7.0 2.980  
2001 8.0 3.254  
2001 9.0 3.104  
2001 10. 4.001  
2001 11. 3.937  
2001 12. 2.794  
2002 1.0 2.047  
2002 2.0 2.479  
2002 3.0 2.011  
2002 4.0 1.510  
2002 5.0 2.140  
2002 6.0 2.233  
2002 7.0 2.672  
2002 8.0 1.502  
2002 9.0 2.857  
2002 10. 3.410  
2002 11. 1.540  
2002 12. 3.550  
2003 1.0 2.330  
2003 2.0 2.540  
2003 3.0 1.960  
2003 4.0 1.940  
2003 5.0 2.180  
2003 6.0 3.150

2003 7.0 1.340  
2003 8.0 3.860  
2003 9.0 3.490  
2003 10. 1.200  
2003 11. 3.850  
2003 12. 2.260  
2004 1.0 2.260  
2004 2.0 1.850  
2004 3.0 1.630  
2004 4.0 2.320  
2004 5.0 0.883  
2004 6.0 3.430  
2004 7.0 1.810  
2004 8.0 4.400  
2004 9.0 3.840  
2004 10. 4.200  
2004 11. 1.500  
2004 12. 0.940  
2005 1.0 0.556  
2005 2.0 1.990  
2005 3.0 1.690  
2005 4.0 2.160  
2005 5.0 2.620  
2005 6.0 3.300  
2005 7.0 2.660  
2005 8.0 4.420  
2005 9.0 4.370  
2005 10. 3.800  
2005 11. 4.220  
2005 12. 2.970  
2006 1.0 1.330  
2006 2.0 2.120  
2006 2.0 2.260  
2006 4.0 2.180  
2006 5.0 1.570  
2006 6.0 3.150  
2006 7.0 1.560  
2006 8.0 4.540  
2006 9.0 3.190  
2006 10. 1.110  
2006 11. 1.990  
2006 12. 1.350  
2007 1.0 1.790  
2007 2.0 2.050  
2007 3.0 2.010  
2007 4.0 4.590  
2007 5.0 2.340  
2007 6.0 6.080  
2007 7.0 2.160  
2007 8.0 6.290  
2007 9.0 5.250  
2007 10. 2.360  
2007 11. 3.620  
2007 12. 2.020

2008 1.0 1.300  
2008 2.0 3.670  
2008 3.0 1.920  
2008 4.0 1.950  
2008 5.0 2.880  
2008 6.0 2.230  
2008 7.0 2.450  
2008 8.0 4.930  
2008 9.0 2.090  
2008 10. 1.260  
2008 11. 3.180  
2008 12. 1.140  
2009 1.0 2.300  
2009 2.0 1.180  
2009 3.0 1.610  
2009 4.0 1.980  
2009 5.0 1.510  
2009 6.0 2.300  
2009 7.0 1.750  
2009 8.0 1.810  
2009 9.0 3.010  
2009 10. 1.550  
2009 11. 1.120  
2009 12. 2.030  
2010 1.0 1.350  
2010 2.0 1.280  
2010 3.0 1.200  
2010 4.0 1.470  
2010 5.0 1.290  
2010 6.0 2.410  
2010 7.0 1.250  
2010 8.0 2.670  
2010 9.0 3.380  
2010 10. 3.010  
2010 11. 2.820  
2010 12. 3.760  
2011 1.0 2.350  
2011 2.0 1.500  
2011 3.0 1.510  
2011 4.0 2.470  
2011 5.0 1.490  
2011 6.0 2.290  
2011 7.0 2.160  
2011 8.0 2.810  
2011 9.0 3.250  
2011 10. 7.300  
2011 11. 3.070  
2011 12. 0.900  
2012 1.0 1.710  
2012 2.0 2.270  
2012 3.0 1.030  
2012 4.0 1.620  
2012 5.0 3.160  
2012 6.0 3.370

2012 7.0 2.550  
2012 8.0 0.431  
2012 9.0 2.350  
2012 10. 6.600  
2012 11. 0.416  
2012 12. 0.720  
2013 1.0 2.600  
2013 2.0 1.990  
2013 3.0 2.160  
2013 4.0 2.290  
2013 5.0 4.070  
2013 6.0 2.200  
2013 7.0 2.320  
2013 8.0 1.930  
2013 9.0 3.850  
2013 10. 3.590  
2013 11. 2.400  
2013 12. 1.850  
2014 1.0 1.620  
2014 2.0 1.150  
2014 3.0 0.994  
2014 4.0 1.430  
2014 5.0 0.229  
2014 6.0 1.190  
2014 7.0 0.988  
2014 8.0 2.230  
2014 9.0 2.580  
2014 10. 3.240  
2014 11. 1.810  
2014 12. 2.320  
2015 1.0 1.380  
2015 2.0 1.330  
2015 3.0 1.210  
2015 4.0 0.998  
2015 5.0 1.350  
2015 6.0 1.760  
2015 7.0 1.590  
2015 8.0 1.930  
2015 8.0 0.643  
2015 9.0 2.180  
2015 10. 2.400  
2015 11. 2.220  
2015 11. 2.000  
2016 1.0 1.640  
2016 2.0 1.770  
2016 3.0 1.470  
2016 4.0 1.530  
2016 5.0 0.589  
2016 6.0 1.400  
2016 7.0 2.360  
2016 8.0 1.100  
2016 9.0 2.700  
2016 10. 4.080  
2016 11. 0.669

2016 12. 1.700  
2017 1.0 7.050  
2017 2.0 1.010  
2017 3.0 2.290  
2017 4.0 1.940  
2017 6.0 1.960  
2017 7.0 4.300  
2017 8.0 0.754  
2017 9.0 3.850  
2017 10. 6.450  
2017 11. 3.740  
2017 12. 4.730

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNOx WHI0065 1999-2017

The record is 20 complete water years with 12 seasons per year beginning in water year 1999.

The tau correlation coefficient is -0.216

S = -416.

z = -4.376

p = 0.0000

p = 0.0101 adjusted for correlation among seasons  
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 2.743 + -0.5131E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1998.75  
(beginning of first water year)

2 0 DNOx 07060500 1993-2017

1993 1. 0.230  
1993 3. 0.210  
1993 4. 0.240  
1993 6. 0.370  
1993 8. 0.400  
1993 11 0.290  
1993 12 0.280  
1994 3. 0.310  
1994 4. 0.280  
1994 7. 0.240  
1994 8. 0.490  
1994 10 0.180  
1995 1. 0.290  
1995 2. 0.220  
1995 4. 0.200  
1995 7. 0.450  
1995 9. 0.430  
1995 10 0.170  
1995 11 0.100  
1996 2. 0.060  
1996 4. 0.050  
1996 6. 0.140  
1996 8. 0.240  
1996 10 0.320  
1996 12 0.220  
1997 2. 0.280  
1997 4. 0.200  
1997 7. 0.410  
1997 8. 0.480  
1997 11 0.220  
1998 1. 0.400  
1998 3. 0.350  
1998 4. 0.230  
1998 6. 0.340  
1998 8. 0.290  
1998 11 0.100  
1999 1. 0.310  
1999 3. 0.240  
1999 6. 0.340  
1999 7. 0.410  
1999 9. 0.450  
1999 11 0.170  
2000 1. 0.180  
2000 3. 0.040  
2000 5. 0.030  
2000 7. 0.150  
2000 8. 0.210  
2000 11 0.180  
2001 1. 0.190  
2001 3. 0.150  
2001 5. 0.100  
2001 8. 0.170

2001 10 0.180  
2001 12 0.250  
2002 2. 0.190  
2002 4. 0.220  
2002 6. 0.330  
2002 8. 0.440  
2002 10 0.360  
2002 12 0.220  
2003 3. 0.150  
2003 5. 0.160  
2003 7. 0.280  
2003 8. 0.310  
2003 11 0.220  
2004 1. 0.170  
2004 2. 0.160  
2004 4. 0.110  
2004 6. 0.260  
2004 8. 0.350  
2004 10 0.400  
2005 1. 0.230  
2005 3. 0.270  
2005 4. 0.320  
2005 6. 0.310  
2005 8. 0.340  
2005 10 0.230  
2006 1. 0.130  
2006 3. 0.080  
2006 5. 0.190  
2006 7. 0.170  
2006 8. 0.200  
2006 11 0.260  
2007 1. 0.250  
2007 3. 0.130  
2007 4. 0.170  
2007 6. 0.210  
2007 8. 0.300  
2007 11 0.210  
2007 12 0.540  
2008 2. 0.450  
2008 4. 0.300  
2008 6. 0.410  
2008 8. 0.670  
2008 10 0.590  
2008 12 0.290  
2009 1. 0.320  
2009 3. 0.250  
2009 4. 0.200  
2009 8. 0.410  
2009 11 0.590  
2010 2. 0.330  
2010 3. 0.390  
2010 6. 0.420  
2010 8. 0.380  
2010 10 0.260

2010 12 0.250  
2011 2. 0.180  
2011 4. 0.170  
2011 6. 0.240  
2011 8. 0.450  
2011 10 0.231  
2012 2. 0.443  
2012 6. 0.313  
2012 8. 0.351  
2012 11 0.292  
2013 3. 0.384  
2013 5. 0.133  
2013 9. 0.348  
2013 11 0.178  
2014 3. 0.214  
2014 4. 0.273  
2014 7. 0.320  
2014 11 0.338  
2015 3. 0.383  
2015 5. 0.181  
2015 12 0.295  
2016 3. 0.359  
2016 5. 0.168  
2016 8. 0.422  
2016 11 0.220  
2017 2. 0.118  
2017 5. 0.369  
2017 8. 0.443  
2017 11 0.186

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNOx 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.138

$$S = 111.$$

$$z = 2.010$$

$$p = 0.0445$$

$$p = 0.2247 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.2096 + 0.3107E-02 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 DNOx 07060710 1993-2017

1993 1. 0.380  
1993 3. 0.240  
1993 4. 0.057  
1993 5. 0.072  
1993 6. 0.059  
1993 7. 0.053  
1993 8. 0.050  
1993 9. 0.057  
1993 10 0.110  
1993 12 0.065  
1993 12 0.180  
1994 1. 0.120  
1994 2. 0.055  
1994 3. 0.078  
1994 5. 0.055  
1994 6. 0.050  
1994 7. 0.050  
1994 8. 0.050  
1994 8. 0.056  
1994 10 0.050  
1994 11 0.070  
1994 12 0.060  
1995 1. 0.070  
1995 2. 0.070  
1995 3. 0.250  
1995 3. 0.060  
1995 4. 0.070  
1995 5. 0.050  
1995 6. 0.050  
1995 7. 0.050  
1995 8. 0.050  
1995 10 0.050  
1995 11 0.060  
1996 1. 0.050  
1996 2. 0.050  
1996 4. 0.050  
1996 5. 0.070  
1996 6. 0.070  
1996 7. 0.110  
1996 8. 0.080  
1996 9. 0.100  
1996 10 0.080  
1997 2. 0.060  
1997 4. 0.080  
1997 5. 0.050  
1997 6. 0.070  
1997 7. 0.050  
1997 8. 0.070  
1997 9. 0.060  
1997 10 0.050  
1997 11 0.060  
1997 12 0.050

1998 1. 0.170  
1998 2. 0.050  
1998 3. 0.090  
1998 4. 0.050  
1998 5. 0.050  
1998 6. 0.050  
1998 7. 0.050  
1998 8. 0.050  
1998 9. 0.050  
1998 10 0.070  
1998 11 0.060  
1998 12 0.060  
1999 1. 0.070  
1999 2. 0.050  
1999 3. 0.080  
1999 4. 0.080  
1999 5. 0.060  
1999 6. 0.100  
1999 7. 0.060  
1999 9. 0.100  
1999 10 0.050  
1999 11 0.050  
1999 12 0.050  
2000 1. 0.050  
2000 2. 0.050  
2000 3. 0.050  
2000 4. 0.050  
2000 5. 0.060  
2000 6. 0.080  
2000 7. 0.050  
2000 8. 0.050  
2000 9. 0.050  
2000 10 0.040  
2000 11 0.090  
2000 12 0.070  
2001 2. 0.070  
2001 3. 0.070  
2001 4. 0.030  
2001 5. 0.100  
2001 6. 0.050  
2001 7. 0.060  
2001 8. 0.030  
2001 9. 0.060  
2001 11 0.040  
2001 12 0.100  
2002 1. 0.100  
2002 2. 0.060  
2002 3. 0.070  
2002 5. 0.070  
2002 7. 0.080  
2002 9. 0.070  
2002 11 0.060  
2002 12 0.040  
2003 1. 0.070

2003 2. 0.050  
2003 3. 0.070  
2003 5. 0.060  
2003 7. 0.120  
2003 9. 0.100  
2003 11 0.030  
2003 12 0.070  
2004 1. 0.070  
2004 2. 0.070  
2004 3. 0.040  
2004 5. 0.060  
2004 7. 0.050  
2004 8. 0.040  
2004 11 0.070  
2005 1. 0.270  
2005 3. 0.040  
2005 5. 0.040  
2005 7. 0.060  
2005 9. 0.070  
2005 11 0.060  
2006 1. 0.040  
2006 3. 0.060  
2006 5. 0.040  
2006 6. 0.048  
2006 7. 0.054  
2006 9. 0.040  
2007 2. 0.054  
2007 3. 0.035  
2007 5. 0.025  
2007 5. 0.014  
2007 6. 0.025  
2007 7. 0.026  
2007 8. 0.037  
2007 9. 0.044  
2007 10 0.038  
2007 12 0.160  
2008 1. 0.070  
2008 2. 0.080  
2008 5. 0.030  
2008 6. 0.040  
2008 9. 0.040  
2009 3. 0.040  
2009 4. 0.030  
2009 6. 0.070  
2009 8. 0.080  
2009 11 0.150  
2010 2. 0.130  
2010 3. 0.140  
2010 6. 0.130  
2010 8. 0.060  
2010 10 0.060  
2010 12 0.060  
2011 2. 0.050  
2011 4. 0.090

2011 6. 0.060  
2011 8. 0.080  
2011 10 0.060  
2011 12 0.137  
2012 2. 0.160  
2012 4. 0.051  
2012 6. 0.058  
2012 8. 0.070  
2012 11 0.030  
2013 1. 0.060  
2013 3. 0.080  
2013 5. 0.040  
2013 7. 0.080  
2013 9. 0.040  
2013 11 0.030  
2014 3. 0.080  
2014 4. 0.050  
2014 5. 0.030  
2014 7. 0.040  
2014 9. 0.100  
2014 11 0.060  
2015 1. 0.050  
2015 3. 0.090  
2015 5. 0.040  
2015 7. 0.030  
2015 10 0.060  
2015 11 0.060  
2015 12 0.070  
2016 1. 0.060  
2016 1. 0.040  
2016 2. 0.040  
2016 2. 0.020  
2016 3. 0.030  
2016 4. 0.020  
2016 4. 0.070  
2016 5. 0.040  
2016 5. 0.050  
2016 7. 0.050  
2016 7. 0.060  
2016 8. 0.090  
2016 9. 0.080  
2016 10 0.070  
2016 11 0.050  
2016 12 0.060  
2017 1. 0.060  
2017 3. 0.050  
2017 3. 0.150  
2017 4. 0.110  
2017 5. 0.130  
2017 6. 0.060  
2017 6. 0.100  
2017 7. 0.070  
2017 8. 0.080  
2017 9. 0.090

2017 10 0.100  
2017 10 0.050  
2017 11 0.030  
2017 11 0.040

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: DNOx 07060710 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is -0.072

$$S = -121.$$

$$z = -1.406$$

$$p = 0.1597$$

$$p = 0.3220 \text{ adjusted for correlation among seasons} \\ \text{(such as serial dependence)}$$

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.6000E-01 + 0.000 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

# **ATTACHMENT 4**

---

**Total Nitrogen Seasonal Mann-Kendall Input and Output**

2 0 TN WHI0011 2000-2017

2000 1. 0.8580  
2000 2. 0.9390  
2000 3. 0.6500  
2000 5. 1.2910  
2000 6. 1.2540  
2000 8. 0.4700  
2000 8. 0.1380  
2000 9. 0.0930  
2000 10 0.4890  
2000 11 1.1350  
2000 12 1.4630  
2001 1. 1.6400  
2001 2. 1.5280  
2001 3. 1.1630  
2001 4. 0.8930  
2001 5. 0.7790  
2001 6. 0.5670  
2001 7. 0.3110  
2001 8. 0.2430  
2001 9. 0.3530  
2001 10 0.5970  
2001 11 0.4750  
2001 12 1.0650  
2002 2. 0.8790  
2002 3. 1.7160  
2002 4. 0.6000  
2002 5. 0.7530  
2002 6. 0.8550  
2002 7. 0.8400  
2002 8. 0.2450  
2002 9. 0.3760  
2002 10 0.3830  
2002 11 0.6620  
2002 12 1.4320  
2003 1. 0.4120  
2003 4. 0.6690  
2003 4. 0.7360  
2003 5. 0.6180  
2003 6. 0.7910  
2003 7. 0.8870  
2003 8. 0.7530  
2003 9. 0.6490  
2003 10 0.7070  
2003 11 0.9820  
2003 12 0.9960  
2004 1. 0.9900  
2004 2. 0.6330  
2004 3. 0.8800  
2004 5. 0.6460  
2004 6. 0.5800  
2004 7. 0.4850  
2004 8. 0.3900

2004 9. 0.1500  
2004 10 1.2200  
2004 11 0.9970  
2004 12 1.0500  
2005 1. 1.0300  
2005 2. 0.7410  
2005 3. 0.5230  
2005 4. 0.5910  
2005 5. 0.4860  
2005 5. 0.6530  
2005 7. 0.3500  
2005 8. 0.2990  
2005 9. 0.7140  
2005 11 1.0900  
2005 12 0.7160  
2006 1. 1.0800  
2006 2. 0.5060  
2006 3. 0.5980  
2006 4. 0.4630  
2006 5. 0.7310  
2006 6. 0.4380  
2006 7. 0.2890  
2006 8. 0.1590  
2006 9. 0.1650  
2006 10 1.2800  
2006 11 1.0100  
2006 12 0.9560  
2007 1. 0.9030  
2007 2. 1.1300  
2007 3. 0.7910  
2007 4. 0.4260  
2007 5. 0.3240  
2007 6. 0.2950  
2007 7. 0.5910  
2007 8. 0.3740  
2007 9. 0.7600  
2007 10 0.5500  
2007 11 0.4130  
2007 12 0.6870  
2008 1. 1.0100  
2008 2. 1.2600  
2008 3. 1.1100  
2008 4. 0.7700  
2008 5. 0.4990  
2008 6. 0.6290  
2008 7. 0.4110  
2008 8. 0.3700  
2008 9. 1.3000  
2008 10 0.6650  
2008 11 0.7840  
2009 1. 0.7370  
2009 2. 0.7760  
2009 3. 0.4580  
2009 4. 0.6770

2009 5. 0.6100  
2009 6. 0.6700  
2009 7. 0.4850  
2009 8. 0.4690  
2009 9. 1.0700  
2009 10 1.0400  
2009 11 0.8150  
2009 12 0.4900  
2010 1. 0.7780  
2010 2. 0.6140  
2010 3. 0.7900  
2010 4. 0.7660  
2010 5. 0.7100  
2010 6. 0.7280  
2010 7. 0.4780  
2010 8. 0.4420  
2010 9. 0.3720  
2010 10 0.6300  
2010 11 0.4750  
2010 12 0.6500  
2011 1. 0.5920  
2011 2. 0.9010  
2011 3. 1.2300  
2011 4. 1.0800  
2011 5. 0.8110  
2011 6. 0.5000  
2011 7. 0.4230  
2011 8. 0.3840  
2011 9. 0.3450  
2011 10 0.4000  
2011 11 0.4160  
2011 12 1.2300  
2012 1. 0.9190  
2012 2. 0.9050  
2012 3. 0.7830  
2012 4. 0.5310  
2012 5. 0.5460  
2012 6. 0.5370  
2012 7. 0.2490  
2012 8. 0.1830  
2012 9. 0.3160  
2012 10 0.5210  
2012 11 0.3550  
2012 12 0.5780  
2013 1. 1.5200  
2013 2. 1.0900  
2013 3. 1.3000  
2013 4. 0.5510  
2013 5. 0.4050  
2013 6. 1.1800  
2013 7. 0.5270  
2013 8. 1.0400  
2013 9. 0.6240  
2013 10 0.7460

2013 11 0.7240  
2013 12 0.7330  
2014 1. 1.3900  
2014 2. 0.9370  
2014 3. 1.0500  
2014 4. 0.9500  
2014 5. 0.8690  
2014 6. 0.8330  
2014 7. 0.7100  
2014 8. 0.6240  
2014 9. 0.6650  
2014 10 0.7340  
2014 11 0.5280  
2014 12 0.6590  
2015 1. 1.8200  
2015 2. 0.8660  
2015 3. 0.7110  
2015 4. 0.9390  
2015 5. 0.6070  
2015 6. 0.8150  
2015 7. 0.7190  
2015 8. 0.5670  
2015 9. 0.3380  
2015 10 0.5340  
2015 11 0.8450  
2016 1. 1.1400  
2016 2. 0.5180  
2016 3. 0.4740  
2016 4. 0.4140  
2016 5. 0.6940  
2016 6. 0.7020  
2016 7. 0.7300  
2016 8. 1.2900  
2016 9. 0.6940  
2016 10 0.8340  
2016 11 1.0600  
2016 12 0.8860  
2017 1. 0.8810  
2017 2. 0.6570  
2017 3. 0.9620  
2017 4. 0.6960  
2017 6. 0.8910  
2017 7. 0.6700  
2017 8. 0.4320  
2017 9. 0.6710  
2017 10 0.5060  
2017 11 0.3910  
2017 12 0.4680

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TN WHI0011 2000-2017

The record is 19 complete water years with 12 seasons per year beginning in water year 2000.

The tau correlation coefficient is 0.001

$$S = 1.$$

$$z = 0.000$$

$$p = 1.0000$$

$$p = 1.0000 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.6940 + 0.000 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

2 0 TN WHI0029 2000-2017

2000 1. 0.4320  
2000 2. 0.6680  
2000 3. 0.3970  
2000 6. 0.9600  
2000 8. 0.5690  
2000 8. 0.3180  
2000 9. 0.4040  
2000 10 0.3340  
2000 11 0.3420  
2000 12 0.5200  
2001 1. 0.4000  
2001 2. 0.4260  
2001 3. 1.0570  
2001 4. 0.5800  
2001 5. 0.3510  
2001 6. 0.3880  
2001 7. 0.3560  
2001 8. 0.1850  
2001 9. 0.3610  
2001 10 0.4080  
2001 11 0.4190  
2001 12 0.5540  
2002 1. 0.6850  
2002 2. 0.6090  
2002 3. 0.5750  
2002 5. 0.5470  
2002 6. 1.0060  
2002 7. 0.7730  
2002 8. 0.5400  
2002 9. 0.6660  
2002 10 0.7470  
2002 11 0.6140  
2002 12 0.8930  
2003 3. 0.5720  
2003 4. 0.5590  
2003 4. 0.4720  
2003 5. 0.3870  
2003 6. 0.5890  
2003 7. 0.5460  
2003 8. 0.5440  
2003 9. 0.5580  
2003 10 0.5590  
2003 11 0.9580  
2003 12 0.4930  
2004 1. 0.4360  
2004 2. 0.4030  
2004 3. 0.6700  
2004 5. 0.5600  
2004 6. 0.4650  
2004 7. 0.6060  
2004 8. 0.5100  
2004 9. 0.5030

2004 10 0.5230  
2004 11 0.7110  
2004 12 0.4770  
2005 1. 0.5010  
2005 2. 0.5420  
2005 3. 0.7110  
2005 4. 0.6620  
2005 5. 0.4680  
2005 7. 0.5040  
2005 8. 0.5700  
2005 9. 0.5290  
2005 11 0.3940  
2005 12 0.4760  
2006 1. 0.3620  
2006 2. 0.3370  
2006 3. 0.3490  
2006 4. 0.3460  
2006 5. 0.3580  
2006 6. 0.2120  
2006 7. 0.4090  
2006 8. 0.4080  
2006 9. 0.2970  
2006 10 0.4220  
2006 11 0.5430  
2006 12 0.6540  
2007 1. 0.4270  
2007 2. 0.9280  
2007 3. 0.5230  
2007 4. 0.3660  
2007 5. 0.3670  
2007 6. 0.2950  
2007 7. 0.4200  
2007 8. 0.4050  
2007 9. 0.7360  
2007 10 0.4450  
2007 11 0.5310  
2007 12 0.4520  
2008 1. 0.4390  
2008 2. 0.9290  
2008 3. 0.4680  
2008 4. 0.6340  
2008 5. 0.5130  
2008 6. 0.5850  
2008 7. 0.6810  
2008 8. 0.7930  
2008 9. 0.9700  
2008 10 0.6770  
2008 11 0.6420  
2009 1. 0.4590  
2009 2. 0.5020  
2009 3. 0.7110  
2009 4. 0.5990  
2009 5. 0.5340  
2009 6. 0.4580

2009 7. 0.5530  
2009 8. 0.5840  
2009 9. 0.8410  
2009 10 0.8270  
2009 11 0.6290  
2009 12 0.4190  
2010 1. 0.5270  
2010 2. 0.6020  
2010 3. 0.6990  
2010 4. 0.6550  
2010 5. 0.4350  
2010 6. 0.6270  
2010 7. 0.7030  
2010 8. 0.6210  
2010 9. 0.9050  
2010 10 0.5800  
2010 10 0.4840  
2010 11 0.5470  
2010 11 0.5920  
2011 1. 0.4320  
2011 2. 0.6350  
2011 3. 0.6320  
2011 4. 0.9940  
2011 5. 0.7500  
2011 6. 0.6120  
2011 7. 0.6090  
2011 8. 0.6160  
2011 9. 0.7940  
2011 11 0.4930  
2011 12 0.5370  
2012 1. 0.8580  
2012 2. 0.3660  
2012 3. 0.6220  
2012 4. 0.5820  
2012 5. 0.8500  
2012 6. 0.6090  
2012 7. 0.4660  
2012 8. 0.4500  
2012 9. 0.4900  
2012 10 0.3720  
2012 11 0.3850  
2012 12 0.4190  
2013 1. 0.5740  
2013 2. 0.5610  
2013 3. 0.6030  
2013 4. 0.4230  
2013 5. 0.3530  
2013 6. 0.4730  
2013 7. 0.5970  
2013 8. 0.5340  
2013 9. 0.5630  
2013 10 0.4950  
2013 11 0.4500  
2013 12 0.4210

2014 1. 0.5850  
2014 2. 0.4610  
2014 3. 0.5530  
2014 4. 0.5460  
2014 5. 0.3480  
2014 6. 0.6340  
2014 7. 0.5010  
2014 8. 0.4290  
2014 9. 0.5070  
2014 10 0.5880  
2014 11 0.3950  
2014 12 0.4220  
2015 1. 0.4720  
2015 2. 0.4420  
2015 3. 0.8860  
2015 4. 0.3010  
2015 5. 0.3680  
2015 6. 0.5690  
2015 7. 0.6160  
2015 8. 0.5580  
2015 9. 0.7500  
2015 10 0.6510  
2015 11 0.6820  
2015 11 0.6650  
2015 12 0.6340  
2016 1. 0.5590  
2016 2. 0.6810  
2016 3. 0.5650  
2016 4. 0.5230  
2016 5. 0.6990  
2016 6. 0.5030  
2016 7. 0.5600  
2016 8. 0.5250  
2016 9. 0.6790  
2016 10 2.5900  
2016 11 0.5090  
2016 11 11.309  
2016 11 0.8780  
2016 11 1.7500  
2016 11 12.550  
2016 11 2.1190  
2016 11 0.4050  
2016 11 11.205  
2016 11 0.7740  
2016 12 0.4110  
2017 1. 0.4560  
2017 2. 0.4790  
2017 3. 0.3910  
2017 4. 0.6210  
2017 5. 0.6580  
2017 6. 0.4740  
2017 7. 0.4430  
2017 8. 0.5970  
2017 9. 0.5910

2017 10 0.5100  
2017 11 0.4710  
2017 12 0.3230

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TN WHI0029 2000-2017

The record is 19 complete water years with 12 seasons per year beginning in water year 2000.

The tau correlation coefficient is 0.053

$$S = 86.$$

$$z = 1.007$$

$$p = 0.3140$$

$$p = 0.5829 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.5189 + 0.1750E-02 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

2 0 TN WHI0046 2000-2017

2000 1. 0.4260  
2000 3. 0.1290  
2000 4. 0.2010  
2000 5. 0.7980  
2000 6. 0.6990  
2000 7. 0.2030  
2000 8. 0.2680  
2000 10 0.3160  
2000 10 0.2550  
2001 1. 0.3090  
2001 2. 0.4080  
2001 3. 0.3900  
2001 5. 0.4140  
2001 6. 1.4670  
2001 7. 0.4160  
2001 8. 0.5620  
2001 9. 0.3440  
2001 10 0.4640  
2001 11 0.6130  
2001 12 0.5520  
2002 1. 0.7690  
2002 2. 0.6810  
2002 3. 0.3720  
2002 4. 0.6460  
2002 5. 0.5500  
2002 6. 0.5090  
2002 7. 0.7980  
2002 8. 0.6390  
2002 9. 0.7830  
2002 10 0.6450  
2002 11 1.0680  
2002 12 0.4350  
2003 1. 0.6360  
2003 2. 0.4570  
2003 3. 0.5760  
2003 4. 0.4430  
2003 5. 0.3510  
2003 6. 0.5080  
2003 7. 0.5360  
2003 8. 0.6890  
2003 9. 0.7390  
2003 10 1.4870  
2003 12 0.4760  
2004 1. 0.3280  
2004 2. 0.4370  
2004 3. 0.4640  
2004 4. 0.3440  
2004 5. 0.3910  
2004 6. 0.4690  
2004 7. 0.5280  
2004 8. 0.7270  
2004 9. 0.5230

2004 10 0.6720  
2004 11 0.7240  
2004 12 0.5280  
2005 1. 1.1200  
2005 2. 0.6120  
2005 3. 0.4480  
2005 4. 0.4780  
2005 5. 0.5320  
2005 6. 0.6920  
2005 7. 0.5880  
2005 8. 0.5570  
2005 9. 0.5630  
2005 10 0.6890  
2005 11 0.3780  
2005 12 0.6500  
2006 1. 0.3270  
2006 2. 0.4720  
2006 2. 0.2210  
2006 4. 0.5380  
2006 5. 0.6430  
2006 6. 0.6170  
2006 7. 0.4260  
2006 8. 0.4970  
2006 9. 0.4100  
2006 10 0.5950  
2006 11 0.6470  
2006 12 0.6400  
2007 1. 0.5710  
2007 2. 0.4260  
2007 3. 0.3610  
2007 4. 0.4140  
2007 5. 0.2840  
2007 6. 0.4700  
2007 7. 0.4410  
2007 8. 0.5260  
2007 9. 1.1400  
2007 10 0.5950  
2007 11 0.4430  
2007 12 0.4100  
2008 1. 0.4430  
2008 2. 0.5130  
2008 3. 0.6470  
2008 4. 0.5540  
2008 5. 0.7430  
2008 6. 0.6050  
2008 7. 0.6880  
2008 8. 0.8780  
2008 9. 0.9420  
2008 10 0.8260  
2008 11 0.6210  
2008 12 0.5660  
2009 1. 0.4440  
2009 2. 0.3910  
2009 3. 0.4960

2009 4. 0.4380  
2009 5. 0.5970  
2009 6. 0.5380  
2009 7. 0.6640  
2009 8. 0.7120  
2009 9. 0.6760  
2009 10 0.6660  
2009 11 0.5440  
2009 12 0.4770  
2010 1. 0.6200  
2010 2. 0.6660  
2010 3. 0.5900  
2010 4. 0.7860  
2010 5. 0.6020  
2010 6. 0.6760  
2010 7. 0.7400  
2010 8. 0.7750  
2010 9. 0.8240  
2010 10 0.7930  
2010 11 0.6530  
2010 12 0.5050  
2011 1. 0.4640  
2011 2. 0.3830  
2011 3. 0.5640  
2011 4. 0.4860  
2011 5. 0.7940  
2011 6. 0.5590  
2011 7. 0.5480  
2011 8. 1.0100  
2011 9. 0.7250  
2011 10 0.7900  
2011 11 0.5650  
2011 12 0.8530  
2012 1. 0.5710  
2012 2. 0.6800  
2012 3. 0.5750  
2012 4. 0.5460  
2012 5. 0.4960  
2012 6. 0.6590  
2012 7. 0.5550  
2012 8. 0.4580  
2012 9. 0.6390  
2012 10 0.5920  
2012 11 0.7460  
2012 12 0.5030  
2013 1. 0.4520  
2013 2. 0.4550  
2013 3. 0.4060  
2013 4. 0.4440  
2013 5. 0.2600  
2013 6. 0.4540  
2013 7. 0.4920  
2013 8. 0.8750  
2013 9. 0.6460

2013 10 0.6210  
2013 11 0.6850  
2013 12 0.5430  
2014 1. 0.5050  
2014 2. 0.4720  
2014 3. 0.8450  
2014 4. 0.5830  
2014 5. 0.4640  
2014 6. 0.5410  
2014 7. 0.4780  
2014 8. 0.4900  
2014 9. 0.6910  
2014 10 0.6250  
2014 11 0.4950  
2014 12 0.4170  
2015 1. 1.0000  
2015 2. 0.4680  
2015 3. 0.6970  
2015 4. 0.4590  
2015 5. 0.4090  
2015 6. 0.4800  
2015 7. 0.5730  
2015 8. 0.5830  
2015 9. 0.8660  
2015 10 0.8890  
2015 11 0.5230  
2016 1. 0.8410  
2016 2. 0.5340  
2016 3. 0.4520  
2016 4. 0.3830  
2016 5. 0.3830  
2016 6. 0.6080  
2016 7. 0.5750  
2016 8. 0.4640  
2016 9. 0.6790  
2016 10 0.7430  
2016 11 0.4660  
2016 12 0.3710  
2017 1. 0.3750  
2017 2. 0.4380  
2017 3. 0.5440  
2017 4. 0.3820  
2017 6. 0.5080  
2017 7. 0.4840  
2017 8. 0.5710  
2017 9. 0.8970  
2017 10 0.3660  
2017 11 0.2560  
2017 12 0.2930

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TN WHI0046 2000-2017

The record is 19 complete water years with 12 seasons per year beginning in water year 2000.

The tau correlation coefficient is 0.023

$$S = 38.$$

$$z = 0.430$$

$$p = 0.6674$$

$$p = 0.7588 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.5333 + 0.1333E-02 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

2 0 TN WHI0065 2000-2017

2000 1. 3.5770  
2000 3. 3.3850  
2000 4. 4.5100  
2000 5. 4.2560  
2000 6. 2.1380  
2000 7. 2.9780  
2000 8. 4.2460  
2000 10 2.9540  
2000 10 2.6810  
2001 1. 2.5400  
2001 2. 1.9920  
2001 3. 1.5230  
2001 5. 3.5460  
2001 6. 6.3870  
2001 7. 3.5460  
2001 8. 3.9000  
2001 9. 3.4140  
2001 10 4.5650  
2001 11 4.5890  
2001 12 3.0070  
2002 2. 2.5780  
2002 4. 1.8680  
2002 5. 2.7000  
2002 6. 3.0960  
2002 7. 3.8810  
2002 8. 2.3320  
2002 9. 3.9230  
2002 10 4.1860  
2002 11 2.3680  
2003 4. 2.4040  
2003 6. 3.8530  
2003 7. 2.1150  
2003 9. 4.1700  
2003 10 1.8310  
2003 11 4.5300  
2003 12 2.4530  
2004 1. 2.5570  
2004 2. 2.4060  
2004 3. 1.7660  
2004 4. 2.7230  
2004 5. 1.0230  
2004 6. 3.8500  
2004 7. 2.2900  
2004 8. 5.2300  
2004 9. 4.3400  
2004 10 4.9500  
2004 11 2.0200  
2004 12 1.3000  
2005 1. 1.2300  
2005 2. 2.3300  
2005 3. 2.0800  
2005 4. 2.1600

2005 5. 3.0400  
2005 6. 4.1000  
2005 7. 3.4800  
2005 8. 5.3000  
2005 9. 5.0500  
2005 10 4.2500  
2005 11 4.6000  
2005 12 4.8100  
2006 1. 1.8700  
2006 2. 2.4900  
2006 2. 2.7000  
2006 4. 2.9200  
2006 5. 2.1000  
2006 6. 4.0800  
2006 7. 2.2500  
2006 8. 5.1200  
2006 9. 3.8400  
2006 10 1.5400  
2006 11 2.3200  
2006 12 1.6100  
2007 1. 1.9600  
2007 2. 2.4500  
2007 3. 2.3100  
2007 4. 6.1000  
2007 5. 2.8900  
2007 6. 6.6500  
2007 7. 2.5300  
2007 8. 7.0000  
2007 9. 6.0500  
2007 10 2.8900  
2007 11 4.1450  
2007 12 2.1000  
2008 1. 1.6200  
2008 2. 4.2600  
2008 3. 2.1100  
2008 4. 2.2400  
2008 5. 3.3500  
2008 6. 2.7800  
2008 7. 2.8300  
2008 8. 5.2000  
2008 9. 2.8400  
2008 10 1.5000  
2008 11 3.8000  
2008 12 1.6700  
2009 1. 2.7500  
2009 2. 1.5700  
2009 3. 2.2400  
2009 4. 2.6300  
2009 5. 1.8400  
2009 6. 2.7800  
2009 7. 2.0200  
2009 8. 2.4000  
2009 9. 3.4800  
2009 10 1.8700

2009 11 1.5000  
2009 12 2.6000  
2010 1. 1.8800  
2010 2. 1.6000  
2010 3. 1.6900  
2010 4. 1.9200  
2010 5. 1.7900  
2010 6. 2.9500  
2010 7. 1.7900  
2010 8. 3.4400  
2010 9. 4.0400  
2010 10 3.7500  
2010 11 3.5900  
2010 12 4.4850  
2011 1. 3.2900  
2011 2. 1.9500  
2011 3. 1.8900  
2011 4. 3.1700  
2011 5. 2.0000  
2011 6. 2.7600  
2011 7. 2.8200  
2011 8. 3.5700  
2011 9. 3.7300  
2011 10 7.7500  
2011 11 3.8200  
2011 12 1.3000  
2012 1. 2.3300  
2012 2. 2.6000  
2012 3. 1.5600  
2012 4. 2.0300  
2012 5. 4.1350  
2012 6. 3.8350  
2012 7. 3.8500  
2012 8. 0.5550  
2012 9. 2.9400  
2012 10 7.5000  
2012 11 0.6720  
2012 12 1.3000  
2013 1. 3.3900  
2013 2. 2.2000  
2013 3. 2.4800  
2013 4. 2.7600  
2013 5. 4.6850  
2013 6. 2.6700  
2013 7. 2.9600  
2013 8. 2.2400  
2013 9. 4.4500  
2013 10 4.2350  
2013 11 3.1300  
2013 12 2.4100  
2014 1. 1.9200  
2014 2. 1.6900  
2014 3. 1.4100  
2014 4. 2.0600

2014 5. 0.4820  
2014 6. 1.9600  
2014 7. 1.4200  
2014 8. 2.8600  
2014 9. 3.3800  
2014 10 3.8100  
2014 11 2.4600  
2014 12 3.0300  
2015 1. 1.7500  
2015 2. 2.0000  
2015 3. 1.5700  
2015 4. 1.6100  
2015 5. 1.7800  
2015 6. 2.1700  
2015 7. 2.0600  
2015 8. 2.3350  
2015 8. 3.9830  
2015 9. 3.2200  
2015 10 3.5400  
2015 11 2.9000  
2015 11 2.5700  
2016 1. 1.8000  
2016 2. 2.4500  
2016 3. 1.9340  
2016 4. 1.7800  
2016 5. 1.0600  
2016 6. 1.8200  
2016 7. 2.7600  
2016 8. 1.4500  
2016 9. 2.7000  
2016 10 4.5450  
2016 11 1.2000  
2016 12 2.1500  
2017 1. 8.0500  
2017 2. 1.5300  
2017 3. 2.4800  
2017 4. 2.5700  
2017 6. 2.3100  
2017 7. 4.5300  
2017 8. 1.2900  
2017 9. 8.2500  
2017 10 7.2500  
2017 11 4.2700  
2017 12 5.8000

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TN WHI0065 2000-2017

The record is 19 complete water years with 12 seasons per year beginning in water year 2000.

The tau correlation coefficient is -0.163

$$S = -257.$$

$$z = -3.119$$

$$p = 0.0018$$

$$p = 0.0335 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 3.136 + -0.4750E-01 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

2 0 TN 07060500 2000-2017

2000 1. 0.400  
2000 3. 0.240  
2000 5. 0.230  
2000 7. 0.350  
2000 8. 0.430  
2000 11 0.660  
2001 1. 0.490  
2001 3. 0.370  
2001 5. 0.330  
2001 8. 0.370  
2001 10 0.480  
2001 12 0.450  
2002 2. 0.590  
2002 4. 0.420  
2002 6. 0.830  
2002 8. 0.640  
2002 10 0.660  
2002 12 0.620  
2003 3. 0.350  
2003 5. 0.360  
2003 7. 0.480  
2003 8. 0.510  
2003 11 0.620  
2004 1. 0.470  
2004 2. 0.360  
2004 4. 0.310  
2004 6. 0.460  
2004 8. 0.570  
2004 10 0.590  
2005 1. 0.410  
2005 3. 0.450  
2005 4. 0.560  
2005 6. 0.550  
2005 8. 0.540  
2005 10 0.410  
2006 1. 0.400  
2006 3. 0.300  
2006 5. 0.380  
2006 7. 0.420  
2006 8. 0.410  
2006 11 0.520  
2007 1. 0.460  
2007 3. 0.320  
2007 4. 0.320  
2007 6. 0.440  
2007 8. 0.540  
2007 11 0.390  
2007 12 0.770  
2008 2. 0.660  
2008 4. 0.580  
2008 6. 0.610  
2008 8. 0.870

2008 10 0.790  
2008 12 0.500  
2009 1. 0.500  
2009 3. 0.430  
2009 4. 0.400  
2009 8. 0.650  
2009 11 0.770  
2010 2. 0.480  
2010 3. 0.580  
2010 6. 0.620  
2010 8. 0.610  
2010 10 0.520  
2010 12 0.470  
2011 2. 0.350  
2011 4. 0.600  
2011 6. 0.440  
2011 8. 0.600  
2011 10 0.540  
2012 2. 0.560  
2012 6. 0.540  
2012 8. 0.550  
2012 11 0.470  
2013 3. 0.580  
2013 5. 0.370  
2013 9. 0.560  
2013 11 0.440  
2014 3. 0.360  
2014 4. 0.570  
2014 7. 1.400  
2014 11 0.530  
2015 3. 0.590  
2015 5. 0.430  
2015 12 0.510  
2016 3. 0.580  
2016 5. 0.320  
2016 8. 0.660  
2016 11 0.450  
2017 2. 0.270  
2017 5. 0.530  
2017 8. 0.680  
2017 11 0.390

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TN 07060500 2000-2017

The record is 19 complete water years with 12 seasons per year beginning in water year 2000.

The tau correlation coefficient is 0.227

$$S = 87.$$

$$z = 2.588$$

$$p = 0.0097$$

$$p = 0.0486 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.4188 + 0.7500E-02 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

# **ATTACHMENT 5**

---

**Total Phosphorus Seasonal Mann-Kendall Input and Output**

2 0 TP WHI0011 1993-2017

1993 5. 0.1110  
1993 7. 0.0740  
1993 8. 0.0637  
1993 9. 0.0606  
1993 10 0.0744  
1993 11 0.0650  
1993 12 0.1100  
1994 1. 0.0740  
1994 2. 0.4480  
1994 3. 0.0000  
1994 4. 0.0316  
1994 5. 0.0423  
1994 6. 0.0712  
1994 7. 0.1080  
1994 8. 0.0873  
1994 9. 0.0481  
1994 10 0.0428  
1994 11 0.1210  
1994 12 0.0566  
1995 1. 0.0389  
1995 2. 0.0383  
1995 3. 0.0384  
1995 4. 0.1080  
1995 5. 0.0372  
1995 6. 0.0559  
1995 7. 0.0751  
1995 8. 0.0870  
1995 9. 0.0810  
1995 10 0.0700  
1995 11 0.0500  
1995 12 0.1000  
1996 1. 0.0000  
1996 2. 0.0000  
1996 4. 0.0760  
1996 5. 0.1160  
1996 6. 0.0650  
1996 7. 0.0600  
1996 8. 0.0720  
1996 9. 0.1200  
1996 10 0.0340  
1996 11 0.0610  
1996 12 0.0390  
1997 1. 0.0000  
1997 2. 0.0320  
1997 3. 0.0000  
1997 4. 0.0310  
1997 5. 0.0550  
1997 6. 0.0900  
1997 7. 0.0600  
1997 8. 0.0700  
1997 9. 0.0860  
1997 11 0.0800

1997 12 0.0640  
1998 1. 0.0000  
1998 2. 0.1060  
1998 3. 0.0710  
1998 4. 0.0490  
1998 5. 0.0600  
1998 10 0.0600  
1998 12 0.0360  
1999 1. 0.0500  
1999 2. 0.0360  
1999 3. 0.0390  
1999 4. 0.0950  
1999 5. 0.0460  
1999 7. 0.0500  
1999 8. 0.0640  
1999 9. 0.0540  
1999 11 0.0840  
1999 12 0.0940  
2000 1. 0.0230  
2000 2. 0.0990  
2000 3. 0.0640  
2000 5. 0.0420  
2000 6. 0.0410  
2000 8. 0.1110  
2000 8. 0.0560  
2000 9. 0.0000  
2000 10 0.0340  
2000 11 0.0870  
2000 12 0.0300  
2001 1. 0.0300  
2001 2. 0.0240  
2001 3. 0.0300  
2001 4. 0.0510  
2001 5. 0.0710  
2001 6. 0.0500  
2001 7. 0.0000  
2001 8. 0.0000  
2001 9. 0.0560  
2001 10 0.0640  
2001 11 0.0390  
2001 12 0.0320  
2002 1. 0.0470  
2002 2. 0.0000  
2002 3. 0.3600  
2002 4. 0.0200  
2002 5. 0.0360  
2002 6. 0.0660  
2002 7. 0.0560  
2002 8. 0.0700  
2002 9. 0.0590  
2002 10 0.0940  
2002 11 0.1070  
2002 12 0.1400  
2003 1. 0.0000

2003 3. 0.0000  
2003 4. 0.0550  
2003 4. 0.0950  
2003 5. 0.0430  
2003 6. 0.0590  
2003 7. 0.0590  
2003 8. 0.0660  
2003 9. 0.3100  
2003 10 0.1260  
2003 11 0.0580  
2003 12 0.0300  
2004 1. 0.0000  
2004 2. 0.0000  
2004 3. 0.0000  
2004 5. 0.0470  
2004 6. 0.0520  
2004 7. 0.0470  
2004 8. 0.0390  
2004 9. 0.0270  
2004 10 0.1870  
2004 11 0.0600  
2004 12 0.0260  
2005 1. 0.0370  
2005 2. 0.0400  
2005 3. 0.0280  
2005 4. 0.0410  
2005 5. 0.0340  
2005 5. 0.0540  
2005 7. 0.0360  
2005 8. 0.0590  
2005 9. 0.0830  
2005 10 0.0480  
2005 11 0.0920  
2005 12 0.0660  
2006 1. 0.0810  
2006 2. 0.0640  
2006 3. 0.0460  
2006 4. 0.0710  
2006 5. 0.0830  
2006 6. 0.1050  
2006 7. 0.0840  
2006 8. 0.0670  
2006 9. 0.0850  
2006 10 0.1180  
2006 11 0.0730  
2006 12 0.0660  
2007 1. 0.0370  
2007 2. 0.1500  
2007 3. 0.0450  
2007 4. 0.0600  
2007 5. 0.0480  
2007 6. 0.0750  
2007 7. 0.1010  
2007 8. 0.0950

2007 9. 0.1010  
2007 10 0.1040  
2007 11 0.1030  
2007 12 0.1200  
2008 1. 0.0540  
2008 2. 0.2400  
2008 3. 0.1850  
2008 4. 0.0460  
2008 5. 0.0350  
2008 6. 0.0600  
2008 7. 0.0880  
2008 8. 0.0670  
2008 9. 0.0520  
2008 10 0.0720  
2008 11 0.0780  
2009 1. 0.0380  
2009 2. 0.0440  
2009 3. 0.0340  
2009 4. 0.0300  
2009 5. 0.0530  
2009 6. 0.0570  
2009 7. 0.0620  
2009 8. 0.0660  
2009 9. 0.0530  
2009 10 0.0610  
2009 11 0.0580  
2009 12 0.0260  
2010 1. 0.0420  
2010 2. 0.0370  
2010 3. 0.0460  
2010 4. 0.0500  
2010 5. 0.0380  
2010 6. 0.0500  
2010 7. 0.0660  
2010 8. 0.0720  
2010 9. 0.0560  
2010 10 0.0750  
2010 11 0.0500  
2010 12 0.0540  
2011 1. 0.0460  
2011 2. 0.0550  
2011 3. 0.0630  
2011 4. 0.0670  
2011 5. 0.3920  
2011 6. 0.0550  
2011 7. 0.0240  
2011 8. 0.0580  
2011 9. 0.0700  
2011 10 0.0710  
2011 11 0.0760  
2011 12 0.2470  
2012 1. 0.0370  
2012 2. 0.0400  
2012 3. 0.0400

2012 4. 0.0400  
2012 5. 0.0780  
2012 6. 0.0640  
2012 7. 0.0640  
2012 8. 0.0640  
2012 9. 0.0790  
2012 10 0.0850  
2012 11 0.0680  
2012 12 0.0560  
2013 1. 0.0540  
2013 2. 0.0470  
2013 3. 0.0420  
2013 4. 0.0350  
2013 5. 0.0440  
2013 6. 0.0640  
2013 7. 0.0550  
2013 8. 0.0710  
2013 9. 0.0600  
2013 10 0.0590  
2013 11 0.0720  
2013 12 0.0540  
2014 1. 0.0530  
2014 2. 0.2390  
2014 3. 0.1630  
2014 4. 0.2210  
2014 5. 0.0570  
2014 6. 0.0870  
2014 7. 0.0510  
2014 8. 0.0580  
2014 9. 0.0710  
2014 10 0.0830  
2014 11 0.0640  
2014 12 0.0540  
2015 1. 0.0520  
2015 2. 0.0260  
2015 3. 0.0390  
2015 4. 0.0650  
2015 5. 0.0350  
2015 6. 0.0360  
2015 7. 0.0510  
2015 8. 0.0600  
2015 9. 0.0450  
2015 10 0.0570  
2015 11 0.0620  
2016 1. 0.0460  
2016 2. 0.0000  
2016 3. 0.0220  
2016 4. 0.0300  
2016 5. 0.0400  
2016 6. 0.0510  
2016 7. 0.0550  
2016 8. 0.0720  
2016 9. 0.0700  
2016 10 0.0380

2016 11 0.0930  
2016 12 0.0510  
2017 1. 0.0720  
2017 2. 0.0000  
2017 3. 0.0370  
2017 4. 0.0320  
2017 6. 0.0680  
2017 7. 0.0840  
2017 8. 0.0380  
2017 9. 0.0800  
2017 10 0.0670  
2017 11 0.0670  
2017 12 0.0860

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TP WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is -0.030

$$S = -92.$$

$$z = -0.687$$

$$p = 0.4924$$

$$p = 0.6490 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.5894E-01 + -0.7208E-04 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 TP WHI0029 1993-2017

1993 1. 0.0953  
1993 2. 0.0000  
1993 3. 0.0000  
1993 4. 0.0000  
1993 5. 0.0484  
1993 6. 0.0426  
1993 7. 0.0735  
1993 8. 0.0000  
1993 9. 0.0000  
1993 10 0.0000  
1993 11 0.1260  
1993 12 0.0692  
1994 1. 0.0540  
1994 2. 0.0930  
1994 3. 0.0000  
1994 4. 0.0524  
1994 5. 0.0322  
1994 6. 0.0410  
1994 7. 0.0380  
1994 8. 0.0470  
1994 9. 0.0000  
1994 10 0.0000  
1994 11 0.0593  
1994 12 0.0357  
1995 1. 0.1400  
1995 2. 0.0000  
1995 3. 0.0000  
1995 4. 0.0878  
1995 5. 0.0474  
1995 6. 0.0559  
1995 7. 0.0751  
1995 8. 0.0460  
1995 9. 0.0400  
1995 10 0.0490  
1995 11 0.0000  
1995 12 0.0600  
1996 1. 0.0000  
1996 2. 0.0300  
1996 4. 0.0760  
1996 5. 0.0750  
1996 6. 0.0000  
1996 7. 0.0500  
1996 8. 0.0000  
1996 9. 0.0390  
1996 10 0.0000  
1996 11 0.0500  
1996 12 0.0000  
1997 1. 0.0530  
1997 2. 0.0000  
1997 3. 0.0000  
1997 4. 0.0310  
1997 5. 0.0750

1997 6. 0.0600  
1997 7. 0.0400  
1997 8. 0.0500  
1997 9. 0.0580  
1997 11 0.0000  
1997 12 0.0310  
1998 1. 0.0000  
1998 2. 0.0830  
1998 3. 0.0750  
1998 4. 0.0460  
1998 5. 0.1340  
1998 6. 0.0310  
1998 7. 0.0270  
1998 8. 0.0430  
1998 9. 0.0530  
1998 10 0.0680  
1998 11 0.0330  
1998 12 0.0360  
1999 1. 0.0440  
1999 2. 0.0000  
1999 3. 0.0360  
1999 4. 0.0990  
1999 5. 0.0390  
1999 6. 0.0430  
1999 7. 0.0250  
1999 8. 0.0410  
1999 9. 0.0300  
1999 11 0.0420  
1999 12 0.1070  
2000 1. 0.0600  
2000 2. 0.1080  
2000 3. 0.0530  
2000 6. 0.0610  
2000 8. 0.0970  
2000 8. 0.0380  
2000 9. 0.0000  
2000 10 0.0370  
2000 11 0.0600  
2000 12 0.0200  
2001 1. 0.0000  
2001 2. 0.0500  
2001 3. 0.0200  
2001 4. 0.0660  
2001 5. 0.0700  
2001 6. 0.0500  
2001 7. 0.0000  
2001 8. 0.0000  
2001 9. 0.0000  
2001 10 0.0000  
2001 11 0.0000  
2001 12 0.0280  
2002 1. 0.0230  
2002 2. 0.0000  
2002 3. 0.1000

2002 5. 0.0240  
2002 6. 0.0410  
2002 7. 0.0250  
2002 8. 0.0300  
2002 9. 0.0230  
2002 10 0.0700  
2002 11 0.0710  
2002 12 0.2490  
2003 3. 0.0000  
2003 4. 0.0690  
2003 4. 0.0960  
2003 5. 0.0410  
2003 6. 0.0540  
2003 7. 0.0300  
2003 8. 0.0000  
2003 9. 0.3590  
2003 10 0.0000  
2003 11 0.0000  
2003 12 0.0000  
2004 1. 0.0000  
2004 2. 0.0000  
2004 3. 0.0000  
2004 5. 0.0370  
2004 6. 0.0440  
2004 7. 0.0330  
2004 8. 0.0270  
2004 9. 0.0380  
2004 10 0.0280  
2004 11 0.1070  
2004 12 0.0170  
2005 1. 0.0210  
2005 2. 0.0410  
2005 3. 0.0300  
2005 4. 0.0390  
2005 5. 0.0320  
2005 7. 0.0260  
2005 8. 0.0230  
2005 9. 0.0280  
2005 10 0.0480  
2005 11 0.0200  
2005 12 0.0470  
2006 1. 0.0400  
2006 2. 0.0610  
2006 3. 0.0620  
2006 4. 0.0440  
2006 5. 0.0450  
2006 6. 0.2050  
2006 7. 0.0480  
2006 8. 0.0280  
2006 9. 0.0470  
2006 10 0.0530  
2006 11 0.0480  
2006 12 0.0530  
2007 1. 0.0320

2007 2. 0.0320  
2007 3. 0.0310  
2007 4. 0.0490  
2007 5. 0.0430  
2007 6. 0.0410  
2007 7. 0.0290  
2007 8. 0.0310  
2007 9. 0.1120  
2007 10 0.0440  
2007 11 0.0620  
2007 12 0.0540  
2008 1. 0.0310  
2008 2. 0.1690  
2008 3. 0.0440  
2008 4. 0.0680  
2008 5. 0.0340  
2008 6. 0.0430  
2008 7. 0.0580  
2008 8. 0.0300  
2008 9. 0.0670  
2008 10 0.0380  
2008 11 0.0510  
2009 1. 0.0350  
2009 2. 0.0410  
2009 3. 0.1050  
2009 4. 0.0200  
2009 5. 0.0760  
2009 6. 0.0270  
2009 7. 0.0290  
2009 8. 0.0320  
2009 9. 0.0580  
2009 10 0.0690  
2009 11 0.0400  
2009 12 0.0320  
2010 1. 0.0350  
2010 2. 0.0480  
2010 3. 0.0840  
2010 4. 0.0400  
2010 5. 0.0210  
2010 6. 0.0300  
2010 7. 0.0450  
2010 8. 0.0280  
2010 9. 0.0470  
2010 10 0.0410  
2010 10 0.0290  
2010 11 0.0410  
2010 11 0.0860  
2011 1. 0.0520  
2011 2. 0.0940  
2011 3. 0.0770  
2011 4. 0.2140  
2011 5. 0.0550  
2011 6. 0.0360  
2011 7. 0.0330

2011 8. 0.0170  
2011 9. 0.0330  
2011 11 0.0410  
2011 12 0.0330  
2012 1. 0.0360  
2012 2. 0.0240  
2012 3. 0.0350  
2012 4. 0.0300  
2012 5. 0.0400  
2012 6. 0.0440  
2012 7. 0.0220  
2012 8. 0.0320  
2012 9. 0.0380  
2012 10 0.0260  
2012 11 0.0280  
2012 12 0.0360  
2013 1. 0.0220  
2013 2. 0.0230  
2013 3. 0.0270  
2013 4. 0.0370  
2013 5. 0.0420  
2013 6. 0.0280  
2013 7. 0.0380  
2013 8. 0.0000  
2013 9. 0.0000  
2013 10 0.0230  
2013 11 0.0440  
2013 12 0.0210  
2014 1. 0.0380  
2014 2. 0.0360  
2014 3. 0.0310  
2014 4. 0.0510  
2014 5. 0.0400  
2014 6. 0.0670  
2014 7. 0.0310  
2014 8. 0.0000  
2014 9. 0.0270  
2014 10 0.0340  
2014 11 0.0000  
2014 12 0.0000  
2015 1. 0.0000  
2015 2. 0.0000  
2015 3. 0.0350  
2015 4. 0.0000  
2015 5. 0.0000  
2015 6. 0.0510  
2015 7. 0.0320  
2015 8. 0.0000  
2015 9. 0.0000  
2015 10 0.0000  
2015 11 0.0240  
2015 11 0.0810  
2015 12 0.0450  
2016 1. 0.0280

2016 2. 0.0640  
2016 3. 0.0520  
2016 4. 0.0000  
2016 5. 0.0450  
2016 6. 0.0250  
2016 7. 0.0240  
2016 8. 0.0370  
2016 9. 0.0220  
2016 10 1.1300  
2016 11 0.0310  
2016 11 2.7000  
2016 11 0.1910  
2016 12 0.0000  
2017 1. 0.0000  
2017 2. 0.0000  
2017 3. 0.0340  
2017 4. 0.1240  
2017 5. 0.0990  
2017 6. 0.0360  
2017 7. 0.0380  
2017 8. 0.0000  
2017 9. 0.0310  
2017 10 0.0410  
2017 11 0.0290  
2017 12 0.1040

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TP WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is -0.060

$$S = -196.$$

$$z = -1.418$$

$$p = 0.1561$$

$$p = 0.3157 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.3830E-01 + -0.1000E-03 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 TP WHI0065 1993-2017

1993 1. 0.4850  
1993 2. 0.2900  
1993 3. 0.4830  
1993 4. 0.6900  
1993 5. 0.5880  
1993 6. 1.2300  
1993 7. 1.2100  
1993 8. 1.1100  
1993 9. 0.4780  
1993 10 0.9390  
1993 11 0.4360  
1993 12 0.4060  
1994 2. 0.5890  
1994 3. 0.6320  
1994 5. 0.7050  
1994 6. 1.0500  
1994 7. 0.7300  
1994 8. 2.2200  
1994 9. 2.3600  
1994 10 2.8500  
1994 11 0.1820  
1994 12 0.3730  
1995 1. 0.3930  
1995 2. 0.6380  
1995 3. 0.5280  
1995 4. 0.6720  
1995 5. 0.4820  
1995 6. 0.4820  
1995 7. 0.8880  
1995 8. 2.2800  
1995 9. 2.7400  
1995 10 0.6720  
1995 10 2.0900  
1995 11 2.0900  
1996 1. 0.6260  
1996 2. 0.7810  
1996 4. 0.8790  
1996 5. 0.6240  
1996 6. 1.8360  
1996 7. 2.3380  
1996 8. 2.6200  
1996 9. 0.8280  
1996 10 1.1520  
1996 11 0.7030  
1996 12 0.4510  
1997 1. 0.7450  
1997 2. 0.4660  
1997 3. 0.3380  
1997 4. 0.8410  
1997 5. 1.5600  
1997 6. 1.6100  
1997 8. 1.2800

1997 9. 2.8200  
1997 10 1.8300  
1997 11 1.9420  
1997 12 0.8800  
1998 1. 0.4250  
1998 2. 1.1060  
1998 3. 0.2010  
1998 4. 0.3820  
1998 5. 0.6720  
1998 7. 2.7140  
1998 8. 2.2940  
1998 9. 2.6780  
1998 10 2.0000  
1998 11 1.5840  
1998 12 1.2500  
1999 1. 0.6000  
1999 2. 0.8080  
1999 3. 0.8380  
1999 4. 0.4620  
1999 5. 0.8450  
1999 6. 1.7300  
1999 7. 2.4300  
1999 8. 1.9360  
1999 9. 3.3000  
1999 10 3.3400  
1999 11 0.9470  
1999 11 2.8210  
2000 1. 1.4900  
2000 3. 1.6040  
2000 4. 2.2320  
2000 5. 2.8250  
2000 6. 0.8140  
2000 7. 1.5150  
2000 8. 2.8890  
2000 10 1.7600  
2000 10 1.5820  
2001 1. 0.9140  
2001 2. 0.8580  
2001 3. 0.5600  
2001 4. 1.7190  
2001 5. 1.6630  
2001 6. 2.1100  
2001 7. 1.7980  
2001 8. 2.3990  
2001 9. 1.5400  
2001 10 2.2600  
2001 11 2.0450  
2001 12 0.8140  
2002 1. 0.7750  
2002 2. 0.4360  
2002 3. 0.5300  
2002 4. 0.3960  
2002 5. 1.0100  
2002 6. 1.1150

2002 7. 1.8200  
2002 8. 0.7500  
2002 9. 2.2140  
2002 10 2.2000  
2002 11 0.7220  
2002 12 2.0900  
2003 1. 0.5630  
2003 2. 1.7800  
2003 3. 0.8660  
2003 4. 0.9840  
2003 5. 0.8980  
2003 6. 1.8700  
2003 7. 0.5280  
2003 8. 2.6600  
2003 9. 2.2800  
2003 10 0.6980  
2003 11 2.7900  
2003 12 0.8730  
2004 1. 1.1400  
2004 2. 0.8350  
2004 3. 0.6540  
2004 4. 1.3400  
2004 5. 0.0000  
2004 6. 2.1200  
2004 7. 1.3500  
2004 8. 2.9800  
2004 9. 2.7400  
2004 10 3.0600  
2004 11 0.6430  
2004 12 0.2560  
2005 1. 0.1880  
2005 2. 0.6850  
2005 3. 0.5340  
2005 4. 0.5250  
2005 5. 0.9010  
2005 6. 1.9400  
2005 7. 1.5600  
2005 8. 3.2100  
2005 9. 2.8800  
2005 10 2.1800  
2005 11 2.5000  
2005 12 1.6800  
2006 1. 0.6770  
2006 2. 0.7900  
2006 2. 1.0000  
2006 4. 1.1800  
2006 5. 0.5520  
2006 6. 2.0200  
2006 7. 0.9320  
2006 8. 3.1900  
2006 9. 2.3100  
2006 10 0.3820  
2006 11 0.7240  
2006 12 0.5610

2007 1. 0.3660  
2007 2. 0.6990  
2007 3. 1.0200  
2007 4. 2.4300  
2007 5. 1.0100  
2007 6. 2.6100  
2007 7. 1.1100  
2007 8. 4.4000  
2007 9. 3.4700  
2007 10 1.8000  
2007 11 0.5120  
2007 12 1.2500  
2008 1. 0.6810  
2008 2. 1.3900  
2008 3. 0.3890  
2008 4. 0.3350  
2008 5. 0.9030  
2008 6. 0.9610  
2008 7. 1.0700  
2008 8. 2.3600  
2008 9. 0.7250  
2008 10 0.7900  
2008 11 2.0700  
2008 12 0.5230  
2009 1. 1.7800  
2009 2. 0.2130  
2009 3. 0.6770  
2009 4. 1.0900  
2009 5. 0.8440  
2009 6. 1.2800  
2009 7. 0.8340  
2009 8. 1.0700  
2009 9. 1.5800  
2009 10 0.3830  
2009 11 0.2470  
2009 12 0.3440  
2010 1. 0.1470  
2010 2. 0.3630  
2010 3. 0.3650  
2010 4. 0.6110  
2010 5. 0.5790  
2010 6. 0.9430  
2010 7. 1.0300  
2010 8. 1.1600  
2010 9. 1.8400  
2010 10 2.4600  
2010 11 1.2600  
2010 12 1.7000  
2011 1. 1.0300  
2011 2. 0.7460  
2011 3. 0.7940  
2011 4. 1.0100  
2011 5. 0.2740  
2011 6. 1.0900

2011 7. 1.4700  
2011 8. 0.8130  
2011 9. 0.4540  
2011 10 4.4400  
2011 11 1.9800  
2011 12 0.3830  
2012 1. 0.8460  
2012 2. 0.5040  
2012 3. 0.4550  
2012 4. 1.0200  
2012 5. 3.1500  
2012 6. 2.0600  
2012 7. 2.8200  
2012 8. 0.0000  
2012 9. 1.9900  
2012 10 3.2600  
2012 11 0.0000  
2012 12 0.2790  
2013 1. 2.1700  
2013 2. 0.6360  
2013 3. 0.7760  
2013 4. 1.1600  
2013 5. 1.3900  
2013 6. 1.3000  
2013 7. 2.8600  
2013 8. 0.6080  
2013 9. 4.3800  
2013 10 2.2000  
2013 11 1.1700  
2013 12 0.6000  
2014 1. 0.6750  
2014 2. 0.4460  
2014 3. 0.5230  
2014 4. 0.9170  
2014 5. 0.1280  
2014 6. 0.8520  
2014 7. 0.6470  
2014 8. 2.0300  
2014 9. 2.8800  
2014 10 2.3100  
2014 11 1.2800  
2014 12 0.7410  
2015 1. 0.2640  
2015 2. 0.9990  
2015 3. 0.2790  
2015 4. 0.5790  
2015 5. 0.9420  
2015 6. 0.6910  
2015 7. 0.6410  
2015 8. 1.9400  
2015 8. 3.8800  
2015 9. 1.5000  
2015 10 2.1900  
2015 11 1.7400

2015 11 1.4000  
2016 1. 0.2970  
2016 2. 0.5970  
2016 3. 0.9820  
2016 4. 0.6740  
2016 5. 0.1710  
2016 6. 0.7760  
2016 7. 1.0700  
2016 8. 0.5300  
2016 9. 2.3700  
2016 10 0.8100  
2016 11 0.3780  
2016 12 0.2650  
2017 1. 2.0100  
2017 2. 0.5350  
2017 3. 0.8220  
2017 4. 0.7950  
2017 6. 0.5090  
2017 7. 2.1600  
2017 8. 0.4730  
2017 9. 5.4300  
2017 10 3.6000  
2017 11 1.5000  
2017 12 2.3100

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: TP WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.000

$$S = -1.$$

$$z = 0.000$$

$$p = 1.0000$$

$$p = 1.0000 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 0.9425 + 0.000 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

# **ATTACHMENT 6**

---

**Fecal Coliform Seasonal Mann-Kendall Input and Output**

2 0 FC 07060500 1993-2017

1993 1 10.  
1993 2 1.0  
1993 2 4.0  
1993 3 170  
1993 3 10.  
1993 4 4.0  
1993 1 14.  
1994 2 32.  
1994 2 5.0  
1994 3 8.0  
1994 4 6.0  
1995 1 45.  
1995 1 4.0  
1995 2 36.  
1995 3 37.  
1995 4 140  
1995 4 53.  
1995 4 39.  
1996 1 5.0  
1996 2 600  
1996 3 100  
1996 3 420  
1996 4 110  
1996 1 11.  
1997 1 58.  
1997 2 3.0  
1997 3 160  
1997 3 120  
1997 4 17.  
1998 1 3.0  
1998 2 140  
1998 3 57.  
1998 3 23.  
1998 4 7.0  
1999 1 1.0  
1999 2 7.0  
1999 3 10.  
1999 3 60.  
1999 4 1.0  
1999 4 15.  
2000 1 35.  
2000 2 4.0  
2000 2 27.  
2000 3 150  
2000 3 33.  
2000 4 32.  
2001 1 1.0  
2001 2 5.0  
2001 2 7.0  
2001 3 55.  
2001 4 10.  
2001 1 12.

2002 1 8.0  
2002 2 12.  
2002 3 280  
2002 3 11.  
2002 4 23.  
2002 1 10.  
2003 2 22.  
2003 2 26.  
2003 3 71.  
2003 3 49.  
2003 4 160  
2004 1 170  
2004 1 8.0  
2004 2 14.  
2004 3 94.  
2004 3 56.  
2004 4 54.  
2005 1 7.0  
2005 2 150  
2005 2 330  
2005 3 120  
2005 3 120  
2005 4 4.0  
2006 1 42.  
2006 2 12.  
2006 2 25.  
2006 3 66.  
2006 3 110  
2006 4 31.  
2007 1 7.0  
2007 2 150  
2007 2 28.  
2007 3 56.  
2007 3 60.  
2007 4 100  
2007 1 76.  
2008 1 110  
2008 2 260  
2008 3 9.0  
2008 3 31.  
2008 4 160  
2008 1 56.  
2009 1 5.0  
2009 2 10.  
2009 2 20.  
2009 3 60.  
2009 4 57.  
2010 1 4.0  
2010 2 5.0  
2010 3 24.  
2010 3 69.  
2010 4 23.  
2010 1 22.  
2011 1 1.0

2011 2 60.  
2011 3 40.  
2011 3 24.  
2011 4 63.  
2012 1 12.  
2012 3 150  
2012 3 27.  
2012 4 10.  
2013 2 3.0  
2013 2 7.0  
2013 4 18.  
2013 4 42.  
2014 2 4.0  
2014 2 2.0  
2014 3 170  
2014 4 16.  
2015 2 110  
2015 2 16.  
2015 1 15.  
2016 2 62.  
2016 2 5.0  
2016 3 110  
2016 4 30.  
2017 1 4.0  
2017 2 47.  
2017 3 9.0  
2017 4 23.

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: FC 07060500 1993-2017

The record is 26 complete water years with 4 seasons per year beginning in water year 1993.

The tau correlation coefficient is 0.048

$$S = 48.$$

$$z = 0.627$$

$$p = 0.5307$$

$$p = 0.5526 \text{ adjusted for correlation among seasons}$$

(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 28.40 + 0.2000 * \text{Time}$$

where Time = Year (as a decimal) - 1992.75  
(beginning of first water year)

2 0 FC 07060500 2000-2017

2000 1 35.  
2000 2 4.0  
2000 2 27.  
2000 3 150  
2000 3 33.  
2000 4 32.  
2001 1 1.0  
2001 2 5.0  
2001 2 7.0  
2001 3 55.  
2001 4 10.  
2001 1 12.  
2002 1 8.0  
2002 2 12.  
2002 3 280  
2002 3 11.  
2002 4 23.  
2002 1 10.  
2003 2 22.  
2003 2 26.  
2003 3 71.  
2003 3 49.  
2003 4 160  
2004 1 170  
2004 1 8.0  
2004 2 14.  
2004 3 94.  
2004 3 56.  
2004 4 54.  
2005 1 7.0  
2005 2 150  
2005 2 330  
2005 3 120  
2005 3 120  
2005 4 4.0  
2006 1 42.  
2006 2 12.  
2006 2 25.  
2006 3 66.  
2006 3 110  
2006 4 31.  
2007 1 7.0  
2007 2 150  
2007 2 28.  
2007 3 56.  
2007 3 60.  
2007 4 100  
2007 1 76.  
2008 1 110  
2008 2 260  
2008 3 9.0  
2008 3 31.

2008 4 160  
2008 1 56.  
2009 1 5.0  
2009 2 10.  
2009 2 20.  
2009 3 60.  
2009 4 57.  
2010 1 4.0  
2010 2 5.0  
2010 3 24.  
2010 3 69.  
2010 4 23.  
2010 1 22.  
2011 1 1.0  
2011 2 60.  
2011 3 40.  
2011 3 24.  
2011 4 63.  
2012 1 12.  
2012 3 150  
2012 3 27.  
2012 4 10.  
2013 2 3.0  
2013 2 7.0  
2013 4 18.  
2013 4 42.  
2014 2 4.0  
2014 2 2.0  
2014 3 170  
2014 4 16.  
2015 2 110  
2015 2 16.  
2015 1 15.  
2016 2 62.  
2016 2 5.0  
2016 3 110  
2016 4 30.  
2017 1 4.0  
2017 2 47.  
2017 3 9.0  
2017 4 23.

Seasonal Kendall Test for Trend  
US Geological Survey, 2009

Data set: FC 07060500 2000-2017

The record is 19 complete water years with 4 seasons per year beginning in water year 2000.

The tau correlation coefficient is -0.085

$$S = -41.$$

$$z = -0.895$$

$$p = 0.3707$$

$$p = 0.3492 \text{ adjusted for correlation among seasons} \\ \text{(such as serial dependence)}$$

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 36.75 + -0.5000 * \text{Time}$$

where Time = Year (as a decimal) - 1999.75  
(beginning of first water year)

## **APPENDIX C**

---

**Calculations for pollutant load estimates based on export coefficients from  
White et al. 2015**

## **APPENDIX C. CALCULATIONS FOR POLLUTANT LOAD ESTIMATES BASED ON EXPORT COEFFICIENTS FROM WHITE ET AL. 2015**

Appendix C Calculations for load estimates based on export coefficients from White et al. 2015

Loads were calculated for each HUC12 subwatershed by multiplying land use export coefficients by the area of the appropriate land use. Land use areas used in these calculations are for 2011, from Homer et al. 2015. The data values and resulting loads for HUC12s are shown in Tables C.1. through C.3.

### **REFERENCES**

- Homer, C., Dewitz, J., Yang, L., Jin, S., Danielson, P., Xian, G., Megown, K. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5, 345-354.
- White, M., Harmel, D., Yen, H., Arnold, J., Gambone, M., & Haney, R. (2015, June). Development of sediment and nutrient export coefficients for U.S. ecoregions. *Journal of the American Water Resources Association*, 758-775.

Table C.1. Data and load estimates for sediment by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		1.04		4.83		0		0.03		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040101	Indian Creek-Piney Creek	2,233,800	940,147	0	0	39,058,200	0	16,114,500	195,639	1,135,786
110100040102	Upper Piney Creek	1,929,600	812,117	0	0	52,371,000	0	7,733,700	93,892	906,009
110100040103	Middle Piney Creek	1,972,800	830,299	0	0	44,975,700	0	13,005,000	157,888	988,187
110100040104	Knob Creek	3,337,200	1,404,539	72,000	140,734	59,625,900	0	22,854,600	277,468	1,822,741
110100040105	Mill Creek-Piney Creek	5,924,700	2,493,549	0	0	76,687,200	0	23,488,200	285,160	2,778,709
110100040106	Lower Piney Creek	3,416,400	1,437,872	26,100	51,016	58,140,900	0	17,657,100	214,367	1,703,255
110100040201	Hicks Creek	23,779,800	10,008,286	41,400	80,922	51,740,100	0	29,656,800	360,051	10,449,259
110100040202	Perry Creek-White River	2,837,700	1,194,313	0	0	67,878,000	0	15,618,600	189,619	1,383,931
110100040203	Farris Creek-White River	3,120,300	1,313,251	20,700	40,461	44,289,000	0	8,568,900	104,031	1,457,744
110100040204	Moccasin Creek-White River	2,863,800	1,205,297	62,100	121,383	43,659,900	0	16,277,400	197,617	1,524,297
110100040205	Sneeds Creek-White River	4,059,000	1,708,325	18,900	36,942	86,096,700	0	12,655,800	153,649	1,898,917
110100040206	Sugarloaf Creek-White River	5,850,000	2,462,110	0	0	83,406,600	0	20,063,700	243,585	2,705,695
110100040301	Headwaters North Sylamore Creek	2,978,100	1,253,403	0	0	1.14E+08	0	1,492,200	18,116	1,271,519
110100040302	Headwaters Roasting Ear Creek	2,999,700	1,262,494	0	0	76,626,000	0	11,356,200	137,871	1,400,365
110100040303	Outlet Roasting Ear Creek	3,371,400	1,418,933	21,600	42,220	49,565,700	0	21,172,500	257,046	1,718,199
110100040304	Headwaters South Sylamore Creek	3,041,100	1,279,918	23,400	45,738	44,178,300	0	26,576,100	322,649	1,648,306
110100040305	Outlet North Sylamore Creek	3,207,600	1,349,994	0	0	74,766,600	0	2,210,400	26,836	1,376,829
110100040306	Outlet South Sylamore Creek	9,375,300	3,945,815	19,800	38,702	96,351,300	0	23,847,300	289,520	4,274,037
110100040401	Livingston Creek	1,782,900	750,375	0	0	52,928,100	0	459,900	5,583	755,959
110100040402	Wideman Creek-White River	2,097,900	882,950	0	0	60,503,400	0	4,608,900	55,955	938,905
110100040403	Prong Cove-Rocky Bayou	5,445,000	2,291,656	0	0	87,368,400	0	17,758,800	215,602	2,507,258
110100040404	East Twin Creek-White River	4,374,000	1,840,900	0	0	78,769,800	0	8,569,800	104,042	1,944,943
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	1,501,508	49,500	96,754	69,209,100	0	18,708,300	227,130	1,825,392
110100040406	Hidden Creek-White River	1,914,300	805,678	0	0	60,364,800	0	4,196,700	50,950	856,628
110100040407	West Lafferty Creek	2,589,300	1,089,768	34,200	66,848	59,616,000	0	17,317,800	210,248	1,366,864
110100040408	Lafferty Creek	2,765,700	1,164,010	0	0	55,494,900	0	18,637,200	226,266	1,390,276
110100040409	Cagens Creek-White River	4,490,100	1,889,764	125,100	244,525	1.01E+08	0	17,991,900	218,432	2,352,721
110100040501	Upper Poke Bayou	4,560,300	1,919,309	29,700	58,053	39,202,200	0	41,301,900	501,429	2,478,791
110100040502	Sullivan Creek	4,652,100	1,957,945	174,600	341,279	66,755,700	0	28,231,200	342,743	2,641,967
110100040503	Middle Poke Bayou	3,587,400	1,509,841	0	0	70,929,000	0	17,183,700	208,620	1,718,461
110100040504	Miller Creek	11,417,400	4,805,280	81,000	158,325	56,826,000	0	41,477,400	503,560	5,467,165
110100040505	Lower Poke Bayou	6,253,200	2,631,806	134,100	262,116	44,073,000	0	6,568,200	79,742	2,973,664
110100040601	Mill Creek-White River	3,546,900	1,492,796	704,700	1,377,430	59,103,000	0	24,300,900	295,027	3,165,253
110100040602	Wolf Bayou	2,183,400	918,935	0	0	63,971,100	0	20,219,400	245,475	1,164,410
110100040603	Brier Creek-White River	2,674,800	1,125,752	1,497,600	2,927,259	54,198,000	0	18,629,100	226,168	4,279,179
110100040604	Greenbriar Creek	6,556,500	2,759,457	2,835,000	5,541,386	46,916,100	0	30,557,700	370,988	8,671,831
110100040605	Sprint Creek	6,597,000	2,776,502	577,800	1,129,387	41,887,800	0	39,138,300	475,162	4,381,051

Table C.1. Data and load estimates for sediment by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		1.04		4.83		0		0.03		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040606	Betsey Gill Creek-White River	4,904,100	2,064,005	2,649,600	5,178,997	41,591,700	0	17,072,100	207,265	7,450,267
110100040701	Upper Salado Creek	3,962,700	1,667,795	461,700	902,454	87,143,400	0	30,544,200	370,824	2,941,074
110100040702	Middle Salado Creek	2,847,600	1,198,479	131,400	256,839	71,920,800	0	19,498,500	236,723	1,692,041
110100040703	Lower Salado Creek	6,302,700	2,652,639	1,262,700	2,468,116	37,853,100	0	28,251,900	342,994	5,463,749
110100040704	Big Creek-White River	10,776,600	4,535,585	9,083,700	17,755,303	41,075,100	0	39,478,500	479,292	22,770,180
110100040705	Goodie Creek-White River	3,223,800	1,356,812	21,703,500	42,422,386	22,713,300	0	14,147,100	171,754	43,950,951
110100040706	Mud Creek-White River	6,428,700	2,705,669	49,392,900	96,545,011	7,780,500	0	12,654,000	153,627	99,404,307

Table C.2. Data and load estimates for total nitrogen by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		10.5		23.2		1.27		1.36		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040101	Indian Creek-Piney Creek	2,233,800	9,491,870	0	0	39,058,200	20,074,010	16,114,500	8,868,985	38,434,864
110100040102	Upper Piney Creek	1,929,600	8,199,262	0	0	52,371,000	26,916,139	7,733,700	4,256,419	39,371,821
110100040103	Middle Piney Creek	1,972,800	8,382,828	0	0	44,975,700	23,115,316	13,005,000	7,157,600	38,655,744
110100040104	Knob Creek	3,337,200	14,180,440	72,000	675,988	59,625,900	30,644,804	22,854,600	12,578,554	58,079,786
110100040105	Mill Creek-Piney Creek	5,924,700	25,175,253	0	0	76,687,200	39,413,480	23,488,200	12,927,270	77,516,003
110100040106	Lower Piney Creek	3,416,400	14,516,977	26,100	245,046	58,140,900	29,881,586	17,657,100	9,717,990	54,361,599
110100040201	Hicks Creek	23,779,800	1.01E+08	41,400	388,693	51,740,100	26,591,888	29,656,800	16,322,301	1.44E+08
110100040202	Perry Creek-White River	2,837,700	12,057,963	0	0	67,878,000	34,885,981	15,618,600	8,596,055	55,539,999
110100040203	Farris Creek-White River	3,120,300	13,258,788	20,700	194,346.4	44,289,000	22,762,386	8,568,900	4,716,091	40,931,611
110100040204	Moccasin Creek-White River	2,863,800	12,168,868	62,100	583,039	43,659,900	22,439,059	16,277,400	8,958,641	44,149,606
110100040205	Sneeds Creek-White River	4,059,000	17,247,515	18,900	177,447	86,096,700	44,249,504	12,655,800	6,965,410	68,639,876
110100040206	Sugarloaf Creek-White River	5,850,000	24,857,838	0	0	83,406,600	42,866,924	20,063,700	11,042,518	78,767,279
110100040301	Headwaters North Sylamore Creek	2,978,100	12,654,551	0	0	1.14E+08	58,385,218	1,492,200	821,266	71,861,036
110100040302	Headwaters Roasting Ear Creek	2,999,700	12,746,334	0	0	76,626,000	39,382,026	11,356,200	6,250,145	58,378,506
110100040303	Outlet Roasting Ear Creek	3,371,400	14,325,763	21,600	202,796	49,565,700	25,474,352	21,172,500	11,652,771	51,655,683
110100040304	Headwaters South Sylamore Creek	3,041,100	12,922,251	23,400	219,696	44,178,300	22,705,491	26,576,100	14,626,767	50,474,205
110100040305	Outlet North Sylamore Creek	3,207,600	13,629,744	0	0	74,766,600	38,426,385	2,210,400	1,216,544	53,272,673
110100040306	Outlet South Sylamore Creek	9,375,300	39,837,553	19,800	185,897	96,351,300	49,519,868	23,847,300	13,124,909	1.03E+08
110100040401	Livingston Creek	1,782,900	7,575,904	0	0	52,928,100	27,202,462	459,900	253,116	35,031,482
110100040402	Wideman Creek-White River	2,097,900	8,914,403	0	0	60,503,400	31,095,796	4,608,900	2,536,614	42,546,813
110100040403	Prong Cove-Rocky Bayou	5,445,000	23,136,910	0	0	87,368,400	44,903,096	17,758,800	9,773,963	77,813,969
110100040404	East Twin Creek-White River	4,374,000	18,586,014	0	0	78,769,800	40,483,835	8,569,800	4,716,586	63,786,435
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	15,159,457	49,500	464,741	69,209,100	35,570,101	18,708,300	10,296,542	61,490,842
110100040406	Hidden Creek-White River	1,914,300	8,134,249	0	0	60,364,800	31,024,563	4,196,700	2,309,750	41,468,562
110100040407	West Lafferty Creek	2,589,300	11,002,461	34,200	321,094	59,616,000	30,639,716	17,317,800	9,531,249	51,494,520
110100040408	Lafferty Creek	2,765,700	11,752,021	0	0	55,494,900	28,521,672	18,637,200	10,257,411	50,531,103
110100040409	Cagens Creek-White River	4,490,100	19,079,346	125,100	1,174,528	1.01E+08	51,883,992	17,991,900	9902,255	82,040,122
110100040501	Upper Poke Bayou	4,560,300	19,377,640	29,700	278,845	39,202,200	20,148,019	41,301,900	22,731,449	62,535,953
110100040502	Sullivan Creek	4,652,100	19,767,717	174,600	1,639,270	66,755,700	34,309,173	28,231,200	15,537,689	71,253,850
110100040503	Middle Poke Bayou	3,587,400	15,243,591	0	0	70,929,000	36,454,046	17,183,700	9,457,444	61,155,081
110100040504	Miller Creek	11,417,400	48,514,850	81,000	760,486	56,826,000	29,205,792	41,477,400	22,828,039	1.01E+08
110100040505	Lower Poke Bayou	6,253,200	2,6571,116	134,100	1,259,027	44,073,000	22,651,372	6,568,200	3,614,960	54,096,475
110100040601	Mill Creek-White River	3,546,900	15,071,498	704,700	6,616,228	59,103,000	30,376,059	24,300,900	13,374,558	65,438,343
110100040602	Wolf Bayou	2,183,400	9,277,710	0	0	63,971,100	32,878,025	20,219,400	11,128,211	53,283,946
110100040603	Brier Creek-White River	2,674,800	11,365,768	1,497,600	14,060,540	54,198,000	27,855,128	18,629,100	10,252,953	63,534,389
110100040604	Greenbriar Creek	6,556,500	27,859,899	2,835,000	26,617,008	46,916,100	24,112,587	30,557,700	16,818,132	95,407,626
110100040605	Sprint Creek	6,597,000	28,031,992	577,800	5,424,800	41,887,800	21,528,286	39,138,300	2,154,0662	76,525,740
110100040606	Betsey Gill Creek-White River	4,904,100	20,838,516	2,649,600	24,876,340	41,591,700	21,376,105	17,072,100	9,396,022	76,486,983

Table C.2. Data and load estimates for total nitrogen by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		10.5		23.2		1.27		1.36		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040701	Upper Salado Creek	3,962,700	16,838,317	461,700	4,334,770	87,143,400	44,787,457	30,544,200	16,810,702	82,771,245
110100040702	Middle Salado Creek	2,847,600	12,100,030	131,400	1,233,677	71,920,800	36,963,783	19,498,500	10,731,447	61,028,938
110100040703	Lower Salado Creek	6,302,700	26,781,452	1,262,700	11,855,131	37,853,100	19,454,647	28,251,900	15,549,082	73,640,311
110100040704	Big Creek-White River	10,776,600	45,791,961	9,083,700	85,284,272	41,075,100	2,111,0598	39,478,500	21,727,899	1.74E+08
110100040705	Goodie Creek-White River	3,223,800	13,698,581	21,703,500	2.04E+08	22,713,300	11,673,528	14,147,100	7,786,181	2.37E+08
110100040706	Mud Creek-White River	6,428,700	27,316,851	49,392,900	4.64E+08	7,780,500	3,998,797	1,2654,000	6,964,419	5.02E+08

Table C.3. Data and load estimates for total phosphorus by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		1.8		2.21		0.059		0.437		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040101	Indian Creek-Piney Creek	2,233,800	1,627,178	0	0	3,9058,200	932,572	16,114,500	2,849,814	5,409,563
110100040102	Upper Piney Creek	1,929,600	1,405,588	0	0	52,371,000	1,250,435	7,733,700	1,367,688	4,023,710
110100040103	Middle Piney Creek	1,972,800	1,437,056	0	0	44,975,700	1,073,861	13,005,000	2,299,905	4,810,823
110100040104	Knob Creek	3,337,200	2,430,933	72,000	64,394	59,625,900	1,423,656	22,854,600	4,041,785	7,960,768
110100040105	Mill Creek-Piney Creek	5,924,700	4,315,758	0	0	76,687,200	1,831,020	23,488,200	4,153,836	10,300,614
110100040106	Lower Piney Creek	3,416,400	2,488,625	26,100	23,343	58,140,900	1,388,200	17,657,100	3,122,619	7,022,786
110100040201	Hicks Creek	23,779,800	17,322,034	41,400	37,026	51,740,100	1,235,371	29,656,800	5,244,739	23,839,171
110100040202	Perry Creek-White River	2,837,700	2,067,079	0	0	67,878,000	1,620,687	15,618,600	2,762,115	6,449,882
110100040203	Farris Creek-White River	3,120,300	2,272,935	20,700	18,513	44,289,000	1,057,465	8,568,900	1,515,391	4,864,304
110100040204	Moccasin Creek-White River	2,863,800	2,086,092	62,100	55,540	43,659,900	1,042,444	16,277,400	2,878,622	6,062,698
110100040205	Sneeds Creek-White River	4,059,000	2,956,717	18,900	16,903	86,096,700	2,055,686	12,655,800	2,238,150	7,267,456
110100040206	Sugarloaf Creek-White River	5,850,000	4,261,344	0	0	83,406,600	1,991,456	20,063,700	3,548,221	9,801,020
110100040301	Headwaters North Sylamore Creek	2,978,100	2,169,352	0	0	1.14E+08	2,712,384	1,492,200	263,892	5,145,628
110100040302	Headwaters Roasting Ear Creek	2,999,700	2,185,086	0	0	76,626,000	1,829,559	11,356,200	2,008,319	6,022,963
110100040303	Outlet Roasting Ear Creek	3,371,400	2,455,845	21,600	19,318	49,565,700	1,183,454	21,172,500	3,744,310	7,402,927
110100040304	Headwaters South Sylamore Creek	3,041,100	2,215,243	23,400	20,928	44,178,300	1,054,822	26,576,100	4,699,924	7,990,917
110100040305	Outlet North Sylamore Creek	3,207,600	2,336,527	0	0	74,766,600	1,785,163	2,210,400	390,904	4,512,595
110100040306	Outlet South Sylamore Creek	9,375,300	6,829,295	19,800	17,708	96,351,300	2,300,529	23,847,300	4,217,342	13,364,874
110100040401	Livingston Creek	1,782,900	1,298,726	0	0	52,928,100	1,263,736	459,900	81,332	2,643,795
110100040402	Wideman Creek-White River	2,097,900	1,528,183	0	0	60,503,400	1,444,608	4,608,900	815,074	3,787,865
110100040403	Prong Cove-Rocky Bayou	5,445,000	3,966,327	0	0	87,368,400	2,086,049	17,758,800	3,140,604	9,192,981
110100040404	East Twin Creek-White River	4,374,000	3,186,174	0	0	78,769,800	1,880,745	8,569,800	1,515,550	6,582,469
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	2,598,764	49,500	44,271	69,209,100	1,652,469	18,708,300	3,308,521	7,604,025
110100040406	Hidden Creek-White River	1,914,300	1,394,443	0	0	60,364,800	1,441,299	4,196,700	742,177	3,577,918
110100040407	West Lafferty Creek	2,589,300	1,886,136	34,200	30,587	59,616,000	1,423,420	17,317,800	3,062,615	6,402,758
110100040408	Lafferty Creek	2,765,700	2,014,632	0	0	55,494,900	1,325,023	18,637,200	3,295,947	6,635,602
110100040409	Cagens Creek-White River	4,490,100	3,270,745	125,100	111,884	1.01E+08	241,0359	17,991,900	3,181,828	8,974,815
110100040501	Upper Poke Bayou	4,560,300	3,321,881	29,700	26,562	39,202,200	936,010	41,301,900	7,304,149	11,588,603
110100040502	Sullivan Creek	4,652,100	3,388,752	174,600	156,155	66,755,700	1,593,891	28,231,200	4,992,625	10,131,422
110100040503	Middle Poke Bayou	3,587,400	2,613,187	0	0	70,929,000	1,693,534	17,183,700	3,038,899	7,345,621
110100040504	Miller Creek	11,417,400	8,316,831	81,000	72,443	56,826,000	1,356,805	41,477,400	7,335,186	17,081,265
110100040505	Lower Poke Bayou	6,253,200	4,555,048	134,100	119,933	44,073,000	1,052,308	6,568,200	1,161,572	6,888,861
110100040601	Mill Creek-White River	3,546,900	2,583,685	704,700	630,253	59,103,000	1,411,171	24,300,900	4,297,560	8,922,670
110100040602	Wolf Bayou	2,183,400	1,590,465	0	0	63,971,100	1,527,404	20,219,400	3,575,756	6,693,625
110100040603	Brier Creek-White River	2,674,800	1,948,417	1,497,600	1,339,388	54,198,000	1,294,057	18,629,100	3,294,515	7,876,377
110100040604	Greenbriar Creek	6,556,500	4,775,983	2,835,000	2,535,499	46,916,100	1,120,191	30,557,700	5,404,061	13,835,735
110100040605	Sprint Creek	6,597,000	4,805,484	577,800	516,759	41,887,800	1,000,133	39,138,300	6,921,522	13,243,898

Table C.3. Data and load estimates for total phosphorus by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		Total Load (kg/yr)
Ozark Highlands export coefficient (kg/ha/yr)		1.8		2.21		0.059		0.437		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	
110100040606	Betsey Gill Creek-White River	4,904,100	3,572,317	2,649,600	2,369,686	41,591,700	993,063	17,072,100	3,019,163	9,954,229
110100040701	Upper Salado Creek	3,962,700	2,886,569	461,700	412,924	87,143,400	2,080,677	30,544,200	5,401,674	10,781,844
110100040702	Middle Salado Creek	2,847,600	2,074,291	131,400	117,518	71,920,800	1,717,215	19,498,500	3,448,266	7,357,291
110100040703	Lower Salado Creek	6,302,700	4,591,106	1,262,700	1,129,303	37,853,100	903,799	28,251,900	4,996,286	11,620,494
110100040704	Big Creek-White River	10,776,600	7,850,050	9,083,700	8,124,062	41,075,100	980,729	39,478,500	6,981,685	23,936,526
110100040705	Goodie Creek-White River	3,223,800	2,348,328	21,703,500	19,410,657	22,713,300	542,314	14,147,100	2,501,883	24,803,182
110100040706	Mud Creek-White River	6,428,700	4,682,889	49,392,900	44,174,839	7,780,500	185,771	12,654,000	2,237,832	51,281,331

# **APPENDIX D**

---

**Calculations for pollutant load estimates based on water quality  
measurements from 2013-2015**

Table D.1. Available TSS data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0168	WHI0202	WHI0166	WHI0167	WHI0162	WHI0090
1/8/2013	1	-	-	-	-	-	-
2/19/2013	1.5	-	-	-	-	-	-
3/5/2013	U	-	-	-	-	-	-
4/2/2013	1	-	-	-	-	-	-
5/7/2013	0.5 U	-	-	-	-	-	-
5/13/2013	-	0.5 U	-	-	-	0.5 U	-
5/14/2013	-	-	0.5 U	10.5	17.5	-	0.5 U
6/4/2013	1.2	-	-	-	-	-	-
7/9/2013	2	-	-	-	-	-	-
8/13/2013	1.5	-	-	-	-	-	-
8/19/2013	-	2.5	-	-	-	1.5	-
8/20/2013	-	-	1	14	-	-	2
9/16/2013	-	-	0.5 U	-	-	-	0.5 U
9/17/2013	0.5 U	-	-	-	-	-	-
10/15/2013	0.5 U	0.5 U	-	-	-	7	-
11/5/2013	1.5	-	-	-	-	-	-
12/2/2013	U	-	-	-	-	-	-
1/7/2014	0.5 U	-	-	-	-	-	-
1/27/2014	-	0.5 U	0.5 U	3.5	27.5	0.5 U	0.5 U
2/18/2014	1.5	-	-	-	-	-	-
3/18/2014	2.5	-	-	-	-	-	-
4/7/2014	-	5.5	-	-	-	1.8	-
4/8/2014	-	-	0.5 U	9.5	17	-	4.5
4/29/2014	1	-	-	-	-	-	-
5/6/2014	0.5 U	-	-	-	-	-	-
5/12/2014	-	-	2	8.5	-	-	-
6/23/2014	4.5	-	-	-	-	-	-
6/24/2014	-	-	-	15.5	-	-	-
7/7/2014	-	11.8	0.5 U	-	7.5	5.7	0.5 U
7/8/2014	3.5	-	-	-	-	-	-
8/4/2014	4.7	-	-	-	-	-	-
9/16/2014	1.3	-	-	-	-	-	-
9/29/2014	-	2.3	-	-	-	4.8	-
9/30/2014	-	-	0.5 U	-	-	-	1.5
10/14/2014	-	-	-	5.7	2.7	-	-
10/28/2014	0.5 U	-	-	-	-	-	-
11/3/2014	1	-	-	-	-	-	-
11/18/2014	-	-	-	3.2	-	-	-
12/1/2014	1	3	-	-	-	1	-
12/2/2014	-	-	0.5 U	-	-	-	1.2
1/6/2015	U	-	-	-	-	-	-
2/9/2015	-	-	-	8.5	7.2	-	-
2/10/2015	1.5	-	-	-	-	-	-
3/2/2015	-	1.5	-	-	-	5.5	-
3/3/2015	-	-	0.5 U	-	-	-	0.5 U

Table D.1. Available TSS data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0168	WHI0202	WHI0166	WHI0167	WHI0162	WHI0090
3/31/2015	2.7	-	-	-	-	-	-
4/14/2015	2	-	-	-	-	-	-
4/27/2015	-	-	-	7.5	11	-	-
5/5/2015	3	-	-	-	-	-	-
6/2/2015	2	-	-	-	-	-	-
6/29/2015	-	-	-	9.3	12.5	-	-
7/13/2015	1.8	-	-	-	-	-	-
8/11/2015	2.5	-	-	-	-	-	-
8/17/2015	-	-	-	5.5	13.3	-	-
8/25/2015	1	-	-	-	-	-	-
9/15/2015	U	-	-	-	-	-	-
9/21/2015	-	-	-	4.5	6.5	-	-
10/13/2015	1.3	-	-	-	-	-	-
11/2/2015	U	-	-	-	-	-	-
11/16/2015	U	-	-	-	-	-	-
12/28/2015	-	-	-	29	19.8	-	-
1/5/2016	1.5	-	-	-	-	-	-
2/2/2016	16.5	-	-	-	-	-	-
3/8/2016	1.5	-	-	-	-	-	-
4/5/2016	1.3	-	-	-	-	-	-
5/17/2016	22.3	-	-	-	-	-	-
6/28/2016	7	-	-	-	-	-	-
7/12/2016	2	-	-	-	-	-	-
8/16/2016	3.5	-	-	-	-	-	-
9/13/2016	3.5	-	-	-	-	-	-
10/11/2016	U	-	-	-	-	-	-
11/28/2016	12.3	-	-	-	-	-	-
12/13/2016	1.8	-	-	-	-	-	-
1/10/2017	1.3	-	-	-	-	-	-
2/7/2017	7.5	-	-	-	-	-	-
3/13/2017	1	-	-	-	-	-	-
4/18/2017	2.7	-	-	-	-	-	-
5/9/2017	2.5	-	-	-	-	-	-
6/6/2017	2	-	-	-	-	-	-
7/25/2017	2.2	-	-	-	-	-	-
8/15/2017	7.7	-	-	-	-	-	-
9/26/2017	1.5	-	-	-	-	-	-
10/31/2017	2.8	-	-	-	-	-	-
11/28/2017	1.3	-	-	-	-	-	-
12/4/2017	U	-	-	-	-	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
1/8/2013	2.17	-	-	-	-	-	-
2/19/2013	0.636	-	-	-	-	-	-
3/5/2013	0.776	-	-	-	-	-	-
4/2/2013	1.16	-	-	-	-	-	-
5/7/2013	1.39	-	-	-	-	-	-
5/13/2013	-	-	0.026	-	-	0.028	-
5/14/2013	-	0.052	-	0.061	0.104	-	0.028
6/4/2013	1.3	-	-	-	-	-	-
7/9/2013	2.86	-	-	-	-	-	-
8/13/2013	0.608	-	-	-	-	-	-
8/19/2013	-	-	0.025	-	-	0.031	-
8/20/2013	-	0.054	-	0.069	-	-	0.026
9/16/2013	-	0.051	-	-	-	-	0.024
9/17/2013	4.38	-	-	-	-	-	-
10/15/2013	2.2	-	0.041	-	-	0.028	-
11/5/2013	1.17	-	-	-	-	-	-
12/2/2013	0.6	-	-	-	-	-	-
1/7/2014	0.675	-	-	-	-	-	-
1/27/2014	-	0.034	0.029	0.041	0.064	0.032	0.023
2/18/2014	0.446	-	-	-	-	-	-
3/18/2014	0.523	-	-	-	-	-	-
4/7/2014	-	-	0.038	-	-	0.042	-
4/8/2014	-	0.056	-	0.058	0.118	-	0.038
4/29/2014	0.917	-	-	-	-	-	-
5/6/2014	0.128	-	-	-	-	-	-
5/12/2014	-	-	-	0.729	-	-	0.495
6/23/2014	0.852	-	-	-	-	-	-
6/24/2014	-	-	-	0.073	-	-	-
7/7/2014	-	0.047	0.027	-	0.086	0.031	0.025
7/8/2014	0.647	-	-	-	-	-	-
8/4/2014	2.03	-	-	-	-	-	-
9/16/2014	2.88	-	-	-	-	-	-
9/29/2014	-	-	0.031	-	-	0.029	-
9/30/2014	-	0.053	-	-	-	-	0.024
10/14/2014	-	-	-	0.046	0.114	-	-
10/28/2014	2.31	-	-	-	-	-	-
11/3/2014	1.28	-	-	-	-	-	-
11/18/2014	-	-	-	0.001 U	-	-	-
12/1/2014	0.741	-	0.001 U	-	-	0.027	-
12/2/2014	-	0.041	-	-	-	-	0.001 U
1/6/2015	0.264	-	-	-	-	-	-
2/9/2015	-	-	-	0.001 U	0.030	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
2/10/2015	0.999	-	-	-	-	-	-
3/2/2015	-	-	0.065	-	-	0.060	-
3/3/2015	-	0.141	-	-	-	-	0.200
3/31/2015	0.279	-	-	-	-	-	-
4/14/2015	0.579	-	-	-	-	-	-
4/27/2015	-	-	-	0.026	0.050	-	-
5/5/2015	0.942	-	-	-	-	-	-
6/2/2015	0.691	-	-	-	-	-	-
6/29/2015	-	-	-	0.023	0.061	-	-
7/13/2015	0.641	-	-	-	-	-	-
8/11/2015	1.94	-	-	-	-	-	-
8/17/2015	-	-	-	0.059	0.118	-	-
8/25/2015	3.88	-	-	-	-	-	-
9/15/2015	1.5	-	-	-	-	-	-
9/21/2015	-	-	-	0.039	0.060	-	-
10/13/2015	2.19	-	-	-	-	-	-
11/2/2015	1.74	-	-	-	-	-	-
11/16/2015	1.4	-	-	-	-	-	-
12/28/2015	-	-	-	0.114	0.156	-	-
1/5/2016	0.297	-	-	-	-	-	-
2/2/2016	0.597	-	-	-	-	-	-
3/7/2016	-	-	-	U	U	-	-
3/8/2016	0.982	-	-	-	-	-	-
4/5/2016	0.674	-	-	-	-	-	-
4/25/2016	-	-	-	1.17	1.23	-	-
5/17/2016	0.171	-	-	-	-	-	-
6/28/2016	0.776	-	-	-	-	-	-
7/12/2016	1.07	-	-	-	-	-	-
8/16/2016	0.53	-	-	-	-	-	-
9/13/2016	2.37	-	-	-	-	-	-
10/11/2016	0.81	-	-	-	-	-	-
11/28/2016	0.378	-	-	-	-	-	-
12/13/2016	0.265	-	-	-	-	-	-
1/10/2017	2.01	-	-	-	-	-	-
2/7/2017	0.535	-	-	-	-	-	-
3/13/2017	0.822	-	-	-	-	-	-
4/18/2017	0.795	-	-	-	-	-	-
6/6/2017	0.509	-	-	-	-	-	-
7/25/2017	2.16	-	-	-	-	-	-
8/15/2017	0.473	-	-	-	-	-	-
9/26/2017	5.43	-	-	-	-	-	-
10/31/2017	3.6	-	-	-	-	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
11/28/2017	1.5	-	-	-	-	-	-
12/4/2017	2.31	-	-	-	-	-	-

Table D.3. Available total nitrogen data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0162	WHI0168	WHI0202	WHI0090	WHI0166	WHI0167
1/7/2013	3.39	-	-	-	-	-	-
2/18/2013	2.2	-	-	-	-	-	-
3/4/2013	2.48	-	-	-	-	-	-
4/1/2013	2.76	-	-	-	-	-	-
5/6/2013	4.685	-	-	-	-	-	-
5/13/2013	-	0.146	0.258	-	-	-	-
5/14/2013	-	-	-	0.217	0.376	0.445	0.788
6/3/2013	2.67	-	-	-	-	-	-
7/8/2013	2.96	-	-	-	-	-	-
8/12/2013	2.24	-	-	-	-	-	-
8/19/2013	-	0.182	0.435	-	-	-	-
8/20/2013	-	-	-	0.362	1.04	0.717	-
9/16/2013	4.45	-	-	0.281	0.404	-	-
10/15/2013	4.235	0.349	0.265	-	-	-	-
11/4/2013	3.13	-	-	-	-	-	-
12/1/2013	2.41	-	-	-	-	-	-
1/6/2014	1.92	-	-	-	-	-	-
1/27/2014	-	0.117	0.331	0.276	0.919	0.663	1.04
2/17/2014	1.69	-	-	-	-	-	-
3/17/2014	1.41	-	-	-	-	-	-
4/7/2014	-	0.146	0.356	-	-	-	-
4/8/2014	-	-	-	0.093	0.597	0.428	0.833
4/28/2014	2.06	-	-	-	-	-	-
5/5/2014	0.482	-	-	-	-	-	-
5/12/2014	-	-	-	0.280	-	0.524	-
6/22/2014	1.96	-	-	-	-	-	-
6/24/2014	-	-	-	-	-	0.679	-
7/7/2014	1.42	0.438	0.384	0.403	0.614	-	0.814
8/3/2014	2.86	-	-	-	-	-	-
9/15/2014	3.38	-	-	-	-	-	-
9/29/2014	-	0.314	0.389	-	-	-	-
9/30/2014	-	-	-	0.381	0.336	-	-
10/14/2014	-	-	-	-	-	0.423	0.452
10/27/2014	3.81	-	-	-	-	-	-
11/2/2014	2.46	-	-	-	-	-	-
11/18/2014	-	-	-	-	-	1.23	-
11/30/2014	3.03	-	-	-	-	-	-
12/1/2014	-	0.200	0.218	-	-	-	-
12/2/2014	-	-	-	0.229	0.535	-	-
1/5/2015	1.75	-	-	-	-	-	-
2/9/2015	2	-	-	-	-	0.531	0.763
3/2/2015	-	0.294	0.385	-	-	-	-

Table D.3. Available total nitrogen data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0162	WHI0168	WHI0202	WHI0090	WHI0166	WHI0167
3/3/2015	-	-	-	0.219	0.681	-	-
3/30/2015	1.57	-	-	-	-	-	-
4/13/2015	1.61	-	-	-	-	-	-
4/27/2015	-	-	-	-	-	0.439	0.668
5/4/2015	1.78	-	-	-	-	-	-
6/1/2015	2.17	-	-	-	-	-	-
6/29/2015	-	-	-	-	-	0.465	0.494
7/12/2015	2.06	-	-	-	-	-	-
8/10/2015	2.335	-	-	-	-	-	-
8/17/2015	-	-	-	-	-	0.453	0.832
8/24/2015	3.983	-	-	-	-	-	-
9/14/2015	3.22	-	-	-	-	-	-
9/21/2015	-	-	-	-	-	0.475	0.575
10/12/2015	3.54	-	-	-	-	-	-
11/1/2015	2.9	-	-	-	-	-	-
11/15/2015	2.57	-	-	-	-	-	-
12/28/2015	-	-	-	-	-	0.512	0.407
1/4/2016	1.8	-	-	-	-	-	-
2/1/2016	2.45	-	-	-	-	-	-
3/7/2016	1.934	-	-	-	-	0.126	0.179
4/4/2016	1.78	-	-	-	-	-	-
4/25/2016	-	-	-	-	-	0.245	0.332
5/16/2016	1.06	-	-	-	-	-	-
6/27/2016	1.82	-	-	-	-	-	-
7/11/2016	2.76	-	-	-	-	-	-
8/15/2016	1.45	-	-	-	-	-	-
9/12/2016	2.7	-	-	-	-	-	-
10/10/2016	4.545	-	-	-	-	-	-
11/27/2016	1.2	-	-	-	-	-	-
12/12/2016	2.15	-	-	-	-	-	-
1/9/2017	8.05	-	-	-	-	-	-
2/6/2017	1.53	-	-	-	-	-	-
3/12/2017	2.48	-	-	-	-	-	-
4/17/2017	2.57	-	-	-	-	-	-
6/5/2017	2.31	-	-	-	-	-	-
7/24/2017	4.53	-	-	-	-	-	-
8/14/2017	1.29	-	-	-	-	-	-
9/25/2017	8.25	-	-	-	-	-	-
10/30/2017	7.25	-	-	-	-	-	-
11/27/2017	4.27	-	-	-	-	-	-
12/3/2017	5.8	-	-	-	-	-	-

Table D.4. Calculations of TSS load and yield at selected ADEQ water quality monitoring stations.

Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.74 (9)	433	3.0
WHI0202	North Sylamore Creek	9.22	9.22	0.57 (10)	78.4	1.1
WHI0065	Hicks Creek	14.1	2.92	0.87 (11)	37.9	2.7
WHI0168	Piney Creek	174	25.7	1.3 (8)	425	2.4
WHI0162	Wideman Creek	13.2	3.81	1.3 (9)	73.6	5.6
WHI0167	Greenbrier Creek	32.5	2.1	7.5 (6)	236	7.2
WHI0166	Salado Creek	112	2.87	6.7 (9)	286	2.6

Table D.5. Calculations of total phosphorus load and yield at selected ADEQ water quality monitoring stations.

Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.051 (9)	19.5	0.11
WHI0202	North Sylamore Creek	9.22	9.22	0.008 (10)	4.61	0.03
WHI0065	Hicks Creek	14.1	2.92	0.945	41.1	2.9
WHI0168	Piney Creek	174	25.7	0.032	1.83	0.14
WHI0162	Wideman Creek	13.2	3.81	0.007	1.00	0.01
WHI0167	Greenbrier Creek	32.5	2.1	0.069	2.14	0.06
WHI0166	Salado Creek	112	2.87	0.004	0.18	0.001

Table D.6. Calculations of total nitrogen load and yield at selected ADEQ water quality monitoring stations.

Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.54	16.7	0.52
WHI0202	North Sylamore Creek	9.22	9.22	0.23	9.95	0.09
WHI0065	Hicks Creek	14.1	2.92	2.4	103	7.3
WHI0168	Piney Creek	174	25.7	0.32	43.9	0.60
WHI0162	Wideman Creek	13.2	3.81	0.20	77.4	0.44
WHI0167	Greenbrier Creek	32.5	2.1	0.73 (6)	431	3.0
WHI0166	Salado Creek	112	2.87	0.56	32.0	2.4

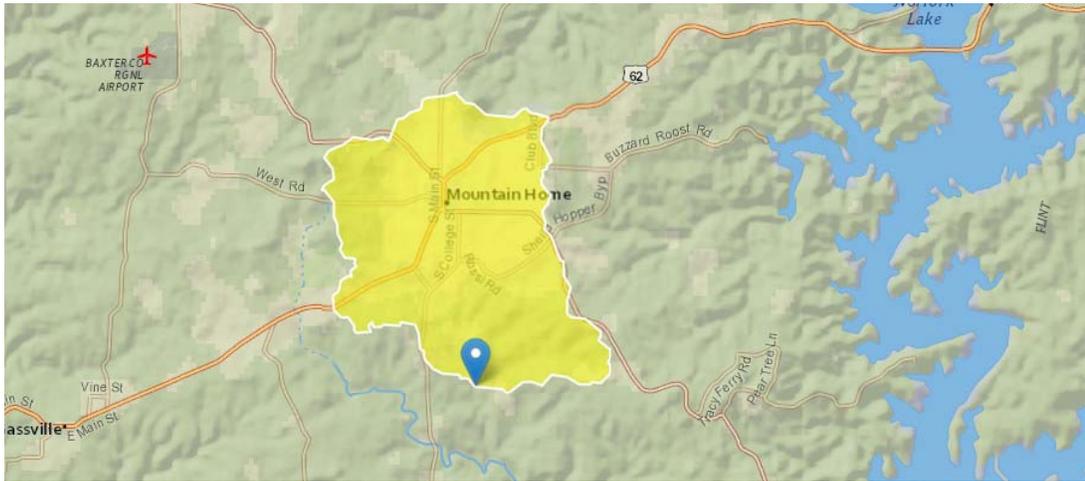
## StreamStats Report

Region ID: AR

Workspace ID: AR20180702180713831000

Clicked Point (Latitude, Longitude): 36.29237, -92.37601

Time: 2018-07-02 13:07:30 -0500



### Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	14.1	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	45.7	feet per mi

### General Flow Statistics Parameters (Harmonic Mean Flow Region 1 2015 5031)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	45.7	feet per mi	2	95.8

### General Flow Statistics Flow Report (Harmonic Mean Flow Region 1 2015 5031)

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	2.92	ft <sup>3</sup> /s	1.02	8.38	57.8

### General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

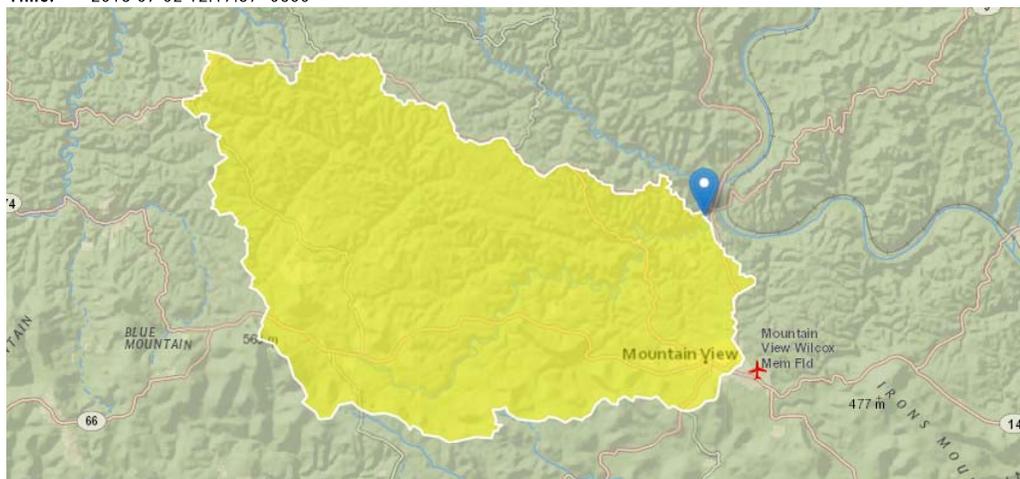
## StreamStats Report WHI0090

Region ID: AR

Workspace ID: AR20180702171721151000

Clicked Point (Latitude, Longitude): 35.93594, -92.12146

Time: 2018-07-02 12:17:37 -0500



### Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	142	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.35	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	16	feet per mi
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	95	percent

### General Flow Statistics Parameters<sup>S</sup> (3 Percent (4.77 square miles) Harmonic Mean Flow Region 1 2015 5031)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	142	square miles	8	7350
BFI	Base Flow Index	0.35	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	16	feet per mi	2	95.8

### General Flow Statistics Parameters<sup>S</sup> (97 Percent (137 square miles) Harmonic Mean Flow Region 2 2015 5031)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	142	square miles	4.1	2090
BFI	Base Flow Index	0.35	dimensionless	0.1	0.4
ORDOMISS	Percent Surficial Geology Ordo and Miss	95	percent	0	100

### General Flow Statistics Flow Report<sup>S</sup> (3 Percent (4.77 square miles) Harmonic Mean Flow Region 1 2015 5031)

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
Harmonic Mean Streamflow	19.5	ft <sup>3</sup> /s	6.84	55.5	57.8

### General Flow Statistics Flow Report<sup>S</sup> (97 Percent (137 square miles) Harmonic Mean Flow Region 2 2015 5031)

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
Harmonic Mean Streamflow	40.2	ft <sup>3</sup> /s	24.6	65.5	76.6

General Flow Statistics Flow Report [Area-Averaged]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu
Harmonic Mean Streamflow	39.5	ft <sup>3</sup> /s	24	65.1

## General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Application Version: 4.2.1

## StreamStats Report WHI0162

Region ID: AR

Workspace ID: AR20180702181500959000

Clicked Point (Latitude, Longitude): 36.03623, -92.05378

Time: 2018-07-02 13:15:16 -0500



### Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	13.2	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	56	feet per mi

### General Flow Statistics Parameters (Harmonic Mean Flow Region 1 2015 5031)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.2	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	56	feet per mi	2	95.8

### General Flow Statistics Flow Report (Harmonic Mean Flow Region 1 2015 5031)

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	3.81	ft <sup>3</sup> /s	1.3	11.2	57.8

### General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

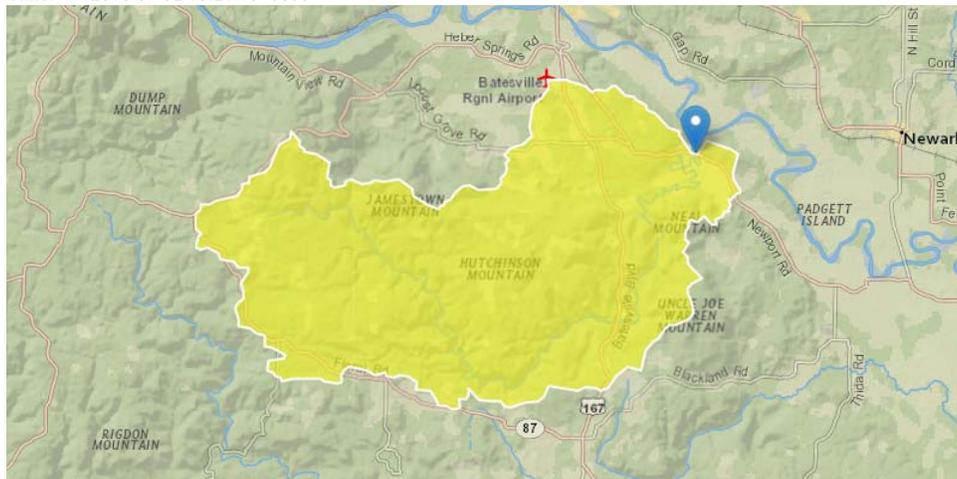
## StreamStats Report WHI0166

Region ID: AR

Workspace ID: AR20180702182054788000

Clicked Point (Latitude, Longitude): 35.69073, -91.56220

Time: 2018-07-02 13:21:10 -0500



Basin Characteristics				
Parameter Code	Parameter Description	Value	Unit	
DRNAREA	Area that drains to a point on a stream	112	square miles	
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.29	dimensionless	
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	15.9	percent	

General Flow Statistics Parameters (100 Percent (112 square miles) Harmonic Mean Flow Region 2 2015 5031)					
Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	112	square miles	4.1	2090
BFI	Base Flow Index	0.29	dimensionless	0.1	0.4
ORDOMISS	Percent Surficial Geology Ordo and Miss	15.9	percent	0	100

General Flow Statistics Flow Report (100 Percent (112 square miles) Harmonic Mean Flow Region 2 2015 5031)					
PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)					
Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	2.87	ft <sup>3</sup> /s	1.8	4.56	76.6

#### General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Application Version: 4.2.1

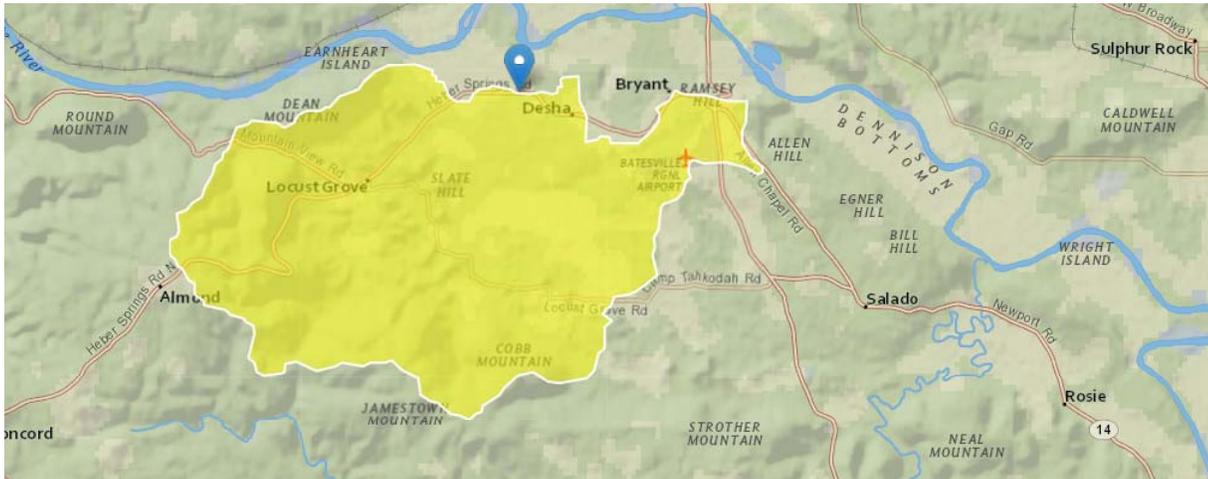
## StreamStats Report WHI0167

Region ID: AR

Workspace ID: AR20180702181804705000

Clicked Point (Latitude, Longitude): 35.74110, -91.69528

Time: 2018-07-02 13:18:20 -0500



Basin Characteristics				
Parameter Code	Parameter Description	Value	Unit	
DRNAREA	Area that drains to a point on a stream	32.5	square miles	
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.29	dimensionless	
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	52.5	percent	

General Flow Statistics Parameters <small>(Harmonic Mean Flow Region 2 2015 5031)</small>					
Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	32.5	square miles	4.1	2090
BFI	Base Flow Index	0.29	dimensionless	0.1	0.4
ORDOMISS	Percent Surficial Geology Ordo and Miss	52.5	percent	0	100

General Flow Statistics Flow Report <small>(Harmonic Mean Flow Region 2 2015 5031)</small>					
PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)					
Statistic	Value	Unit	PII	Plu	SEp
Harmonic Mean Streamflow	2.1	ft <sup>3</sup> /s	1.29	3.43	76.6

General Flow Statistics Citations					
<b>Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<a href="http://pubs.usgs.gov/sir/2015/5031/">http://pubs.usgs.gov/sir/2015/5031/</a>)</b>					

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Application Version: 4.2.1

## StreamStats Report WHI0168

Region ID: AR

Workspace ID: AR20180702181225706000

Clicked Point (Latitude, Longitude): 36.06266, -92.07597

Time: 2018-07-02 13:12:41 -0500



### Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	174	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	12.7	feet per mi

### General Flow Statistics Parameters (Harmonic Mean Flow Region 1 2015 5031)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	174	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	12.7	feet per mi	2	95.8

### General Flow Statistics Flow Report (Harmonic Mean Flow Region 1 2015 5031)

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	25.7	ft <sup>3</sup> /s	9.1	72.7	57.8

### General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

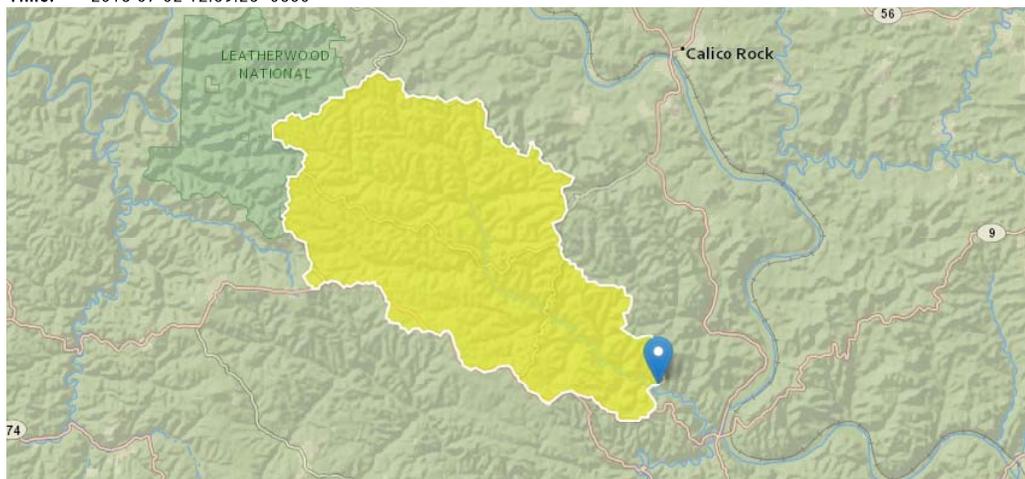
## StreamStats Report WHI0202

Region ID: AR

Workspace ID: AR20180702175908413000

Clicked Point (Latitude, Longitude): 35.96290, -92.15062

Time: 2018-07-02 12:59:25 -0500



### Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	72.5	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.35	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	19.5	feet per mi
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	100	percent

### General Disclaimers

Parameter values have been edited, computed flows may not apply.

### General Flow Statistics Parameters<sup>(99 Percent (71.6 square miles) Harmonic Mean Flow Region 1 2015 5031)</sup>

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	72.5	square miles	8	7350
BFI	Base Flow Index	0.35	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	19.5	feet per mi	2	95.8

### General Flow Statistics Parameters<sup>(1 Percent (0.903 square miles) Harmonic Mean Flow Region 2 2015 5031)</sup>

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	72.5	square miles	4.1	2090
BFI	Base Flow Index	0.35	dimensionless	0.1	0.4
ORDOMISS	Percent Surficial Geology Ordo and Miss	100	percent	0	100

### General Flow Statistics Flow Report<sup>(99 Percent (71.6 square miles) Harmonic Mean Flow Region 1 2015 5031)</sup>

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
Harmonic Mean Streamflow	9.05	ft <sup>3</sup> /s	3.17	25.8	57.8

## General Flow Statistics Flow Report (1 Percent (0.903 square miles) Harmonic Mean Flow Region 2 2015 5031)

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	23	ft <sup>3</sup> /s	13.9	38	76.6

## General Flow Statistics Flow Report (Area-Averaged)

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu
Harmonic Mean Streamflow	9.22	ft <sup>3</sup> /s	3.3	26

## General Flow Statistics Citations

**Breaker, B.K., 2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 25 p. (<http://pubs.usgs.gov/sir/2015/5031/>)**

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

USGS Software Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Application Version: 4.2.1

# **APPENDIX E**

---

**Linear Regression Analysis of Dissolved Oxygen and Nutrients at Selected  
Water Quality Monitoring Stations**

Appendix E

Greenbrier Cr results of linear regression of DO to other parameters.

Parameter	N	p-value	R squared	equation
TKN	25	0.007	0.273	10.2-5.10 * TKN
Ammonia-N	25	0.008	0.266	9.07 – 36.2 * NH3N
NOx	25	0.712	0.006	-
TN (calculated)	25	0.078	0.129	-
TP	25	0.884	0.001	-
BOD	10	0.497	0.060	-
Temperature, C	25	0.000	0.634	13.2 – 0.35 * temperature
Turbidity	25	0.544	0.016	-
Ln(TP)	25	0.421	0.028	-
Ln(NOx)	25	0.789	0.003	-
LN(TKN)	25	0.002	0.339	5.12 – 3.16 * ln(TKN)
Ln(TN)	25	0.054	0.152	-
Ln(turbidity)	25	0.598	0.012	-
Ln(NH3)	17	0.154	0.131	-

Lower Salado Cr (WHI0166) results of linear regression of DO to other parameters

Parameter	N	p-value	R squared	equation
TKN	25	0.011	0.251	9.86 – 5.74 * TKN
Ammonia-N	26	0.000	0.525	9.22 – 59.0 * NH3N
NOx	26	0.003	0.308	5.51 + 10.1 * NOx
TN (calculated)	25	0.408	0.030	-
TP	26	0.496	0.020	-
BOD	10	0.245	0.164	-
Temperature, C	26	0.000	0.616	12.4 – 0.28 * temperature
Turbidity	26	0.574	0.013	-
Ln(TP)	26	0.086	0.118	-
Ln(NOx)	25	0.030	0.188	10.12 + 1.37 * ln(NOx)
LN(TKN)	25	0.002	0.359	4.22 – 3.23 * ln(TKN)
Ln(TN)	25	0.458	0.024	-
Ln(turbidity)	26	0.348	0.037	-
Ln(NH3)	12	0.047	0.338	-
Ln(BOD)	10	0.140	0.251	-

Appendix E

File: C:\local work\ANRC WMPs\Mid White\GreenbrierCr DO and nutrients.syz

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TKN\_RESULT

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.523
Squared Multiple R	0.273
Adjusted Squared Multiple R	0.242
Standard Error of Estimate	2.408

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	10.248	1.009	0.000		10.160	0.000
TKN_RESULT	-5.099	1.734	-0.523	1.000	-2.940	0.007

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	50.105	1	50.105	8.643	0.007
Residual	133.334	23	5.797		

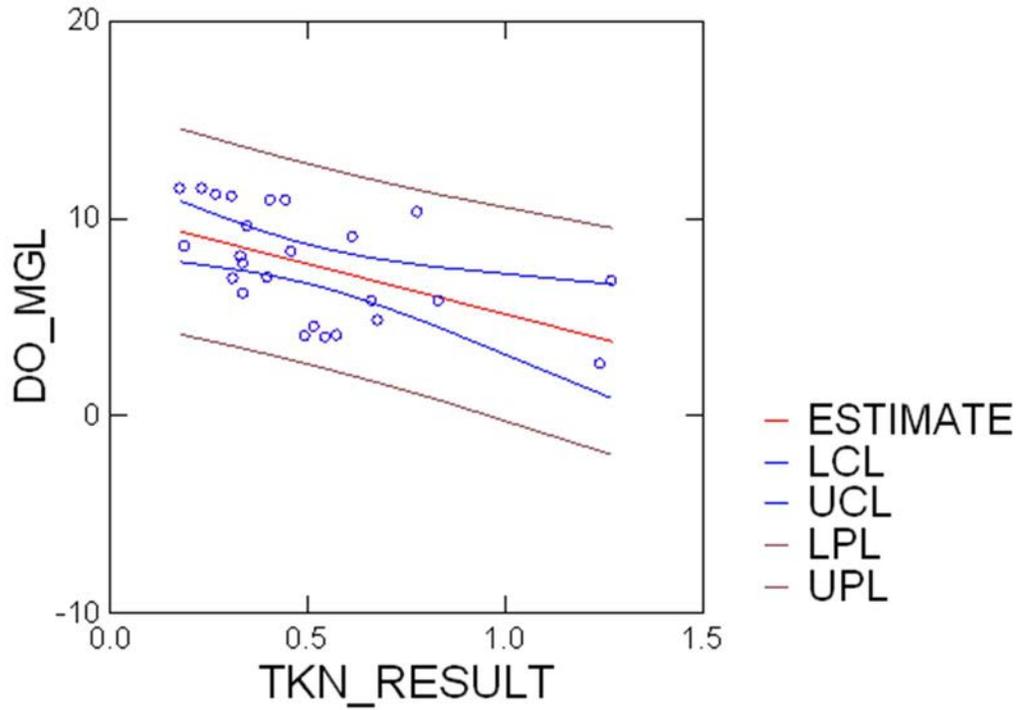
**WARNING**

Case 5 has large Leverage (Leverage : 0.339)

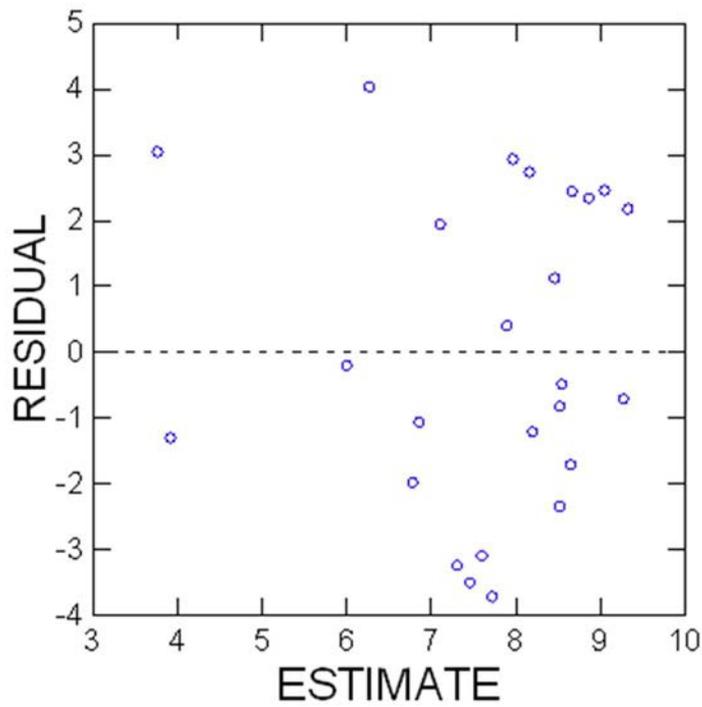
Durbin-Watson D Statistic	1.867
First Order Autocorrelation	0.029

Information Criteria	
AIC	118.796
AIC (Corrected)	119.939
Schwarz's BIC	122.453

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+NH3N\_MGL

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.515
Squared Multiple R	0.266
Adjusted Squared Multiple R	0.234
Standard Error of Estimate	2.420

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.073	0.693	0.000		13.088	0.000
NH3N_MGL	-36.210	12.557	-0.515	1.000	-2.884	0.008

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	48.709	1	48.709	8.315	0.008
Residual	134.730	23	5.858		

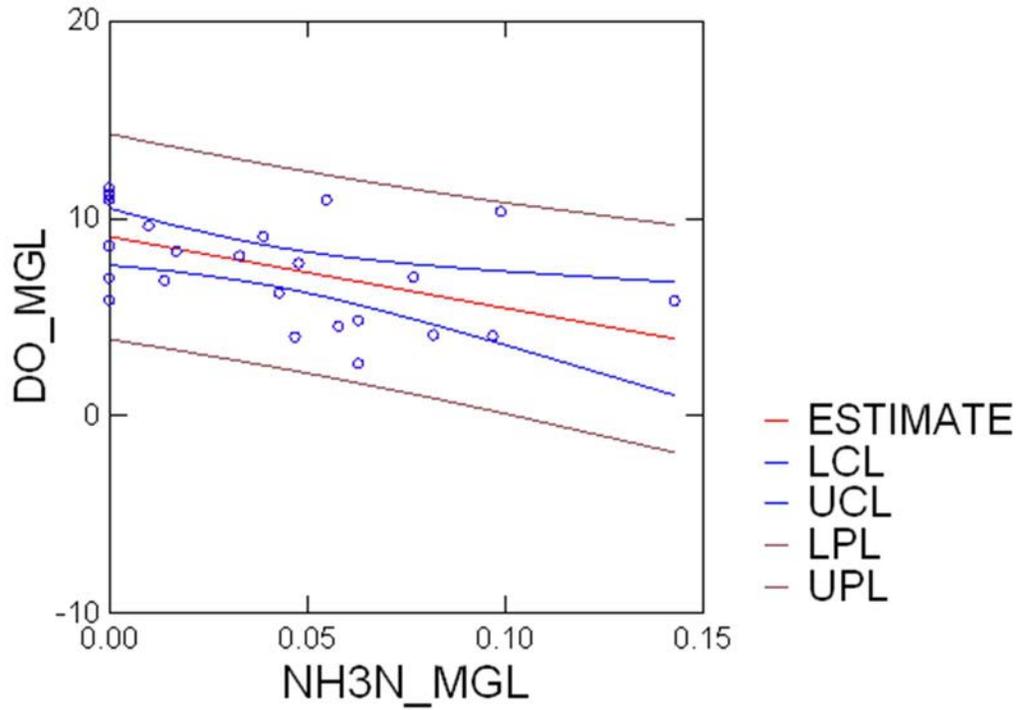
**WARNING**

Case 10 has large Leverage (Leverage : 0.328)

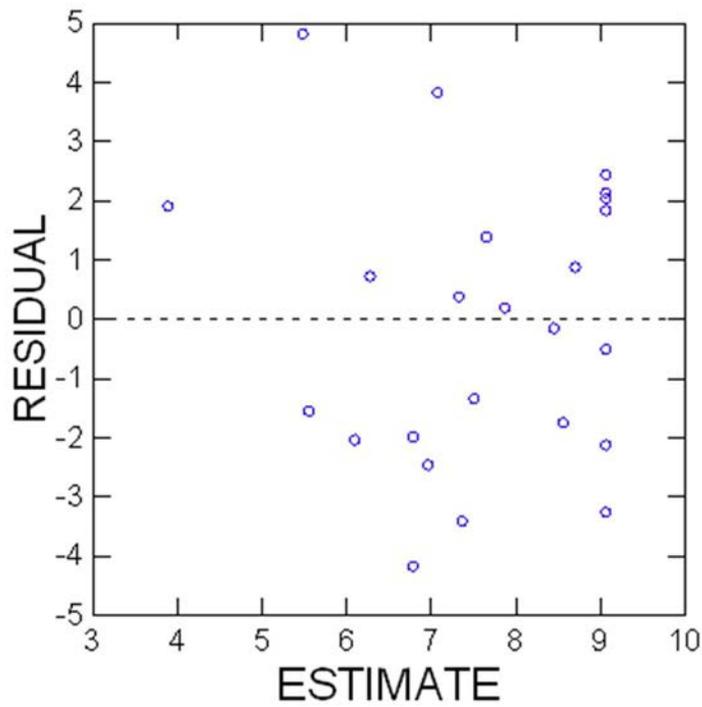
Durbin-Watson D Statistic	1.410
First Order Autocorrelation	0.272

Information Criteria	
AIC	119.057
AIC (Corrected)	120.200
Schwarz's BIC	122.713

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+NOX\_RESULT

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.078
Squared Multiple R	0.006
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.816

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	7.318	1.035	0.000	1.000	0.000
NOX_RESULT	0.704	1.885	0.078	1.000	0.712

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	1.105	1	1.105	0.139	0.712
Residual	182.334	23	7.928		

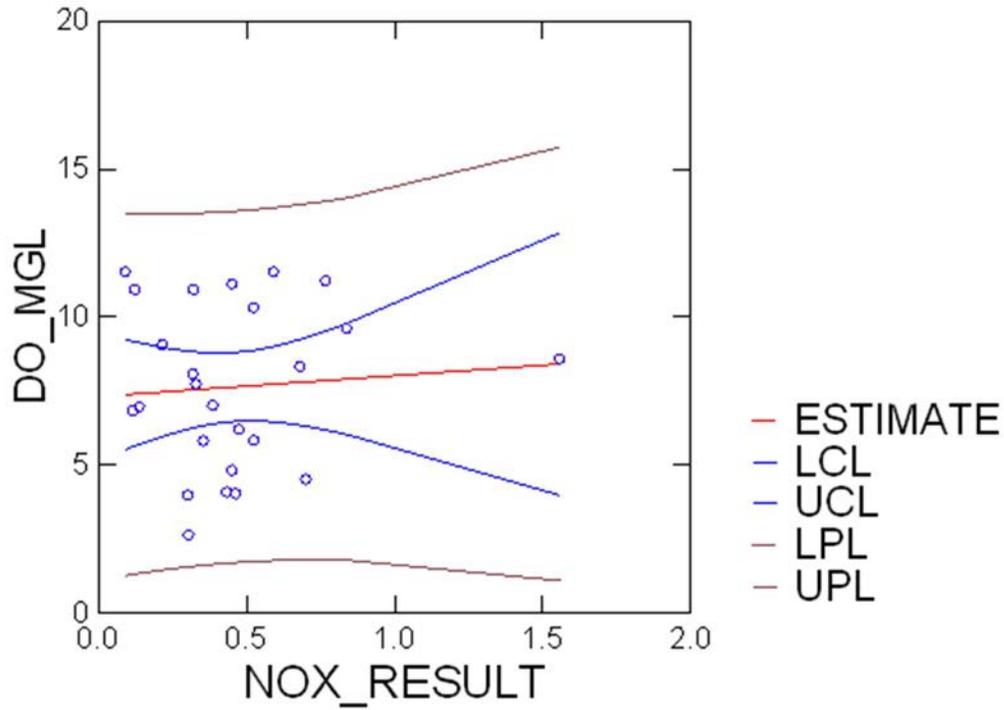
**WARNING**

Case 13 has large Leverage (Leverage : 0.582)

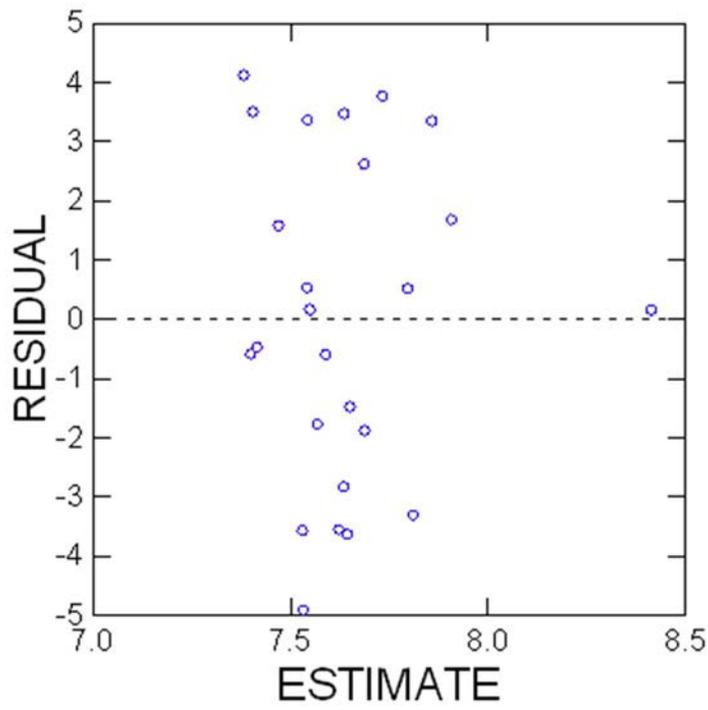
Durbin-Watson D Statistic	1.749
First Order Autocorrelation	0.095

Information Criteria	
AIC	126.621
AIC (Corrected)	127.764
Schwarz's BIC	130.278

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TN\_CALC

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.359
Squared Multiple R	0.129
Adjusted Squared Multiple R	0.091
Standard Error of Estimate	2.636

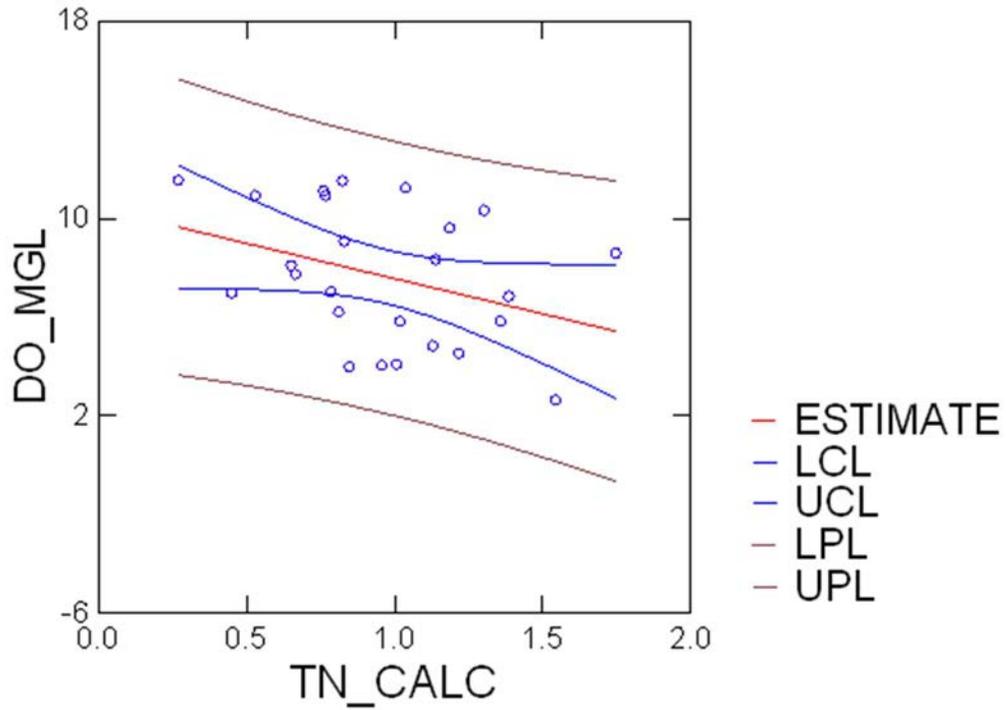
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	10.416	1.596	0.000		6.527	0.000
TN_CALC	-2.856	1.551	-0.359	1.000	-1.842	0.078

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	23.576	1	23.576	3.392	0.078
Residual	159.863	23	6.951		

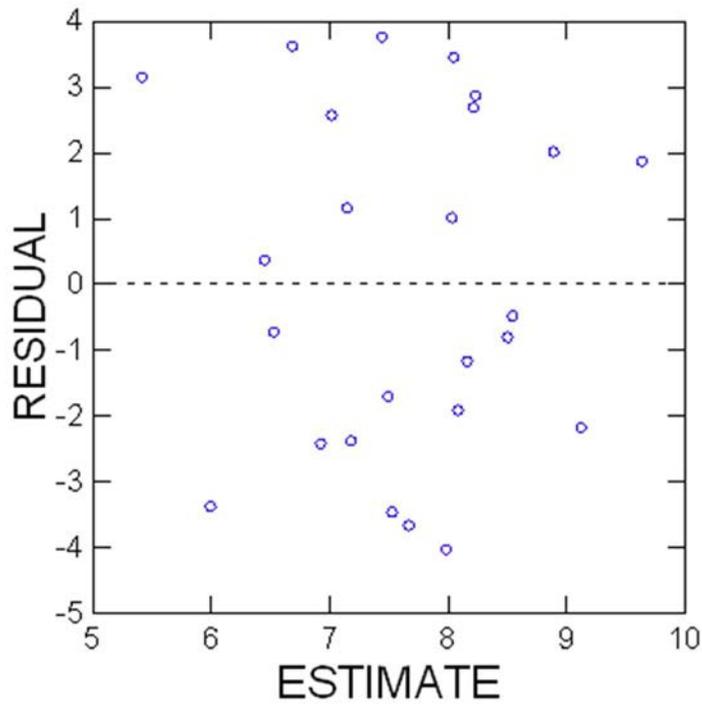
Durbin-Watson D Statistic	2.128
First Order Autocorrelation	-0.083

Information Criteria	
AIC	123.333
AIC (Corrected)	124.476
Schwarz's BIC	126.990

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TP\_MGL

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.031
Squared Multiple R	0.001
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.823

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.690	0.648	0.000		11.861	0.000
TP_MGL	-0.263	1.776	-0.031	1.000	-0.148	0.884

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	0.174	1	0.174	0.022	0.884
Residual	183.265	23	7.968		

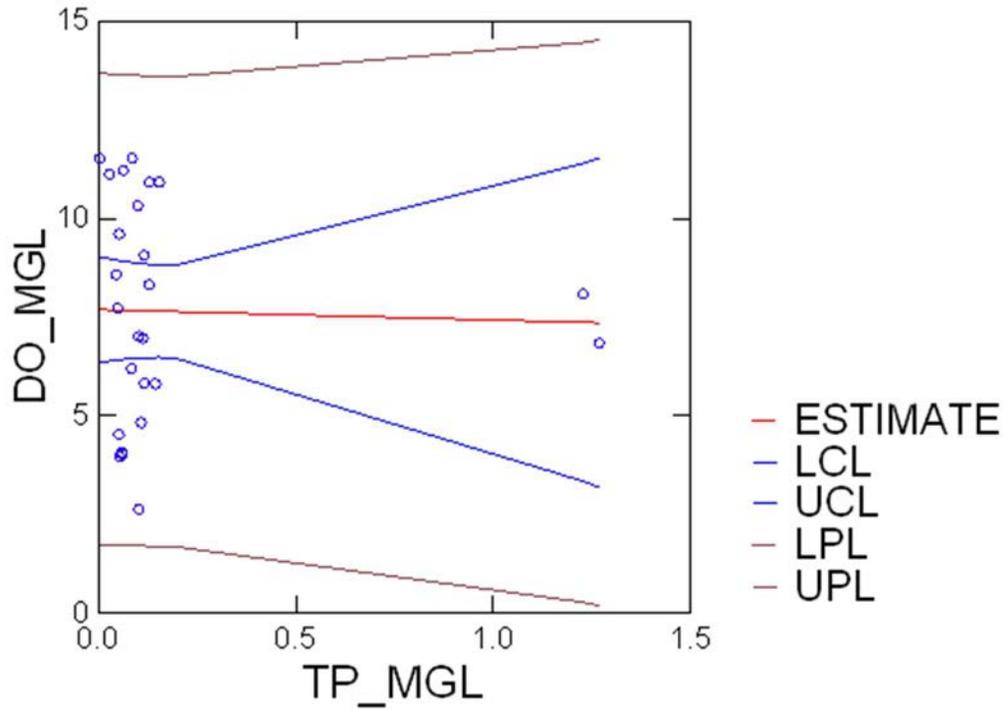
**WARNING**

Case 5 has large Leverage (Leverage : 0.511)  
 Case 26 has large Leverage (Leverage : 0.477)

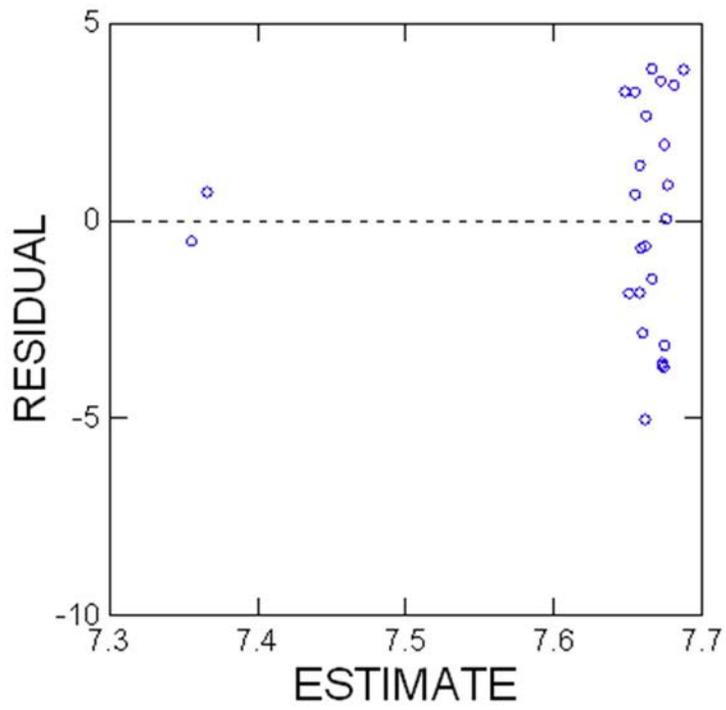
Durbin-Watson D Statistic	1.814
First Order Autocorrelation	0.064

Information Criteria	
AIC	126.748
AIC (Corrected)	127.891
Schwarz's BIC	130.405

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+BOD\_MGL

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.244
Squared Multiple R	0.060
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	3.348

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	8.444	2.016	0.000		4.189
BOD_MGL	-0.877	1.232	-0.244	1.000	0.497

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.676	1	5.676	0.507	0.497
Residual	89.652	8	11.206		

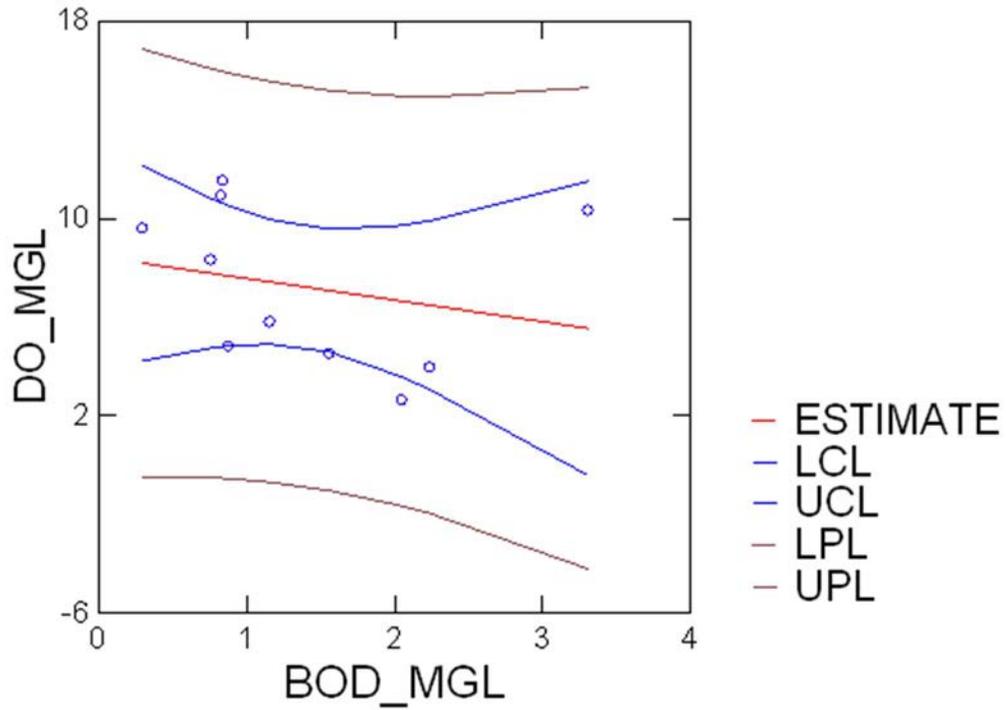
**WARNING**

Case 8 has large Leverage (Leverage : 0.597)  
 Case 8 is an Outlier (Studentized Residual : 3.431)

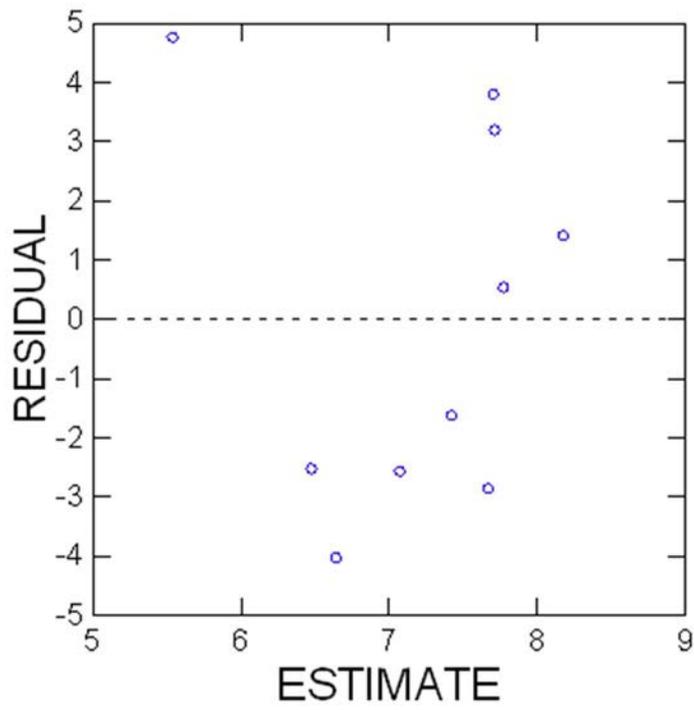
Durbin-Watson D Statistic	1.286
First Order Autocorrelation	0.284

Information Criteria	
AIC	56.312
AIC (Corrected)	60.312
Schwarz's BIC	57.220

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TEMP\_DEGC

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.796
Squared Multiple R	0.634
Adjusted Squared Multiple R	0.618
Standard Error of Estimate	1.708

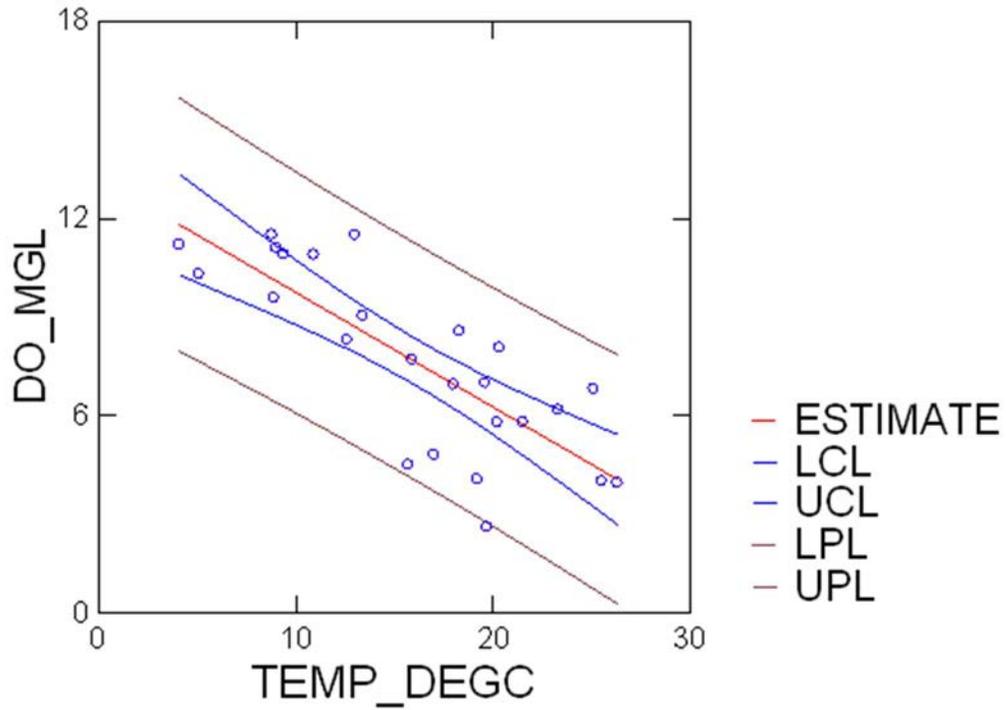
Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	13.240	0.950	0.000		13.9420.000
TEMP_DEGC	-0.349	0.055	-0.796	1.000	6.3170.000

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	116.369	1	116.369	39.906	0.000
Residual	67.070	23	2.916		

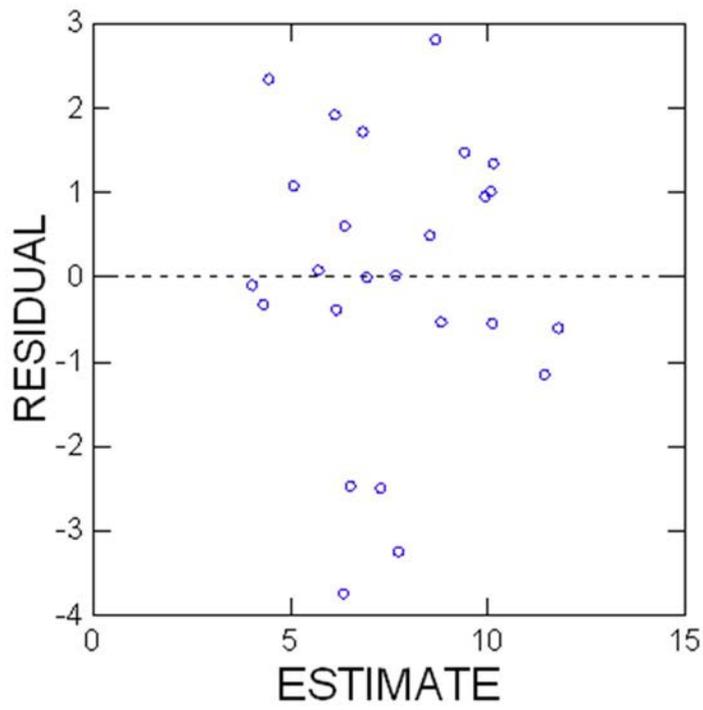
Durbin-Watson D Statistic	2.213
First Order Autocorrelation	-0.213

Information Criteria	
AIC	101.618
AIC (Corrected)	102.761
Schwarz's BIC	105.275

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TURBIDITY\_NTU

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.127
Squared Multiple R	0.016
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.801

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	7.144	0.984	0.000	1.000	0.000
TURBIDITY_NTU	0.033	0.053	0.127	1.000	0.544

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.978	1	2.978	0.380	0.544
Residual	180.461	23	7.846		

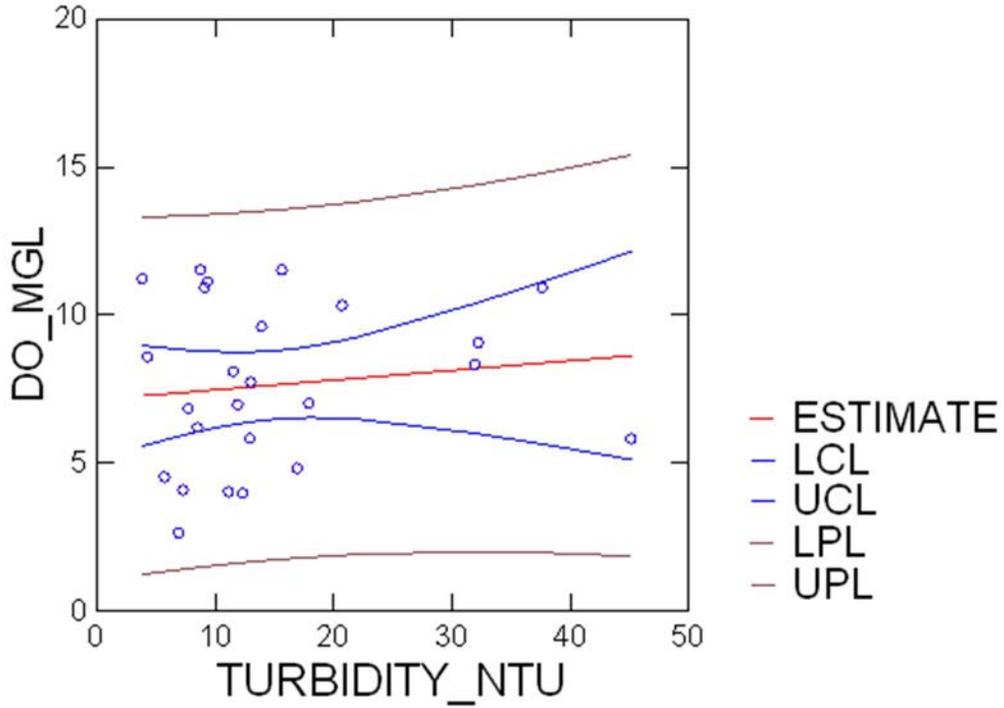
**WARNING**

Case 10 has large Leverage (Leverage : 0.369)

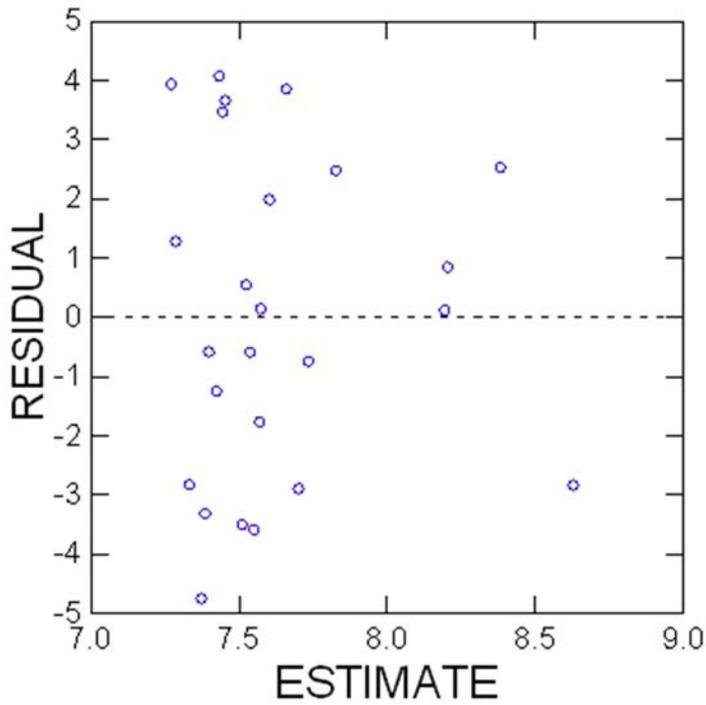
Durbin-Watson D Statistic	1.863
First Order Autocorrelation	0.046

Information Criteria	
AIC	126.363
AIC (Corrected)	127.506
Schwarz's BIC	130.020

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

```
> REGRESS
> MODEL DO_MGL =
CONSTANT+TURBIDITY_NTU+NOX_RESULT+TKN_RESULT+TN_CALC+TP_MGL+BOD_MGL+TEMP_DEGC
```

**Stepwise Selection of Variables**

16 case(s) are deleted due to missing data.  
 Unable to enter effect 4.  
 This effect may fail tolerance checks.

Step number : 0  
 R : 0.985  
 R-square : 0.970

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.063	0.056	0.235	0.228	1	1.255	0.344
3	NOX_RESULT	-5.081	5.691	-0.298	0.090	1	0.797	0.438
5	TN_CALC	0.000	2.060	0.000	0.435	1	6.079	0.090
6	TP_MGL	-5.080	29.074	-0.375	0.111	1	0.593	0.497
7	BOD_MGL	-22.383	0.697	-0.232	0.268	1	0.332	0.605
8	TEMP_DEGC	-0.401	0.111	-0.112	0.210	1	23.199	0.017

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT			0		

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	31.942
AIC (Corrected)	175.942
Schwarz's BIC	34.363

The following effects have lost degrees of freedom.

Effect	Initial df	Lost df	Final df
TKN_RESULT	1	1	0

Dependent Variable : DO\_MGL  
 Minimum Tolerance for Entry into Model : 0.000  
 Backward Stepwise with Alpha-to-Enter : 0.150  
 Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1  
 R : 0.983  
 R-square : 0.966  
 Term Removed : BOD\_MGL

Appendix E

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.042	0.040	0.159	0.378	1	1.141	0.346
3	NOX_RESULT	-2.373	2.930	-0.139	0.284	1	0.656	0.463
5	TN_CALC	0.000	1.296	0.000	0.917	1	21.009	0.010
6	TP_MGL	-5.940	17.338	-0.439	0.259	1	0.313	0.606
8	TEMP_DEGC	-0.795	0.072	-0.221	0.409	1	45.585	0.003

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT			0		
7	BOD_MGL	-0.316	0.268	1	0.332	0.605

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	30.991
AIC (Corrected)	86.991
Schwarz's BIC	33.110

Step number : 2  
R : 0.982  
R-square : 0.964  
Term Removed : TP\_MGL

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.025	0.023	0.094	0.987	1	1.196	0.324
3	NOX_RESULT	-1.147	1.806	-0.067	0.644	1	0.403	0.553
5	TN_CALC	0.000	1.181	0.000	0.952	1	26.496	0.004
8	TEMP_DEGC	-0.022	0.053	0.006	0.663	1	77.205	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT			0		
6	TP_MGL	-0.269	0.259	1	0.313	0.606
7	BOD_MGL	0.005	0.628	1	0.000	0.992

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	29.745
AIC (Corrected)	57.745
Schwarz's BIC	31.561

Step number : 3  
R : 0.980  
R-square : 0.961  
Term Removed : NOX\_RESULT

Appendix E

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.025	0.022	0.093	0.987	1	1.297	0.298
5	TN_CALC	-6.221	1.101	-0.460	0.987	1	31.947	0.001
8	TEMP_DEGC	-0.443	0.041	-0.880	0.997	1	118.282	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
3	NOX_RESULT	-0.273	0.644	1	0.403	0.553
4	TKN_RESULT	0.273	0.302	1	0.403	0.553
6	TP_MGL	0.032	0.588	1	0.005	0.945
7	BOD_MGL	0.143	0.845	1	0.104	0.760

Information Criteria	
AIC	28.521
AIC (Corrected)	43.521
Schwarz's BIC	30.034

Step number : 4  
R : 0.976  
R-square : 0.952  
Term Removed : TURBIDITY\_NTU

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
5	TN_CALC	-6.353	1.118	-0.469	0.998	1	32.312	0.001
8	TEMP_DEGC	-0.442	0.042	-0.877	0.998	1	112.764	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	TURBIDITY_NTU	0.422	0.987	1	1.297	0.298
3	NOX_RESULT	-0.239	0.645	1	0.363	0.569
4	TKN_RESULT	0.239	0.302	1	0.363	0.569
6	TP_MGL	0.291	0.991	1	0.556	0.484
7	BOD_MGL	0.086	0.854	1	0.045	0.839

Information Criteria	
AIC	28.477
AIC (Corrected)	36.477
Schwarz's BIC	29.688

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.836
Squared Multiple R	0.699

Appendix E

Dependent Variable	DO_MGL
Adjusted Squared Multiple R	0.672
Standard Error of Estimate	1.584

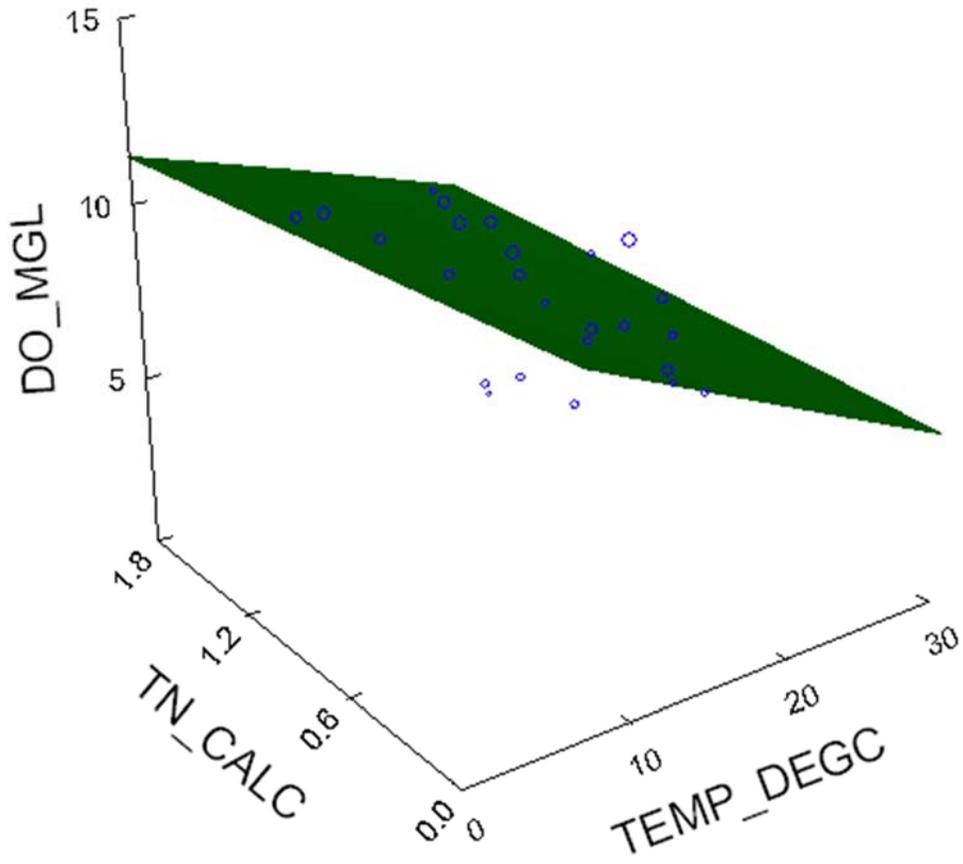
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	14.983	1.192	0.000		12.575	0.000
TN_CALC	-2.043	0.940	-0.257	0.982	-2.173	0.041
TEMP_DEGC	-0.334	0.052	-0.762	0.982	-6.457	0.000

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	128.223	2	64.111	25.544	0.000
Residual	55.217	22	2.510		

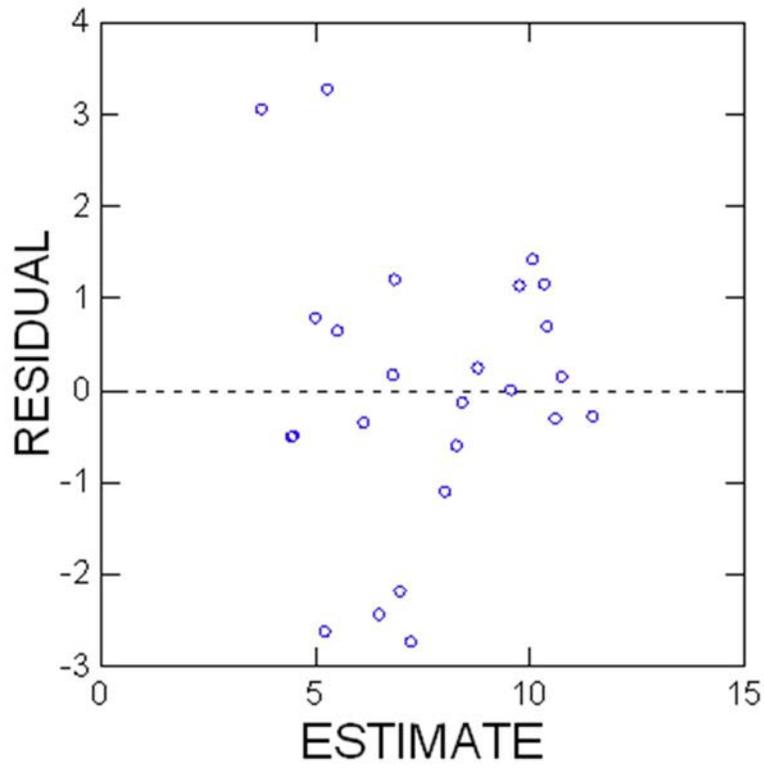
Durbin-Watson D Statistic	2.625
First Order Autocorrelation	-0.393

Information Criteria	
AIC	98.757
AIC (Corrected)	100.757
Schwarz's BIC	103.632

### Fitted Model Plot



Plot of Residuals vs Predicted Values



## Appendix E

```
> REGRESS
> MODEL DO_MGL = CONSTANT+LNTP
```

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.168
Squared Multiple R	0.028
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.784

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	6.584	1.407	0.000		4.678	0.000
LNTP	-0.443	0.541	-0.168	1.000	-0.819	0.421

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.195	1	5.195	0.670	0.421
Residual	178.244	23	7.750		

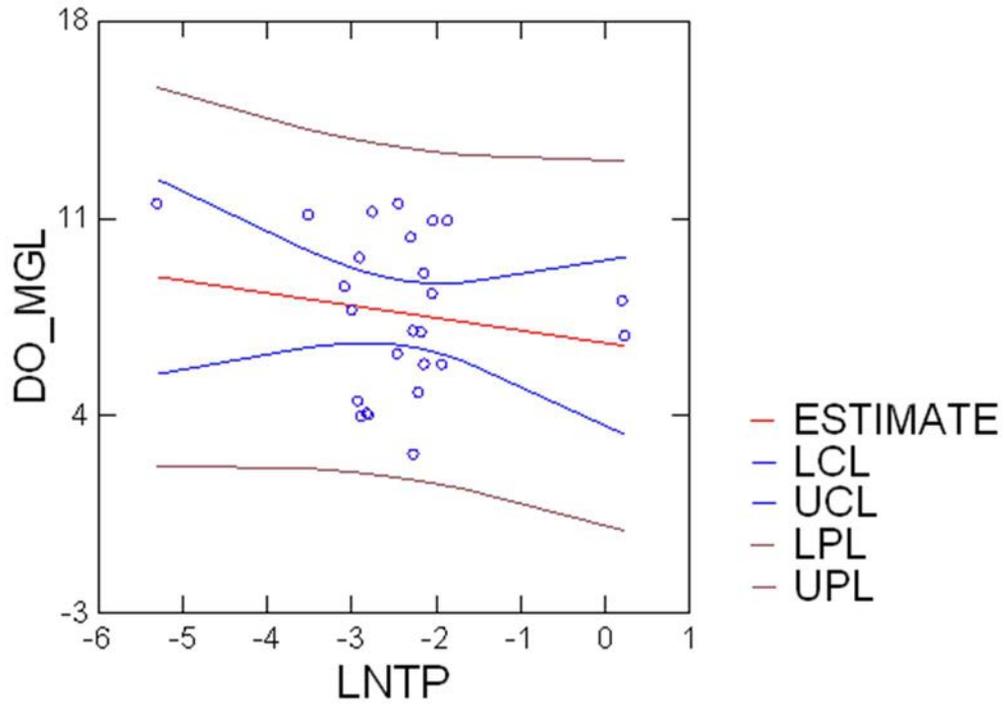
### WARNING

Case 25 has large Leverage (Leverage : 0.360)

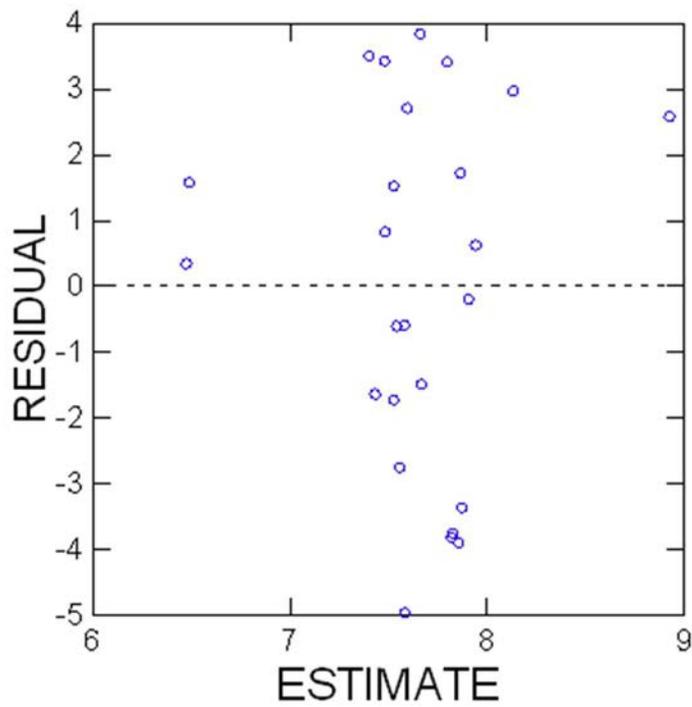
Durbin-Watson D Statistic	1.879
First Order Autocorrelation	0.022

Information Criteria	
AIC	126.054
AIC (Corrected)	127.197
Schwarz's BIC	129.710

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNNOX

▼ OLS Regression

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.056
Squared Multiple R	0.003
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.820

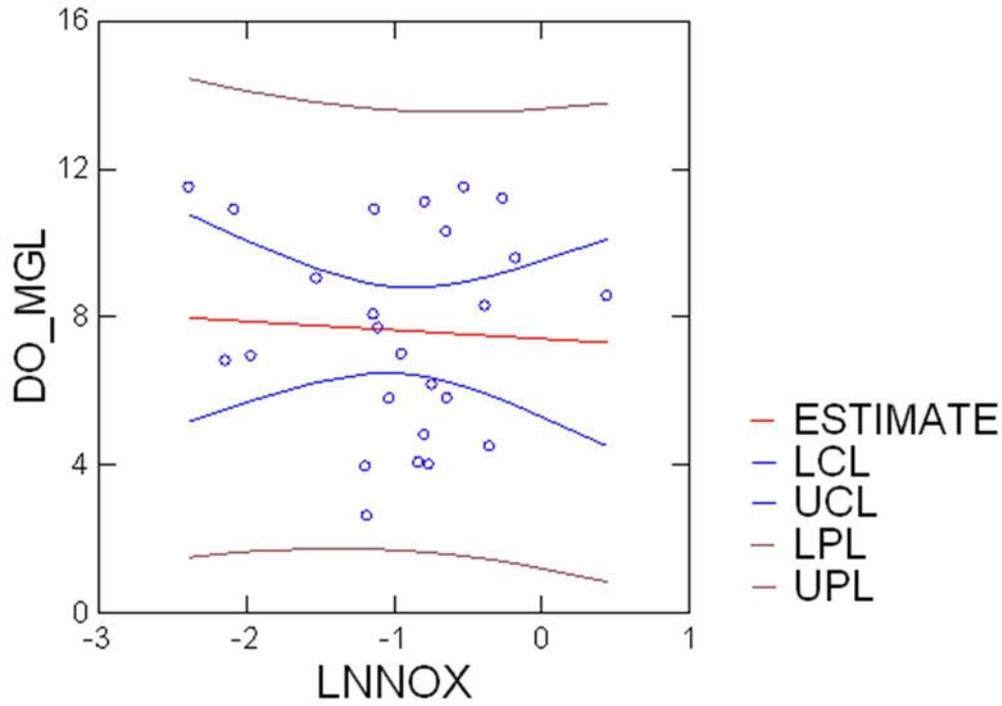
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.414	1.015	0.000		7.308	0.000
LNNOX	-0.235	0.869	-0.056	1.000	-0.271	0.789

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	0.582	1	0.582	0.073	0.789
Residual	182.858	23	7.950		

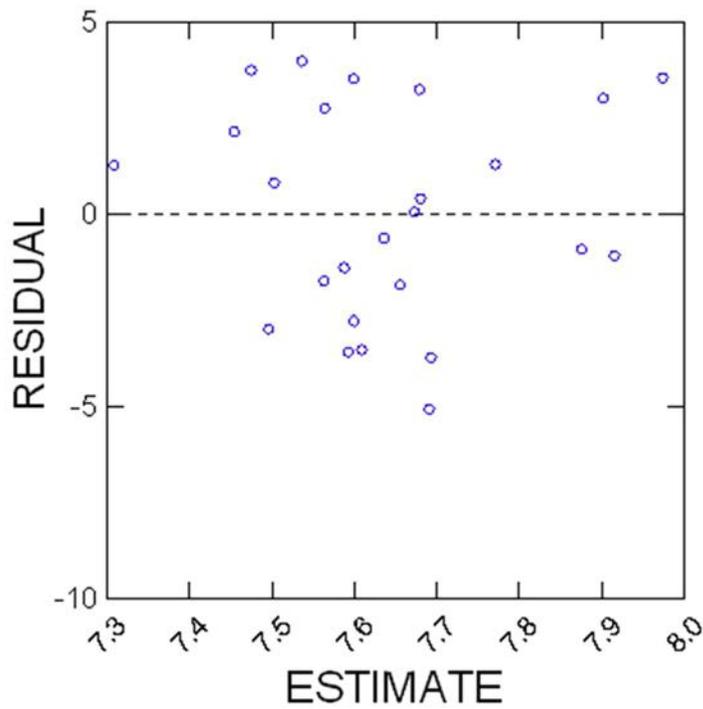
Durbin-Watson D Statistic	1.823
First Order Autocorrelation	0.064

Information Criteria	
AIC	126.693
AIC (Corrected)	127.836
Schwarz's BIC	130.349

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTKN

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.582
Squared Multiple R	0.339
Adjusted Squared Multiple R	0.310
Standard Error of Estimate	2.297

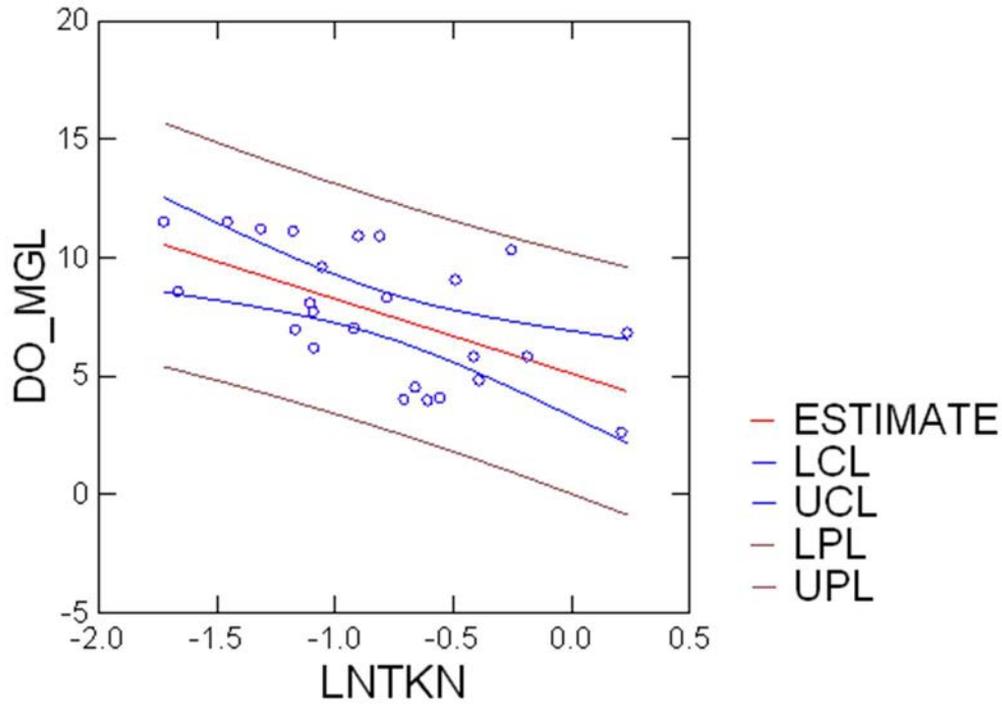
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.117	0.868	0.000		5.899	0.000
LNTKN	-3.157	0.920	-0.582	1.000	-3.431	0.002

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.112	1	62.112	11.775	0.002
Residual	121.327	23	5.275		

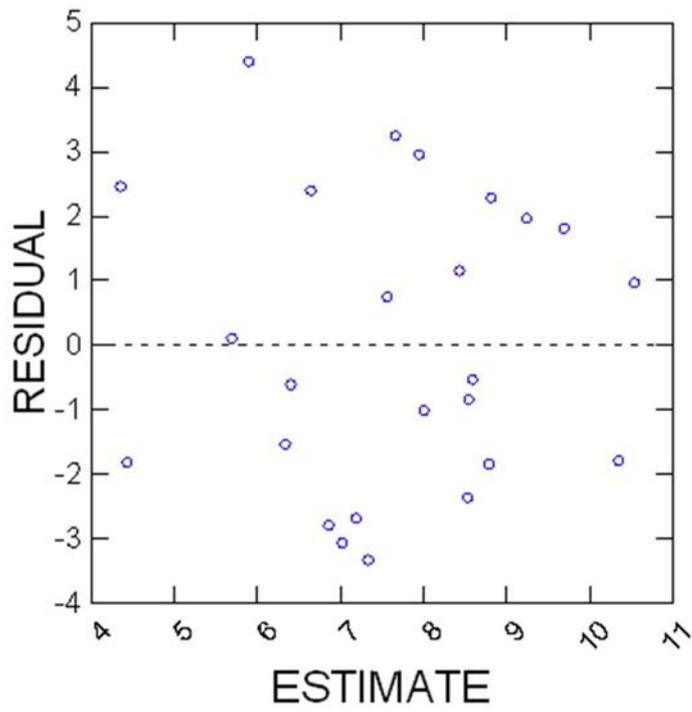
Durbin-Watson D Statistic	1.868
First Order Autocorrelation	0.035

Information Criteria	
AIC	116.437
AIC (Corrected)	117.580
Schwarz's BIC	120.094

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTN

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.390
Squared Multiple R	0.152
Adjusted Squared Multiple R	0.115
Standard Error of Estimate	2.601

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	7.378	0.536	0.000		13.759
LNTN	-2.623	1.293	-0.390	1.000	2.028

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	27.835	1	27.835	4.114	0.054
Residual	155.605	23	6.765		

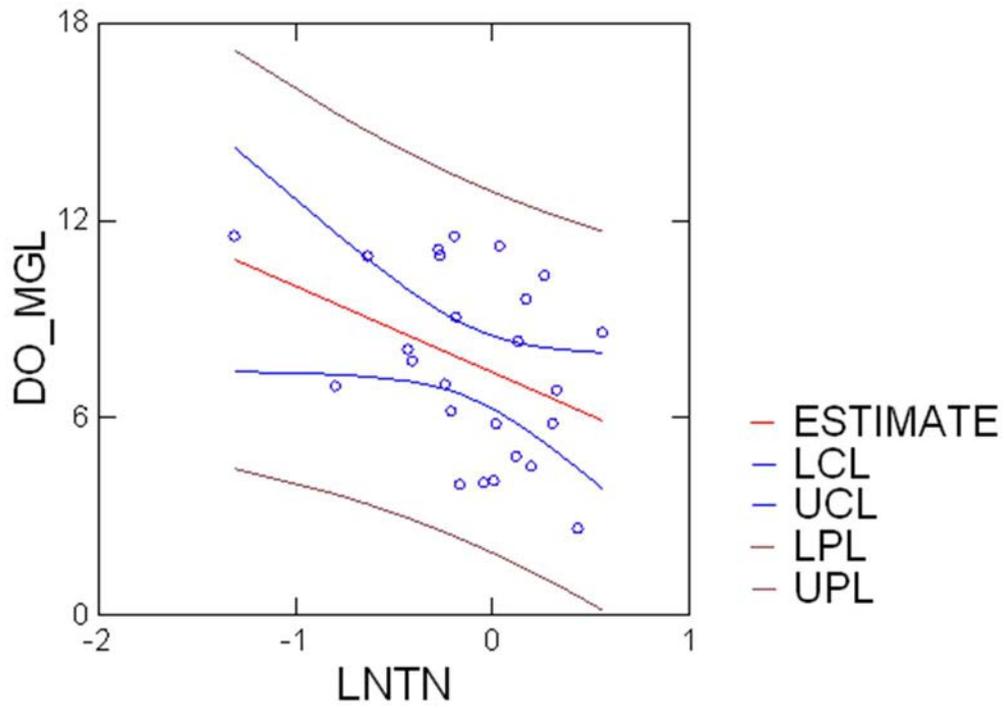
**WARNING**

Case 25 has large Leverage (Leverage : 0.399)

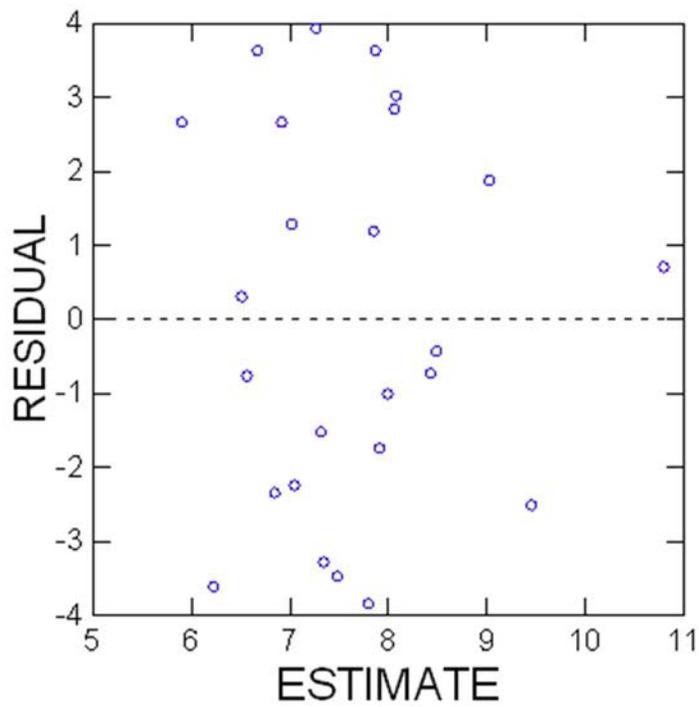
Durbin-Watson D Statistic	2.105
First Order Autocorrelation	-0.071

Information Criteria	
AIC	122.658
AIC (Corrected)	123.801
Schwarz's BIC	126.315

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTURB

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.111
Squared Multiple R	0.012
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.807

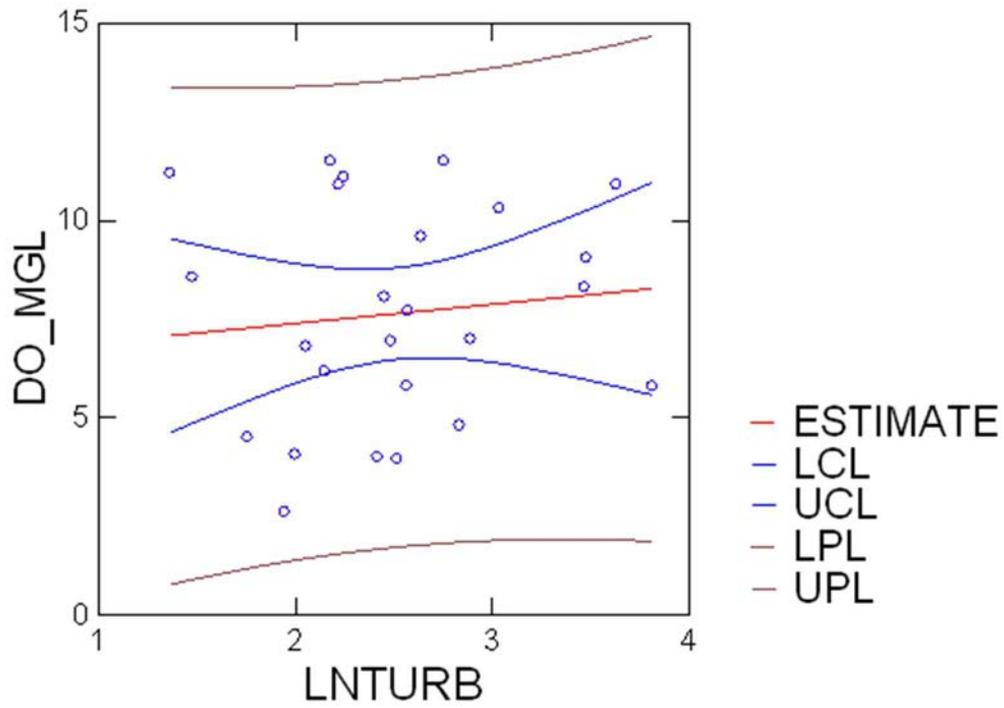
Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	6.419	2.357	0.000		2.724
LNTURB	0.486	0.909	0.111	1.000	0.535

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.251	1	2.251	0.286	0.598
Residual	181.188	23	7.878		

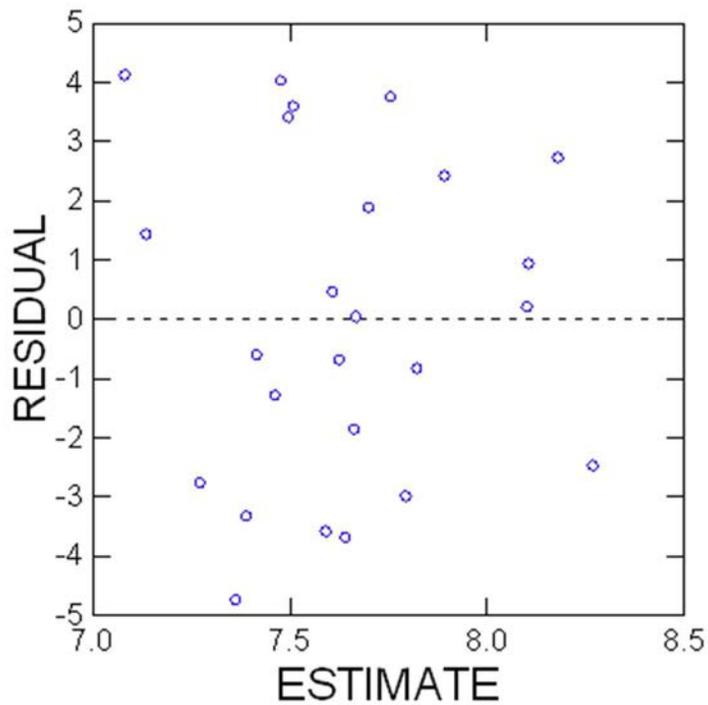
Durbin-Watson D Statistic	1.869
First Order Autocorrelation	0.044

Information Criteria	
AIC	126.463
AIC (Corrected)	127.606
Schwarz's BIC	130.120

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNNH3N

9 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	17
Multiple R	0.362
Squared Multiple R	0.131
Adjusted Squared Multiple R	0.073
Standard Error of Estimate	2.383

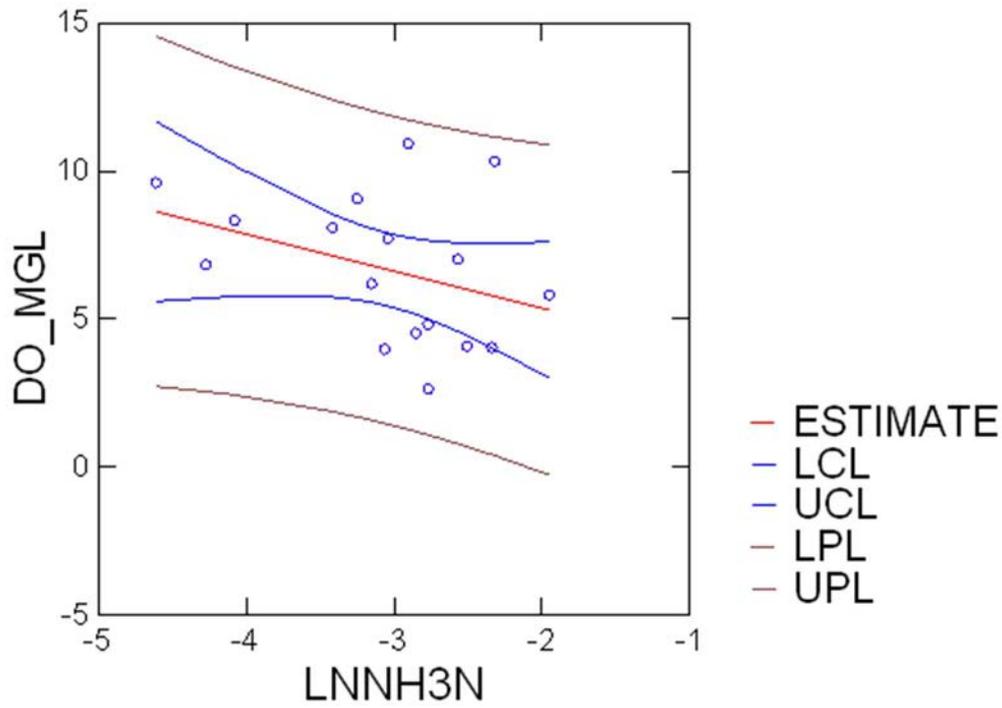
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value	
CONSTANT	2.867	2.603	0.000	1.101	0.288	
LNNH3N	-1.252	0.833	-0.362	1.000	0.154	

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	12.812	1	12.812	2.256	0.154
Residual	85.167	15	5.678		

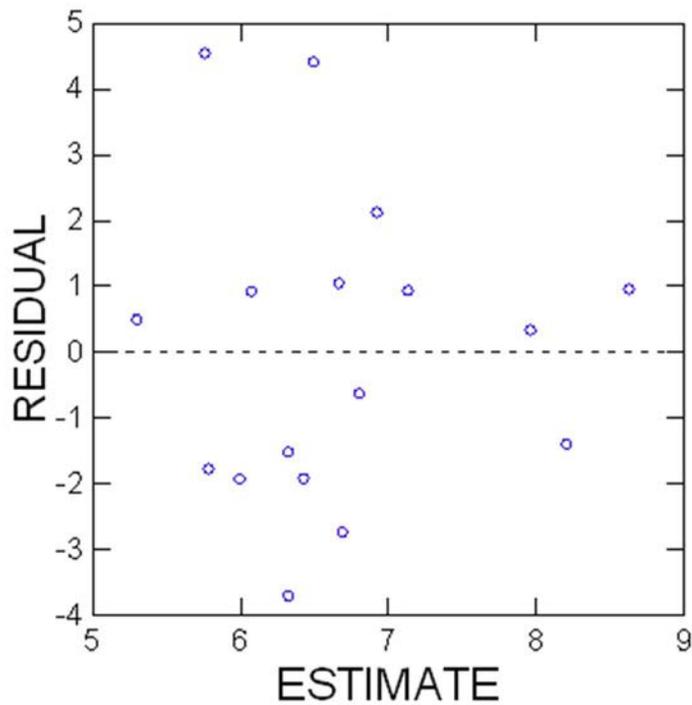
Durbin-Watson D Statistic	1.780
First Order Autocorrelation	0.083

Information Criteria	
AIC	81.638
AIC (Corrected)	83.484
Schwarz's BIC	84.137

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



## Appendix E

> REGRESS

> MODEL DO\_MGL = CONSTANT+LNNH3N+TEMP\_DEGC+LNTTP+LNNOX+LNTKN+LNTN+LNTURB

### Stepwise Selection of Variables

9 case(s) are deleted due to missing data.

Step number : 0

R : 0.958

R-square : 0.917

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	LNNH3N	0.563	0.716	0.163	0.215	1	0.619	0.452
3	TEMP_DEGC	-0.372	0.050	-0.903	0.626	1	55.447	0.000
4	LNTTP	0.534	0.338	0.207	0.536	1	2.493	0.149
5	LNNOX	-6.087	2.500	-1.140	0.042	1	5.927	0.038
6	LNTKN	-9.325	4.212	-1.549	0.019	1	4.902	0.054
7	LNTN	9.021	5.882	0.931	0.025	1	2.352	0.159
8	LNTURB	0.669	0.451	0.159	0.802	1	2.197	0.172

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
	none					

Information Criteria	
AIC	53.686
AIC (Corrected)	79.400
Schwarz's BIC	61.185

Dependent Variable : DO\_MGL

Minimum Tolerance for Entry into Model : 0.000

Backward Stepwise with Alpha-to-Enter : 0.150

Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1

R : 0.955

R-square : 0.911

Term Removed : LNNH3N

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.359	0.046	-0.873	0.696	1	59.898	0.000
4	LNTTP	0.501	0.329	0.195	0.544	1	2.323	0.158
5	LNNOX	-4.507	1.461	-0.845	0.118	1	9.520	0.012
6	LNTKN	-6.489	2.135	-1.078	0.070	1	9.234	0.012
7	LNTN	5.090	3.040	0.525	0.090	1	2.802	0.125
8	LNTURB	0.631	0.440	0.150	0.812	1	2.057	0.182

Appendix E

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	0.254	0.215	1	0.619	0.452

Information Criteria	
AIC	52.816
AIC (Corrected)	70.816
Schwarz's BIC	59.482

Step number : 2  
R : 0.945  
R-square : 0.893  
Term Removed : LNTURB

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.381	0.046	-0.925	0.778	1	68.621	0.000
4	LNTTP	0.565	0.341	0.219	0.554	1	2.740	0.126
5	LNNOX	-4.070	1.496	-0.763	0.124	1	7.404	0.020
6	LNTKN	-5.709	2.162	-0.948	0.075	1	6.974	0.023
7	LNTN	3.801	3.041	0.392	0.099	1	1.562	0.237

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	0.186	0.218	1	0.357	0.563
8	LNTURB	0.413	0.812	1	2.057	0.182

Information Criteria	
AIC	53.996
AIC (Corrected)	66.441
Schwarz's BIC	59.829

Step number : 3  
R : 0.937  
R-square : 0.878  
Term Removed : LNTN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.379	0.047	-0.921	0.779	1	65.018	0.000
4	LNTTP	0.716	0.327	0.278	0.633	1	4.798	0.049
5	LNNOX	-2.496	0.826	-0.468	0.425	1	9.133	0.011
6	LNTKN	-3.148	0.706	-0.523	0.739	1	19.883	0.001

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	0.211	0.807	1	0.513	0.489
7	LNTN	0.353	0.099	1	1.562	0.237
8	LNTURB	0.265	0.889	1	0.831	0.382

Appendix E

Information Criteria	
AIC	54.254
AIC (Corrected)	62.654
Schwarz's BIC	59.253

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.915
Squared Multiple R	0.838
Adjusted Squared Multiple R	0.805
Standard Error of Estimate	1.220

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	11.297	1.147	0.000		9.848	0.000
TEMP_DEGC	-0.322	0.043	-0.734	0.846	-7.498	0.000
LNTPI	0.646	0.276	0.245	0.739	2.340	0.030
LNNOX	-0.986	0.385	-0.236	0.954	-2.560	0.019
LNTKN	-2.616	0.586	-0.482	0.695	-4.461	0.000

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	153.647	4	38.412	25.786	0.000
Residual	29.792	20	1.490		

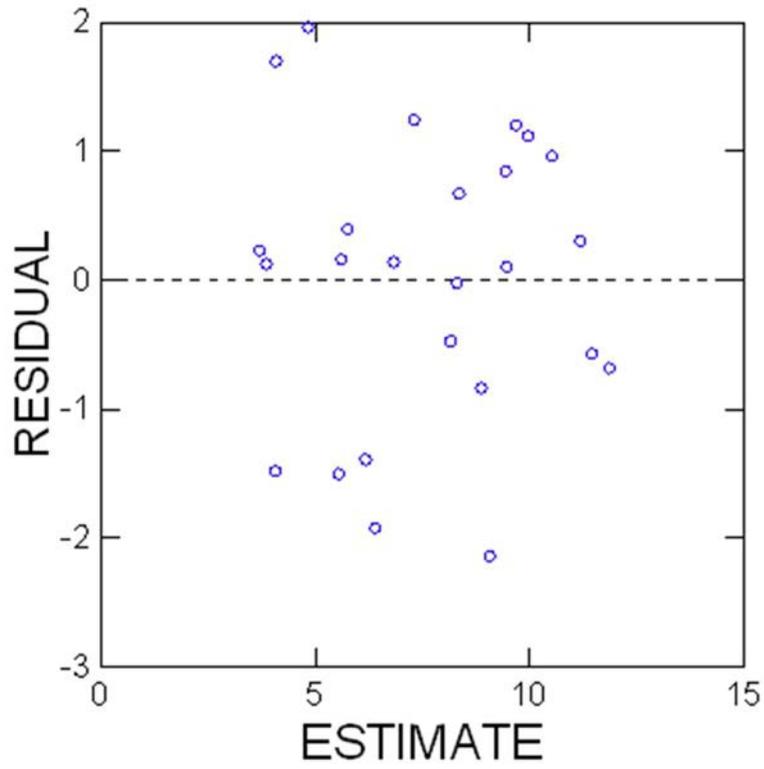
**WARNING**

Case 25 has large Leverage (Leverage : 0.655)

Durbin-Watson D Statistic	2.706
First Order Autocorrelation	-0.427

Information Criteria	
AIC	87.331
AIC (Corrected)	91.998
Schwarz's BIC	94.644

Plot of Residuals vs Predicted Values



Appendix E

File: C:\local work\ANRC WMPs\Mid White\LSaladoCr DO and nutrients.syz

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TKN\_RESULT

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.501
Squared Multiple R	0.251
Adjusted Squared Multiple R	0.218
Standard Error of Estimate	2.376

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	9.856	0.972	0.000	10.138	0.000
TKN_RESULT	-5.742	2.070	-0.501	1.000	0.011

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	43.445	1	43.445	7.698	0.011
Residual	129.812	23	5.644		

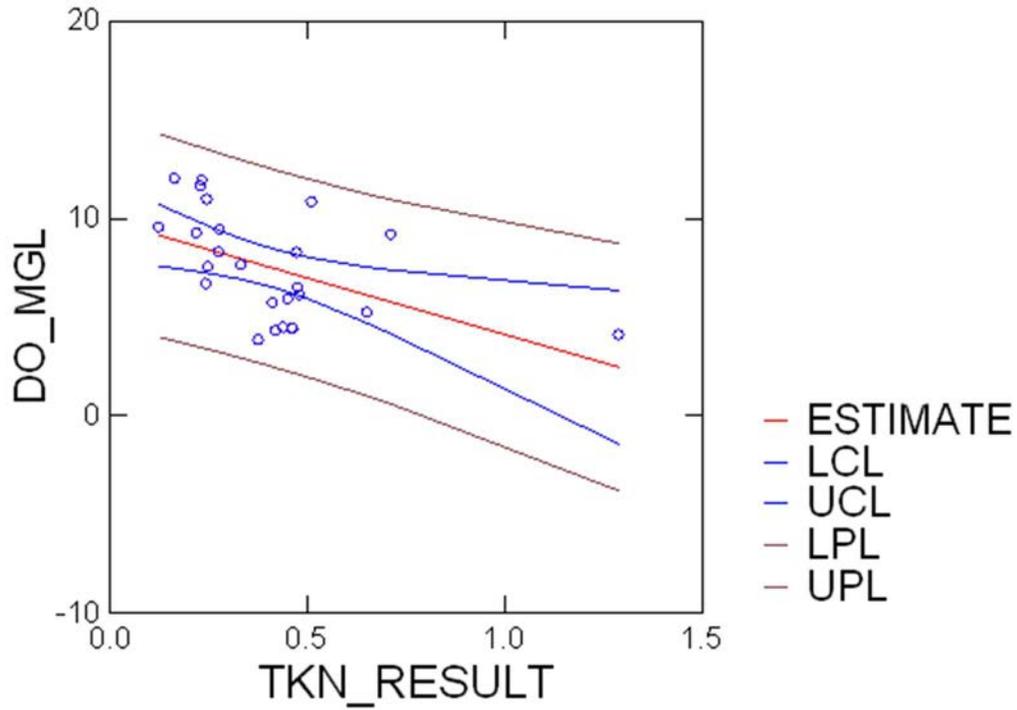
**WARNING**

Case 6 has large Leverage (Leverage : 0.628)

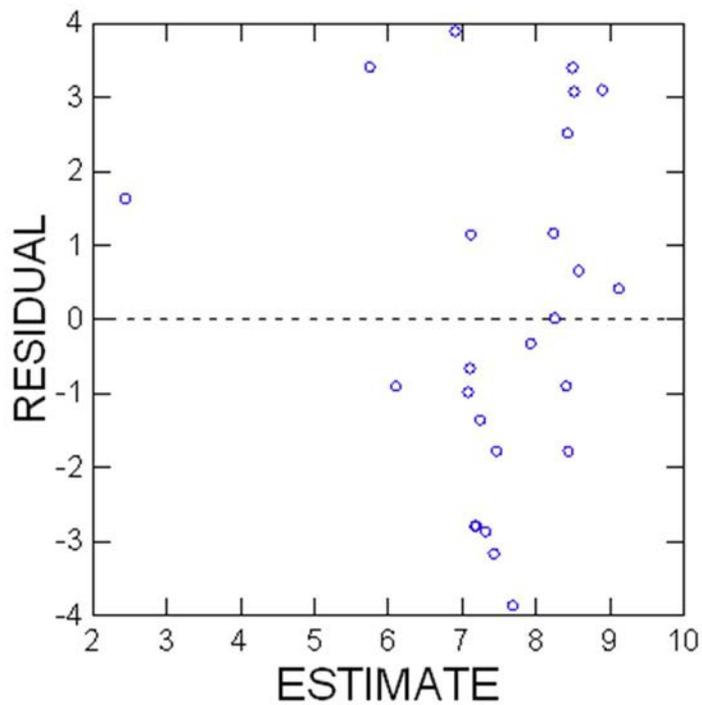
Durbin-Watson D Statistic	2.130
First Order Autocorrelation	-0.080

Information Criteria	
AIC	118.127
AIC (Corrected)	119.270
Schwarz's BIC	121.784

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+NH3N\_MGL

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.724
Squared Multiple R	0.525
Adjusted Squared Multiple R	0.505
Standard Error of Estimate	1.929

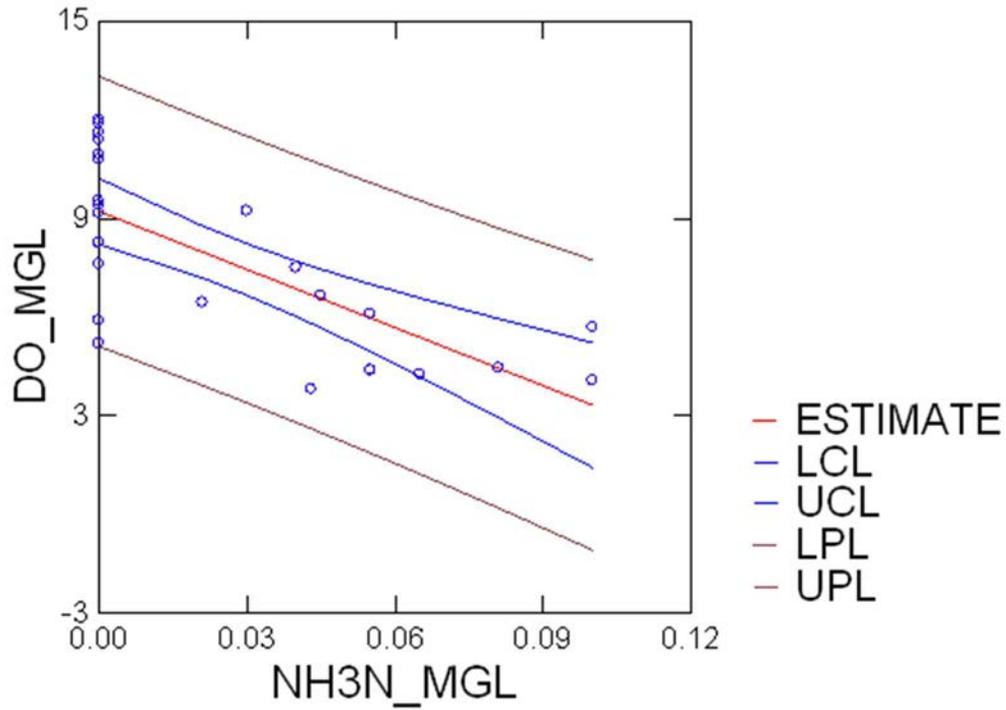
Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	9.217	0.485	0.000		0.000
NH3N_MGL	-58.959	11.451	-0.724	1.000	0.000

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	98.598	1	98.598	26.510	0.000
Residual	89.263	24	3.719		

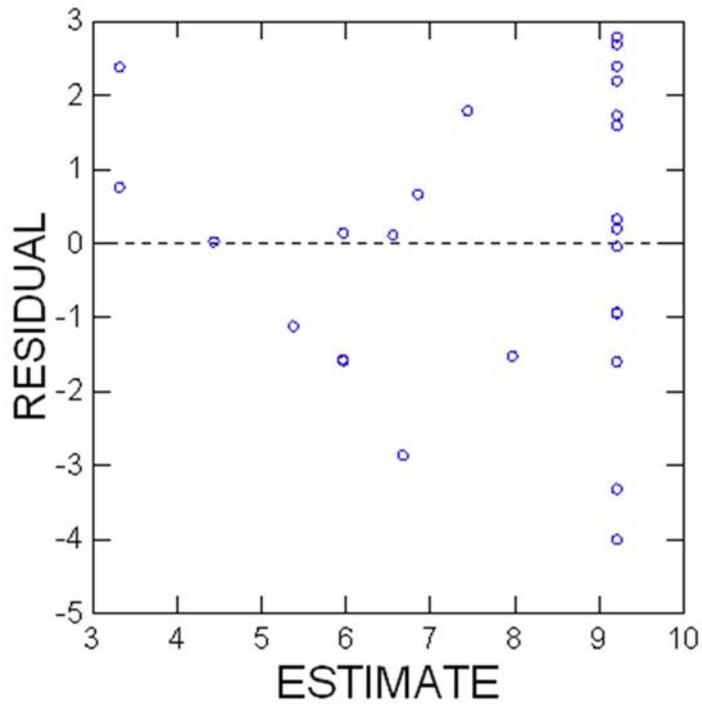
Durbin-Watson D Statistic	1.546
First Order Autocorrelation	0.136

Information Criteria	
AIC	111.856
AIC (Corrected)	112.947
Schwarz's BIC	115.630

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+NOX\_RESULT

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.555
Squared Multiple R	0.308
Adjusted Squared Multiple R	0.279
Standard Error of Estimate	2.327

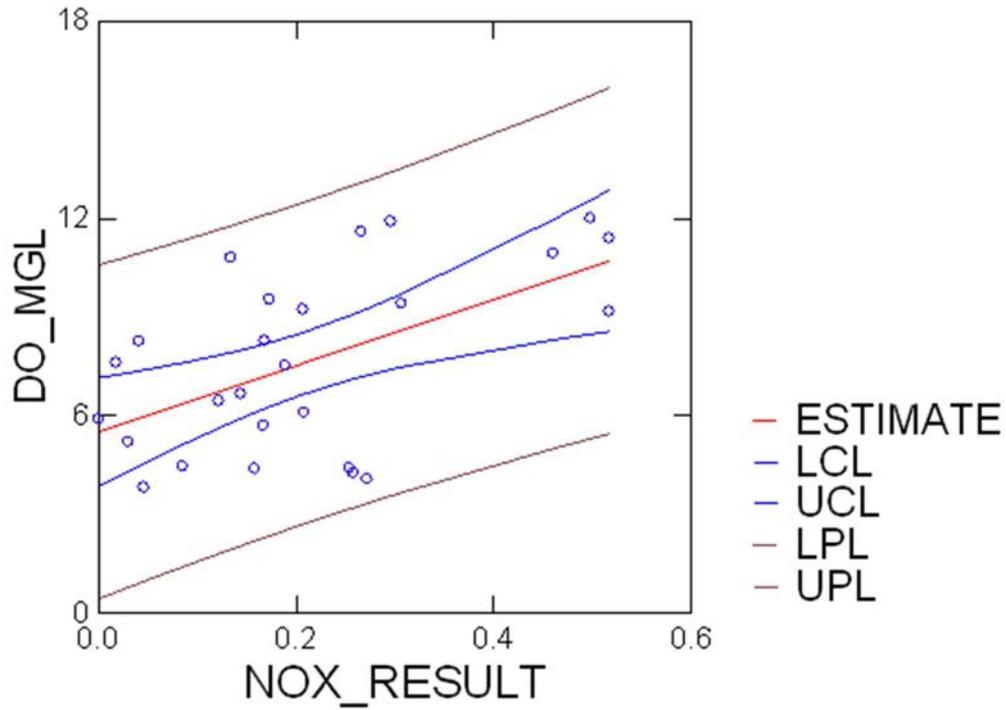
Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	5.512	0.798	0.000	6.904	0.000
NOX_RESULT	10.058	3.076	0.555	1.000	0.003

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	57.885	1	57.885	10.688	0.003
Residual	129.977	24	5.416		

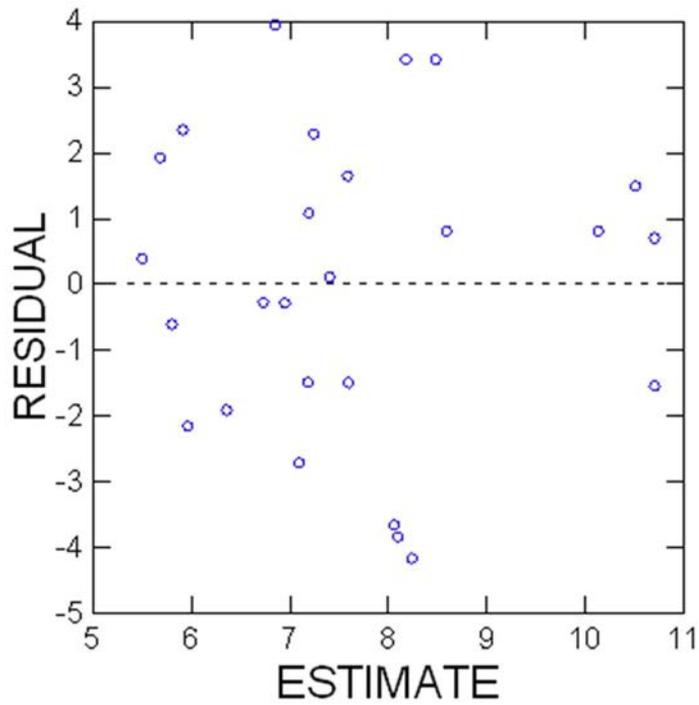
Durbin-Watson D Statistic	1.777
First Order Autocorrelation	0.110

Information Criteria	
AIC	121.626
AIC (Corrected)	122.716
Schwarz's BIC	125.400

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TN\_CALC

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.173
Squared Multiple R	0.030
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.703

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value	
CONSTANT	8.560	1.366	0.000		6.265	0.000
TN_CALC	-1.732	2.055	-0.173	1.000	0.843	0.408

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.189	1	5.189	0.710	0.408
Residual	168.068	23	7.307		

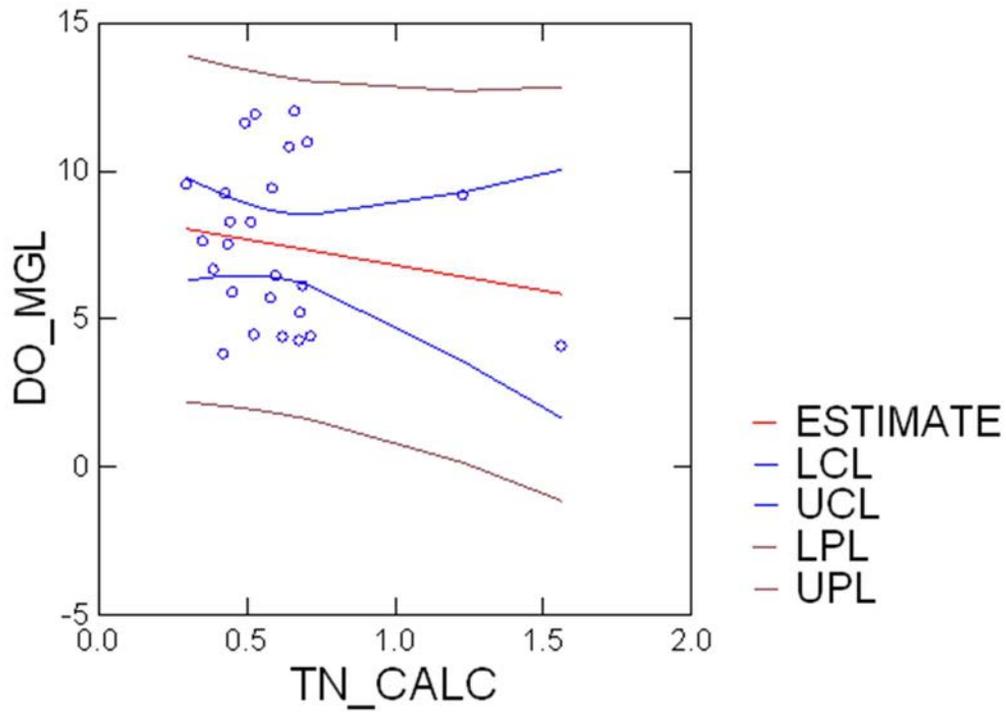
**WARNING**

Case 6 has large Leverage (Leverage : 0.563)

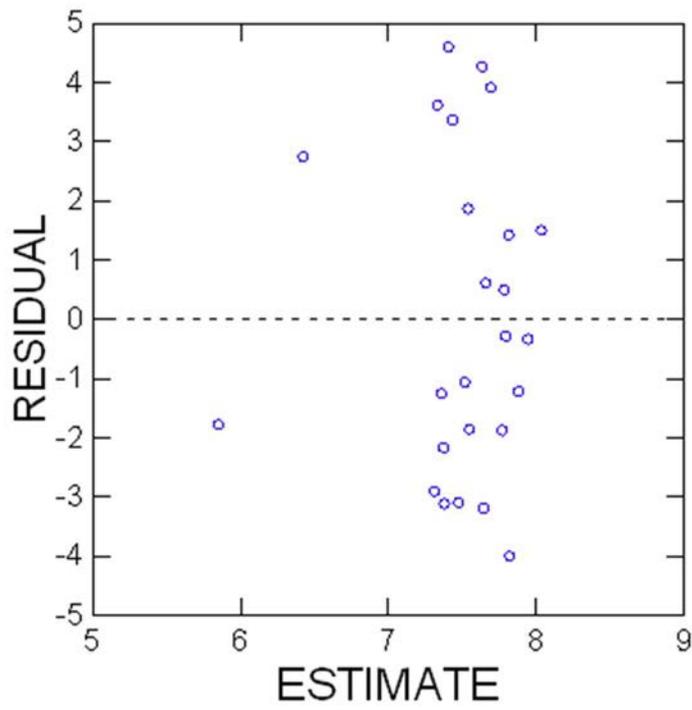
Durbin-Watson D Statistic	2.008
First Order Autocorrelation	-0.022

Information Criteria	
AIC	124.584
AIC (Corrected)	125.727
Schwarz's BIC	128.241

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TP\_MGL

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.140
Squared Multiple R	0.020
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.770

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	7.834	0.603	0.000		0.000
TP_MGL	-1.640	2.369	-0.140	1.000	0.496

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	3.676	1	3.676	0.479	0.496
Residual	184.185	24	7.674		

**WARNING**

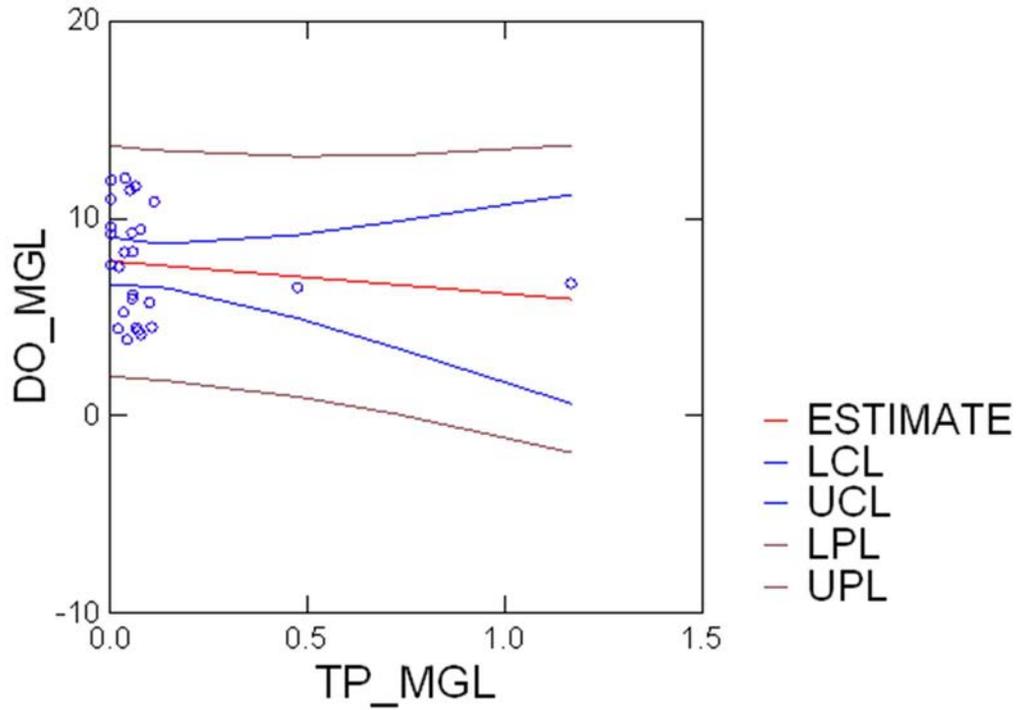
Case 17 has large Leverage (Leverage : 0.318)

Case 28 has large Leverage (Leverage : 0.860)

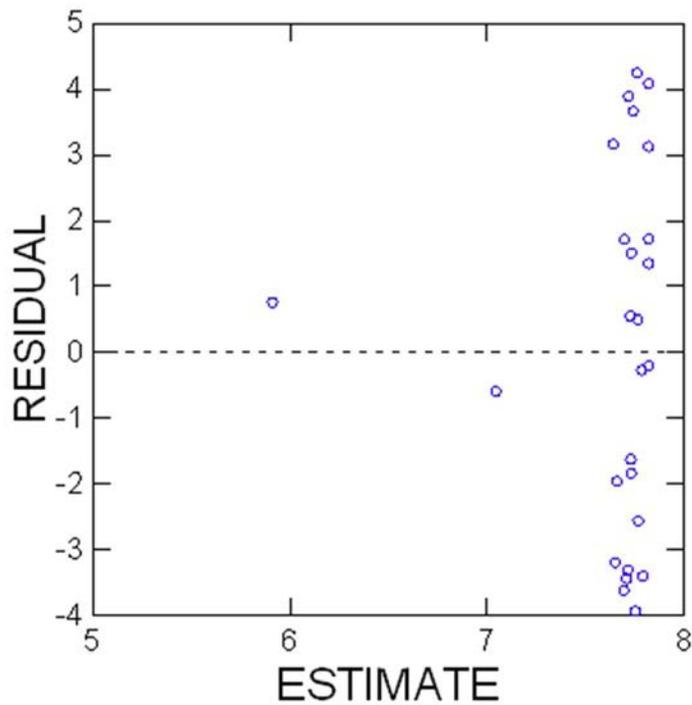
Durbin-Watson D Statistic	1.777
First Order Autocorrelation	0.092

Information Criteria	
AIC	130.689
AIC (Corrected)	131.780
Schwarz's BIC	134.463

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+BOD\_MGL

18 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.405
Squared Multiple R	0.164
Adjusted Squared Multiple R	0.060
Standard Error of Estimate	2.870

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.054	1.444	0.000		6.269	0.000
BOD_MGL	-1.456	1.162	-0.405	1.000	-1.253	0.245

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	12.945	1	12.945	1.571	0.245
Residual	65.911	8	8.239		

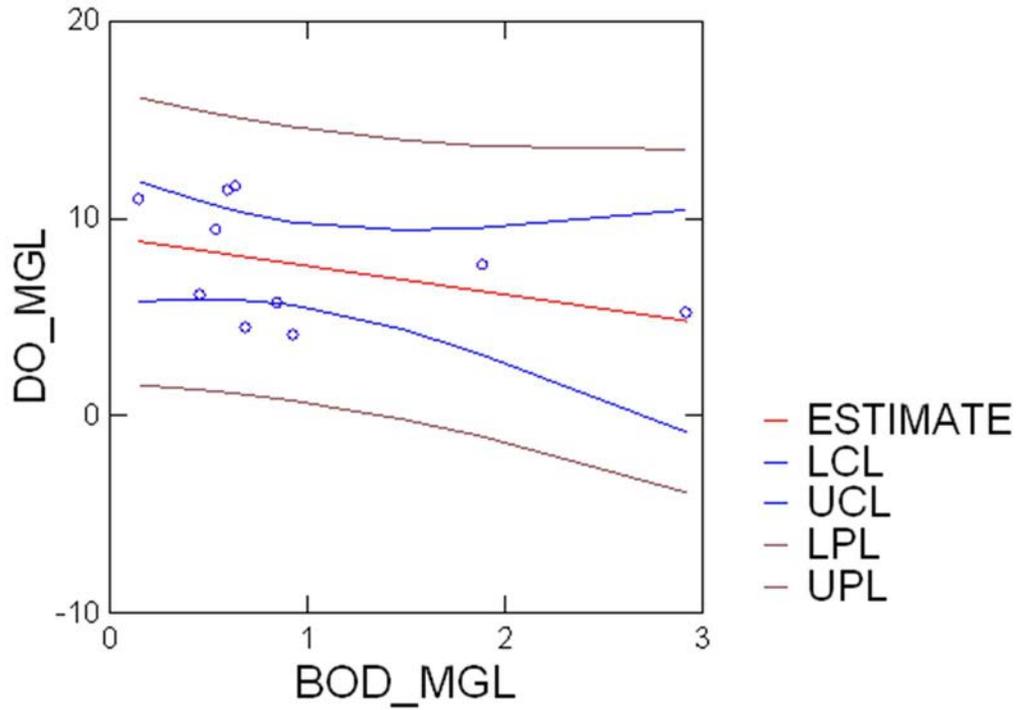
**WARNING**

Case 1 has large Leverage (Leverage : 0.725)

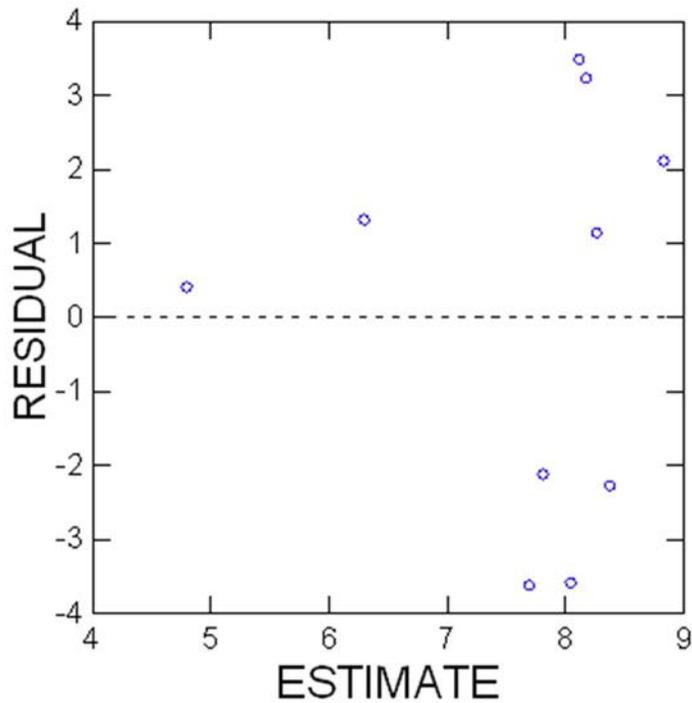
Durbin-Watson D Statistic	1.625
First Order Autocorrelation	0.173

Information Criteria	
AIC	53.236
AIC (Corrected)	57.236
Schwarz's BIC	54.144

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TEMP\_DEGC

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.785
Squared Multiple R	0.616
Adjusted Squared Multiple R	0.600
Standard Error of Estimate	1.733

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	12.358	0.831	0.000		14.8750.000
TEMP_DEGC	-0.285	0.046	-0.785	1.000	6.2070.000

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	115.752	1	115.752	38.526	0.000
Residual	72.109	24	3.005		

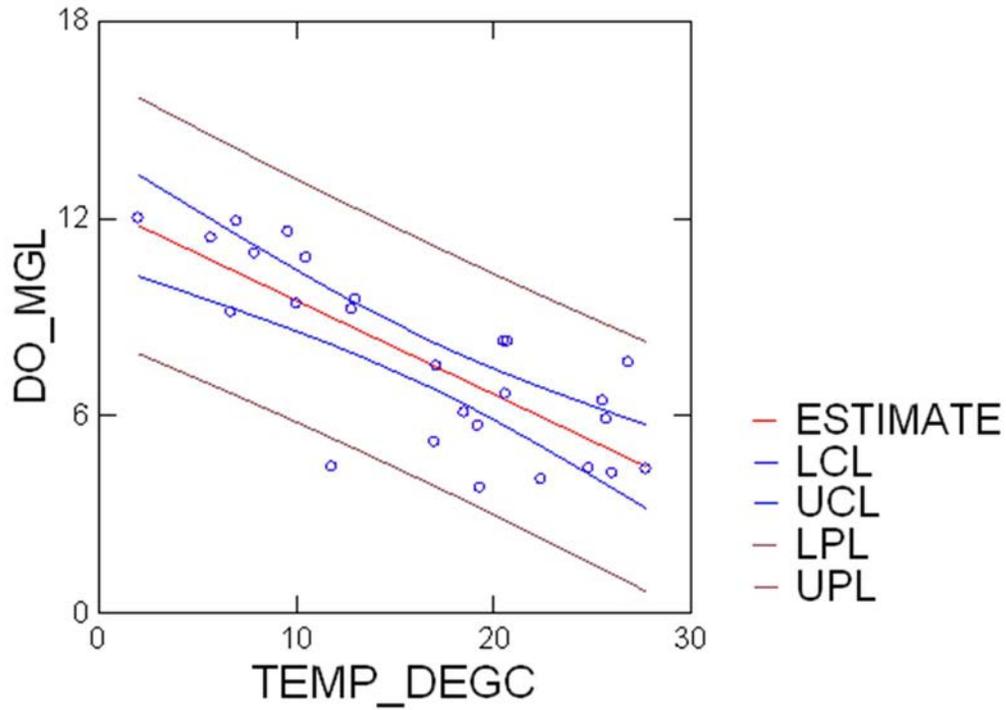
**WARNING**

Case 7 is an Outlier (Studentized Residual : -3.157)

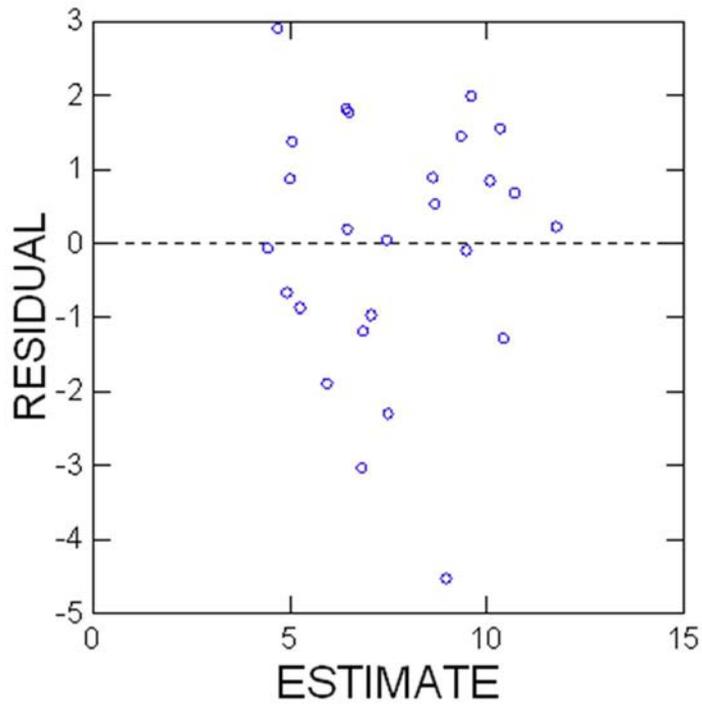
Durbin-Watson D Statistic	1.706
First Order Autocorrelation	0.110

Information Criteria	
AIC	106.307
AIC (Corrected)	107.398
Schwarz's BIC	110.081

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+TURBIDITY\_NTU

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.116
Squared Multiple R	0.013
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.779

Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	8.016	0.839	0.000	9.556	0.000
TURBIDITY_NTU	-0.028	0.049	-0.116	1.000	0.574

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.508	1	2.508	0.325	0.574
Residual	185.354	24	7.723		

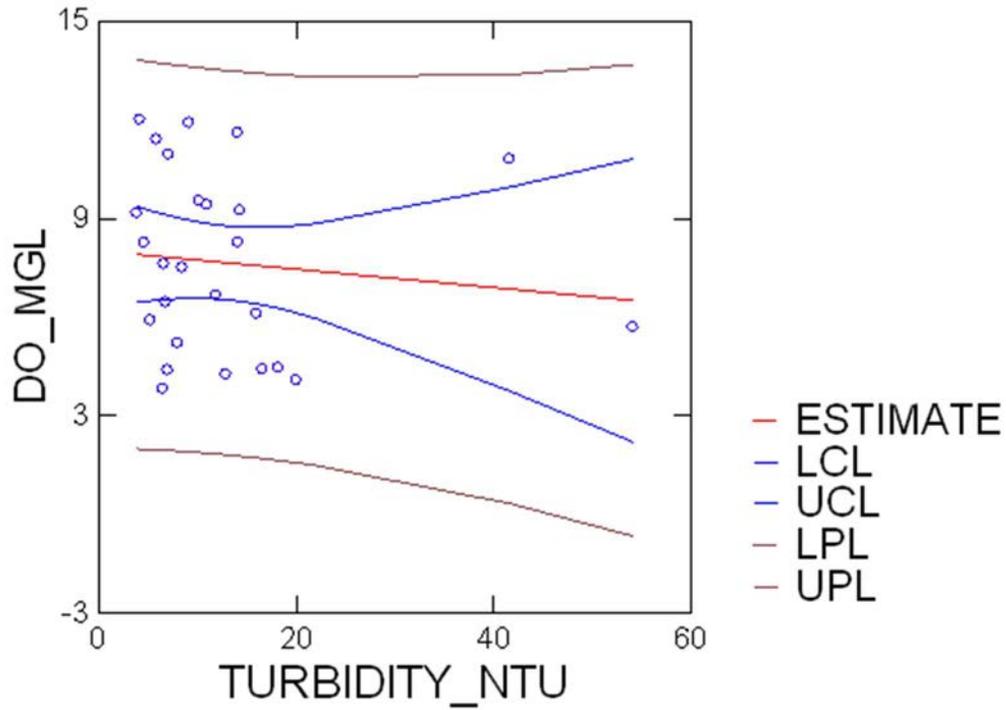
**WARNING**

Case 10 has large Leverage (Leverage : 0.563)

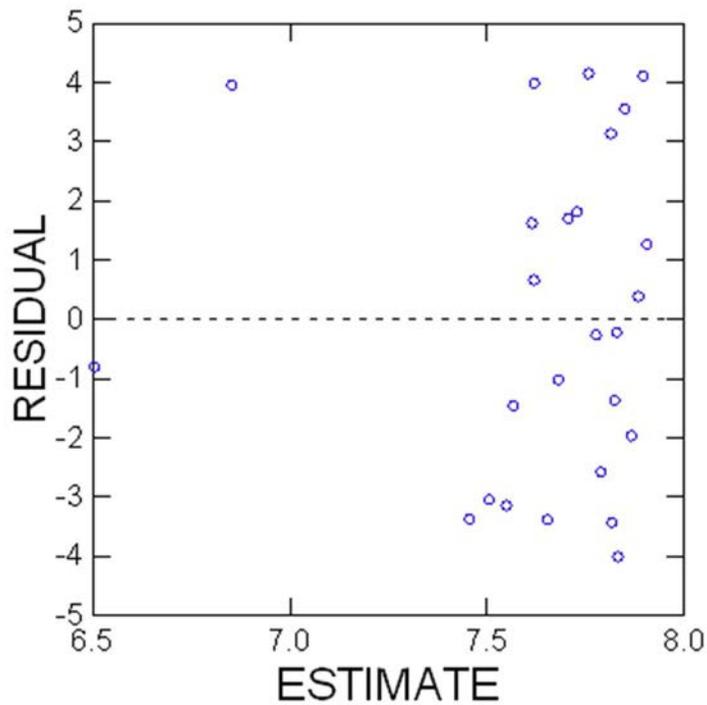
Durbin-Watson D Statistic	1.695
First Order Autocorrelation	0.132

Information Criteria	
AIC	130.853
AIC (Corrected)	131.944
Schwarz's BIC	134.627

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



## Appendix E

```
> REGRESS
> MODEL DO_MGL =
CONSTANT+TURBIDITY_NTU+NOX_RESULT+TKN_RESULT+TN_CALC+TP_MGL+BOD_MGL+TEMP_DEGC+N
H3N_MGL
```

### Stepwise Selection of Variables

19 case(s) are deleted due to missing data.  
 Unable to enter effect 3.  
 This effect may fail tolerance checks.

Step number : 0  
 R : 0.993  
 R-square : 0.986

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.369	0.166	1.923	0.019	1	4.955	0.269
4	TKN_RESULT	0.000	34.718	0.000	0.001	1	2.981	0.334
5	TN_CALC	59.941	25.055	7.029	0.001	1	2.822	0.342
6	TP_MGL	-42.089	44.562	-5.192	0.038	1	2.778	0.344
7	BOD_MGL	-74.278	4.076	-1.007	0.009	1	4.849	0.271
8	TEMP_DEGC	-8.975	0.262	-2.756	0.038	1	2.547	0.356
9	NH3N_MGL	-0.417	70.815	-0.962	0.010	1	7.603	0.221

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
3	NOX_RESULT		0			

Effect 3 lost 1 degree(s) of freedom.

Information Criteria	
AIC	22.556
AIC (Corrected)	
Schwarz's BIC	24.331

The following effects have lost degrees of freedom.

Effect	Initial df	Lost df	Final df
NOX_RESULT	1	1	0

Dependent Variable : DO\_MGL  
 Minimum Tolerance for Entry into Model : 0.000  
 Backward Stepwise with Alpha-to-Enter : 0.150  
 Backward Stepwise with Alpha-to-Remove : 0.150

Nothing to do!

19 case(s) are deleted due to missing data.

## Appendix E

Dependent Variable	DO_MGL
N	9
Multiple R	0.993
Squared Multiple R	0.986
Adjusted Squared Multiple R	0.889
Standard Error of Estimate	0.935

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	28.168	10.756	0.000		2.619	0.232
TURBIDITY_NTU	0.369	0.166	1.923	0.019	2.226	0.269
TKN_RESULT	59.941	34.718	7.029	0.001	1.727	0.334
TN_CALC	-42.089	25.055	-5.192	0.001	-1.680	0.342
TP_MGL	-74.278	44.562	-1.007	0.038	-1.667	0.344
BOD_MGL	-8.975	4.076	-2.756	0.009	-2.202	0.271
TEMP_DEGC	-0.417	0.262	-0.962	0.038	-1.596	0.356
NH3N_MGL	-195.261	70.815	-3.206	0.010	-2.757	0.221

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.3237	8	8.903	10.184	0.237
Residual	0.874	1	0.874		

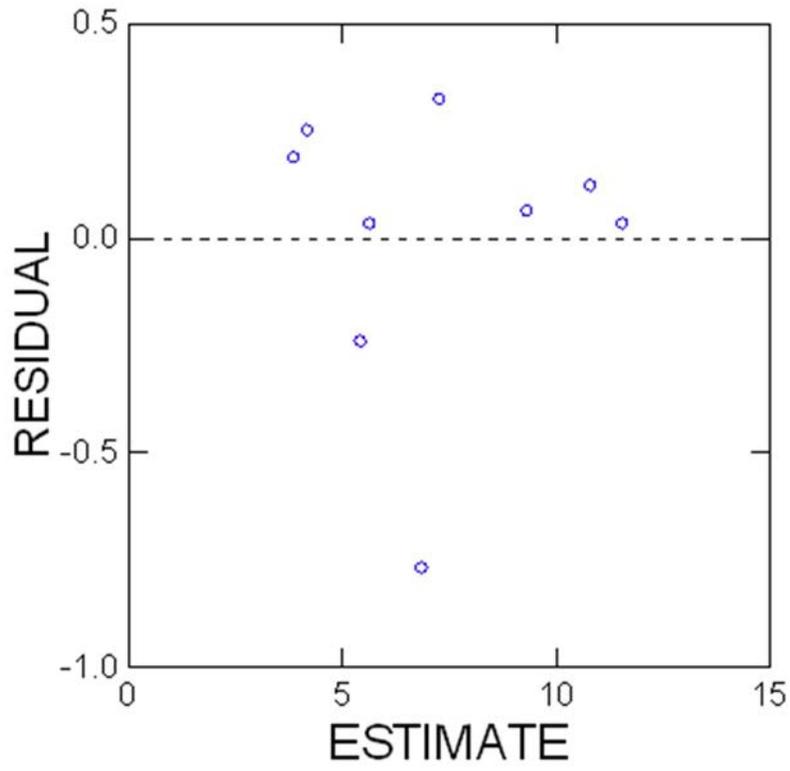
### WARNING

Case 1 has large Leverage (Leverage : 0.933)  
 Case 1 has large Influence (Studentized Residual : 1.750)  
 Case 2 has large Leverage (Leverage : 0.983)  
 Case 2 has large Influence (Studentized Residual : 7.309)  
 Case 3 has large Leverage (Leverage : 0.996)  
 Case 3 has large Influence (Studentized Residual : 27.899)  
 Case 6 has large Leverage (Leverage : 0.960)  
 Case 6 has large Influence (Studentized Residual : 2.998)  
 Case 7 has large Leverage (Leverage : 0.928)  
 Case 7 has large Influence (Studentized Residual : 1.608)  
 Case 9 has large Leverage (Leverage : 0.999)  
 Case 9 has large Influence (Studentized Residual : 97.646)  
 Case 10 has large Leverage (Leverage : 0.999)  
 Case 10 has large Influence (Studentized Residual : 100.423)  
 Case 11 has large Leverage (Leverage : 12.917)  
 Case 12 has large Leverage (Leverage : 0.881)  
 Case 12 has large Influence (Studentized Residual : 0.922)

Durbin-Watson D Statistic	2.149
First Order Autocorrelation	-0.168

Information Criteria	
AIC	22.556
AIC (Corrected)	
Schwarz's BIC	24.331

Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTP

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.343
Squared Multiple R	0.118
Adjusted Squared Multiple R	0.081
Standard Error of Estimate	2.628

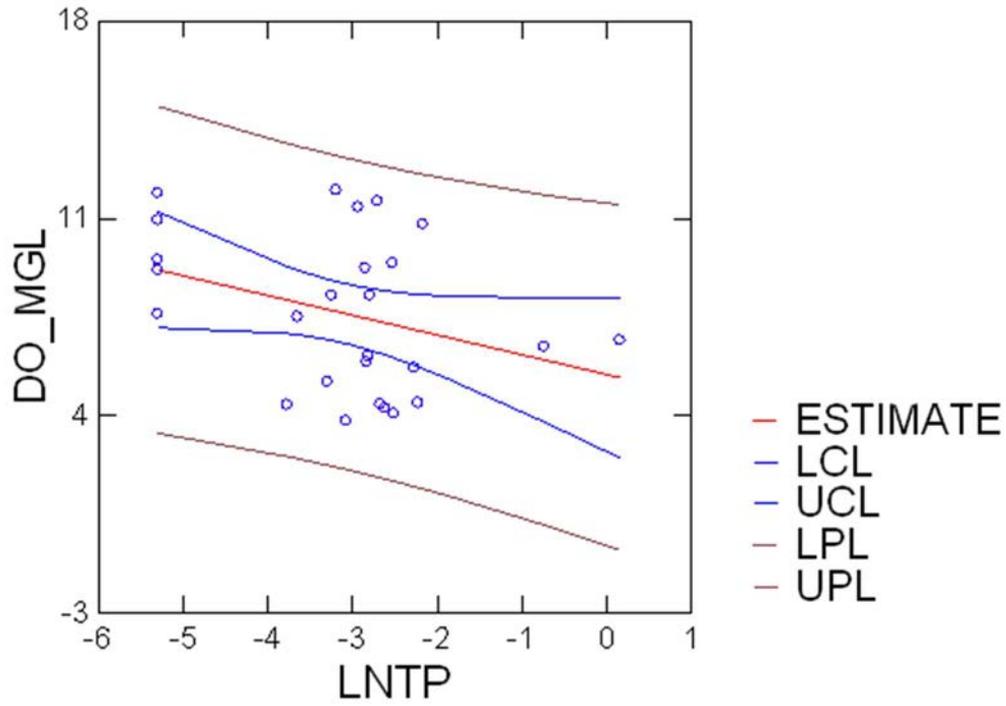
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.462	1.328	0.000		4.114	0.000
LNTP	-0.701	0.392	-0.343	1.000	-1.791	0.086

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	22.143	1	22.143	3.207	0.086
Residual	165.718	24	6.905		

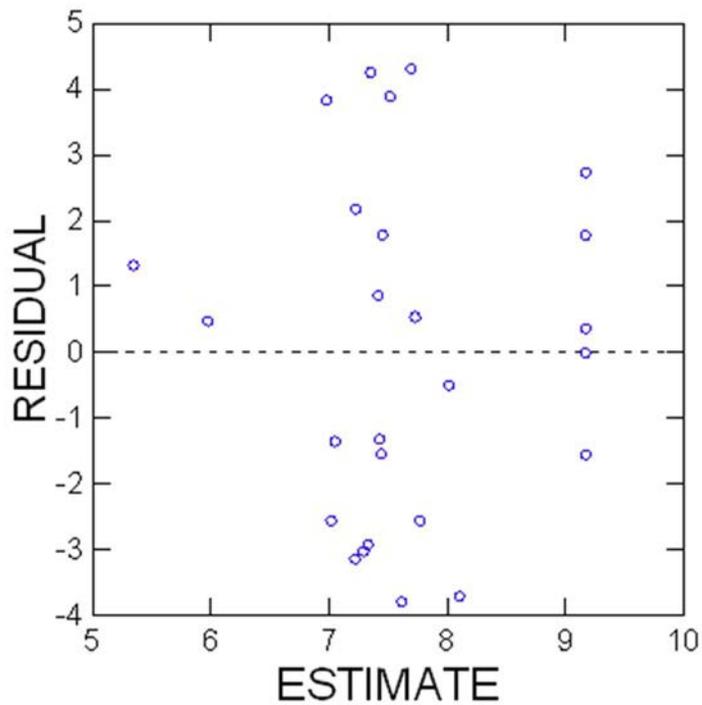
Durbin-Watson D Statistic	1.806
First Order Autocorrelation	0.072

Information Criteria	
AIC	127.942
AIC (Corrected)	129.033
Schwarz's BIC	131.716

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNNOX

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.434
Squared Multiple R	0.188
Adjusted Squared Multiple R	0.153
Standard Error of Estimate	2.553

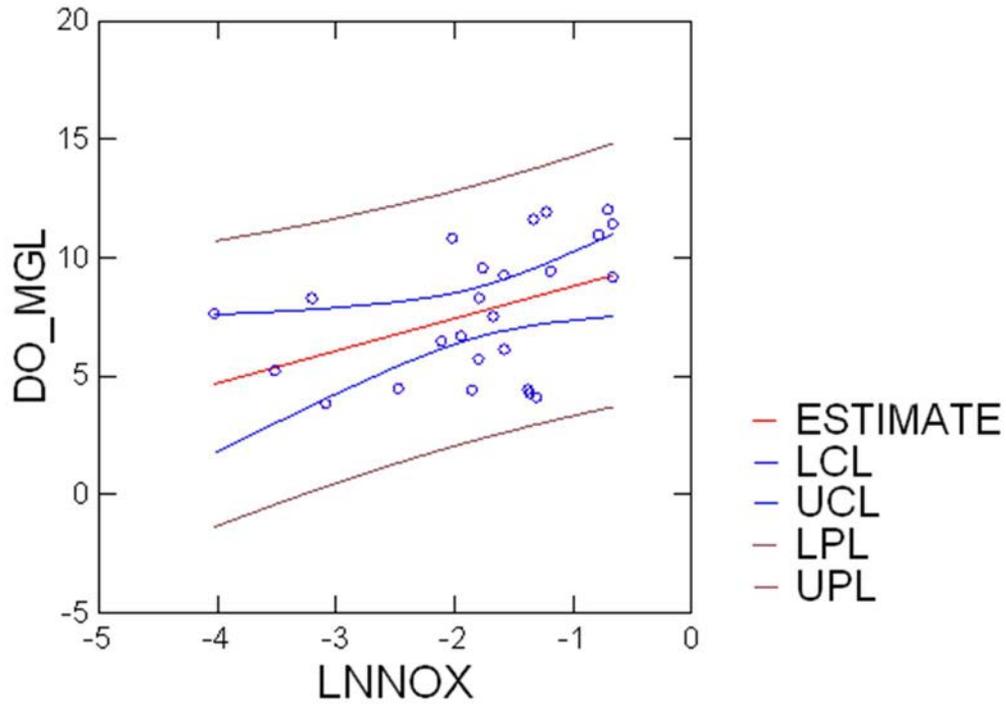
Regression Coefficients $B = (X'X)^{-1}X'Y$					
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value
CONSTANT	10.176	1.179	0.000	1.000	8.6330.000
LNNOX	1.368	0.592	0.434	1.000	2.3090.030

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	34.743	1	34.743	5.331	0.030
Residual	149.887	23	6.517		

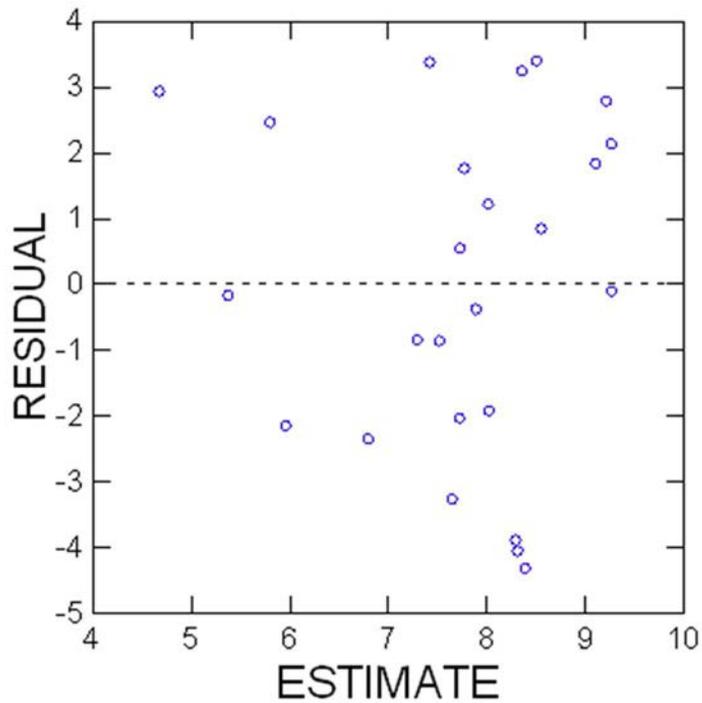
Durbin-Watson D Statistic	1.932
First Order Autocorrelation	0.031

Information Criteria	
AIC	121.722
AIC (Corrected)	122.865
Schwarz's BIC	125.379

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTKN

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.599
Squared Multiple R	0.359
Adjusted Squared Multiple R	0.331
Standard Error of Estimate	2.197

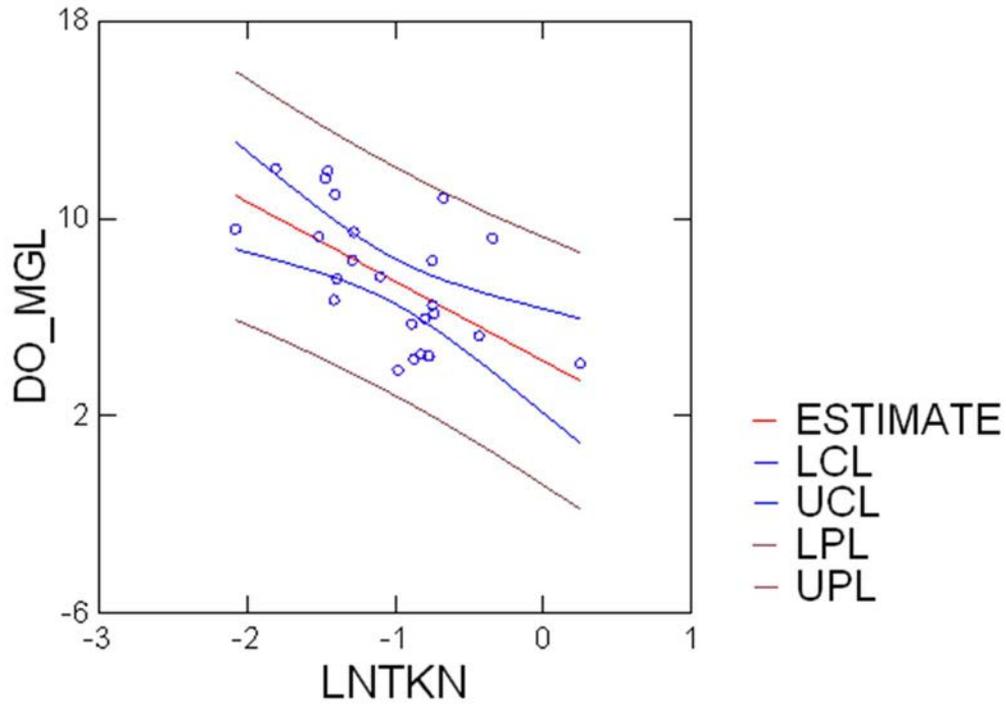
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	4.221	1.014	0.000		4.163	0.000
LNTKN	-3.229	0.899	-0.599	1.000	-3.592	0.002

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.253	1	62.253	12.899	0.002
Residual	111.004	23	4.826		

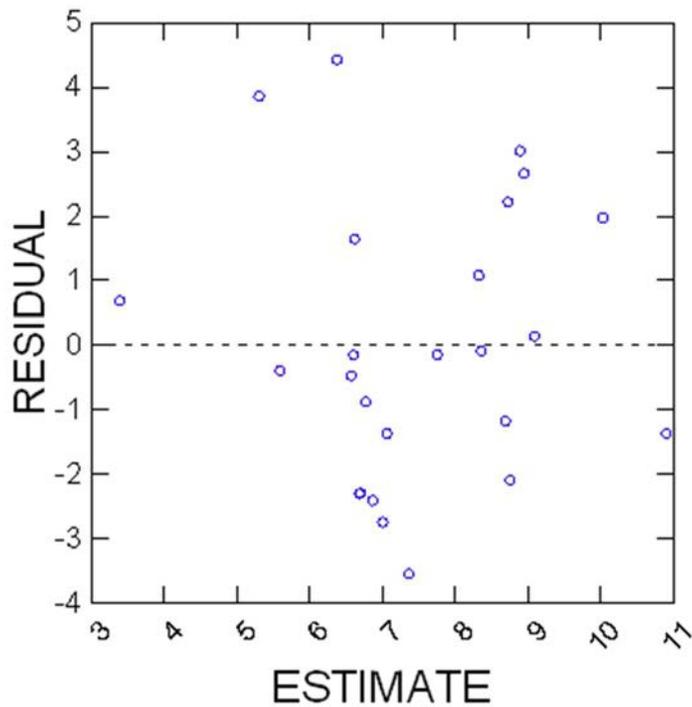
Durbin-Watson D Statistic	2.021
First Order Autocorrelation	-0.031

Information Criteria	
AIC	114.214
AIC (Corrected)	115.357
Schwarz's BIC	117.871

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTN

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.156
Squared Multiple R	0.024
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.711

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value	
CONSTANT	6.844	1.028	0.000		6.660	0.000
LNTN	-1.173	1.554	-0.156	1.000	0.755	0.458

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	4.191	1	4.191	0.570	0.458
Residual	169.066	23	7.351		

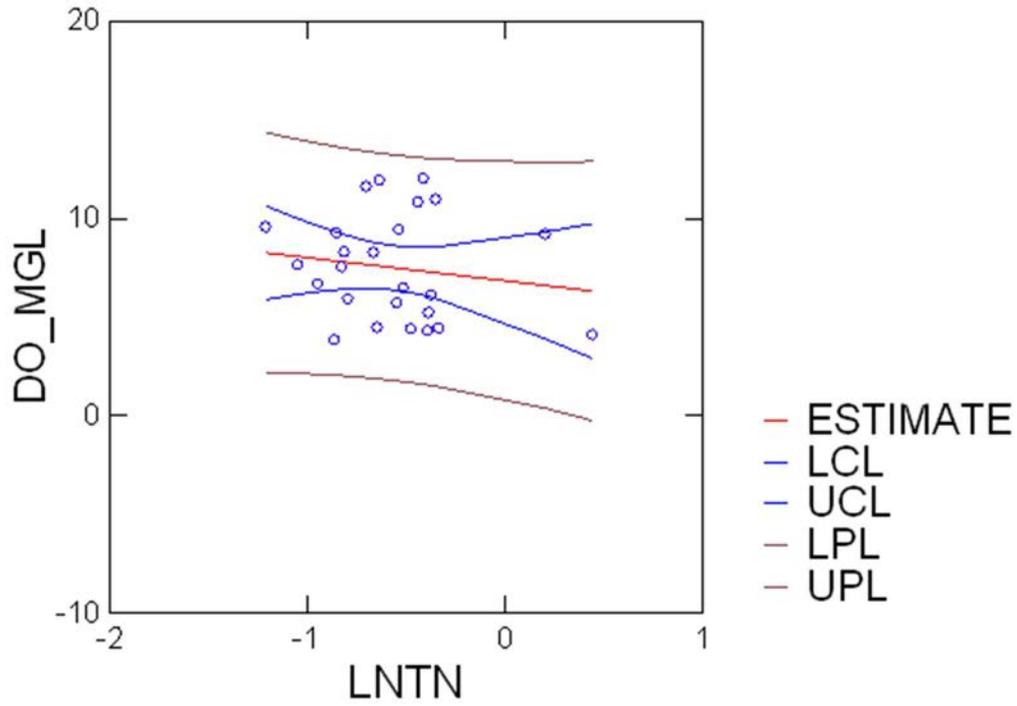
**WARNING**

Case 6 has large Leverage (Leverage : 0.374)

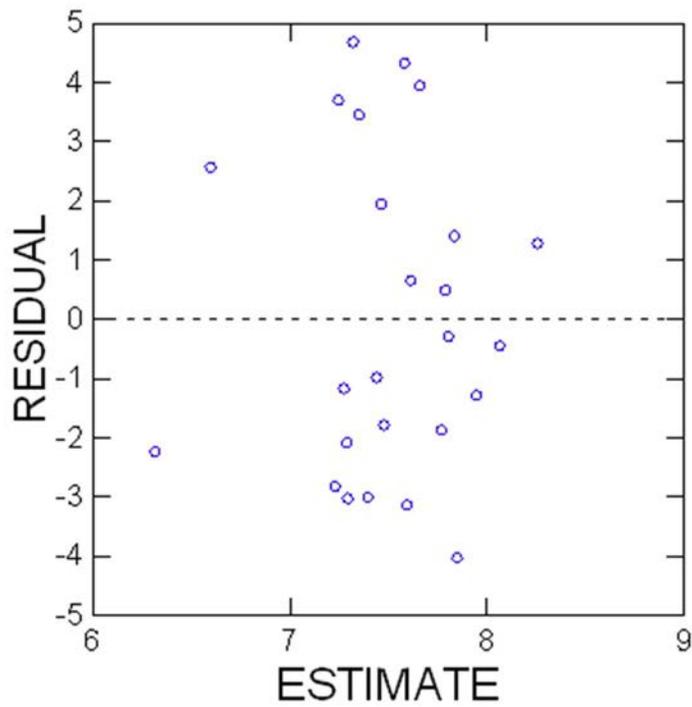
Durbin-Watson D Statistic	1.982
First Order Autocorrelation	-0.009

Information Criteria	
AIC	124.732
AIC (Corrected)	125.875
Schwarz's BIC	128.389

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNTURB

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.192
Squared Multiple R	0.037
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.746

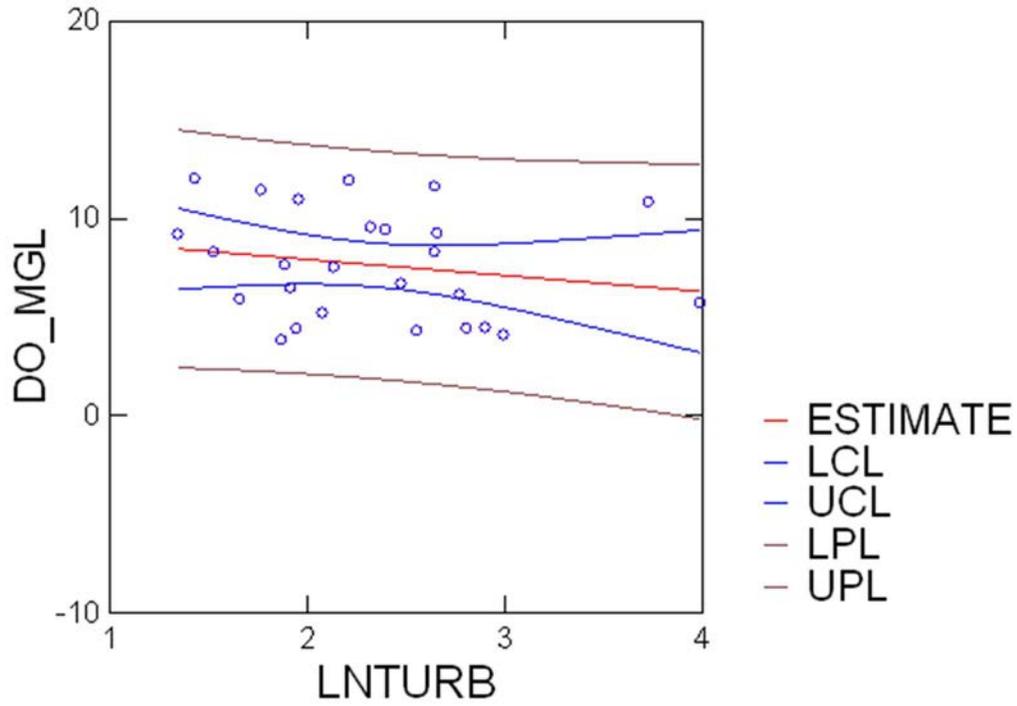
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	p-value	
CONSTANT	9.552	2.054	0.000	4.650	0.000	
LNTURB	-0.814	0.850	-0.192	1.000	0.9580.348	

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	6.919	1	6.919	0.918	0.348
Residual	180.943	24	7.539		

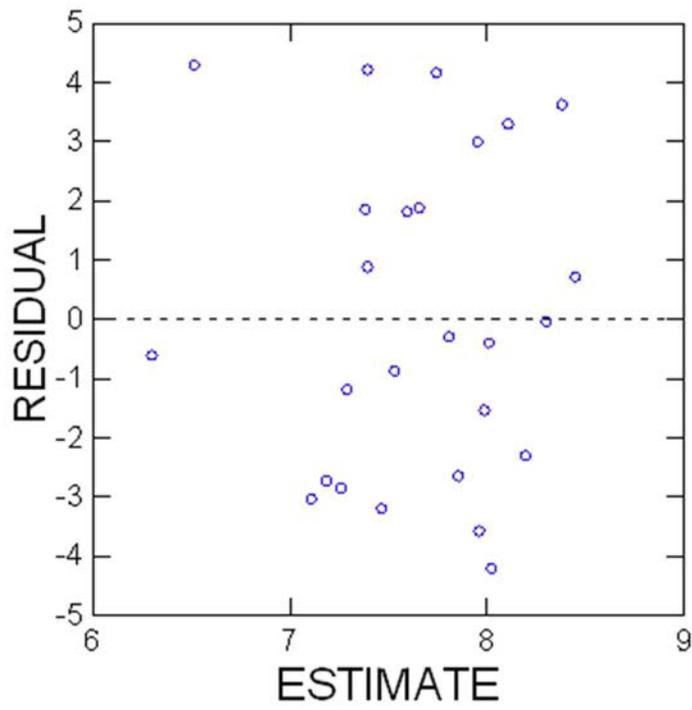
Durbin-Watson D Statistic	1.647
First Order Autocorrelation	0.155

Information Criteria	
AIC	130.227
AIC (Corrected)	131.318
Schwarz's BIC	134.001

### Confidence Interval and Prediction Interval



### Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNNH3N

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	12
Multiple R	0.582
Squared Multiple R	0.338
Adjusted Squared Multiple R	0.272
Standard Error of Estimate	1.421

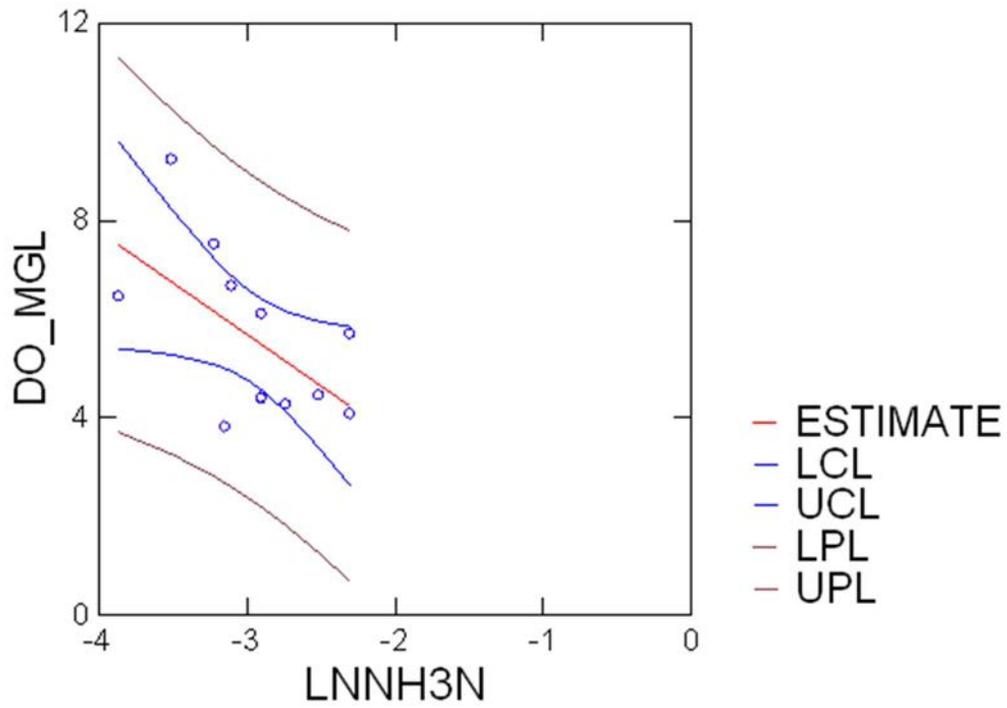
Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-0.585	2.758	0.000		-0.212	0.836
LNNH3N	-2.092	0.925	-0.582	1.000	-2.262	0.047

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	10.330	1	10.330	5.117	0.047
Residual	20.188	10	2.019		

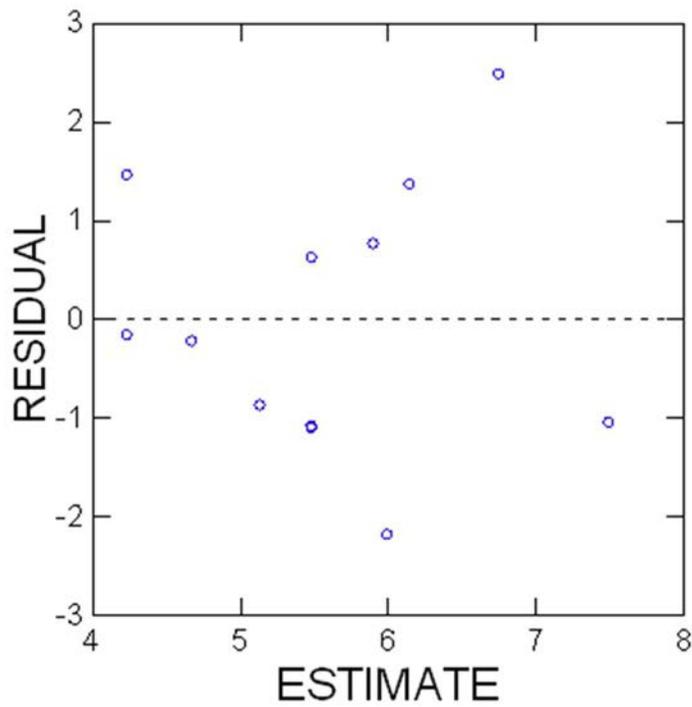
Durbin-Watson D Statistic	3.003
First Order Autocorrelation	-0.525

Information Criteria	
AIC	46.297
AIC (Corrected)	49.297
Schwarz's BIC	47.752

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



Appendix E

> REGRESS  
 > MODEL DO\_MGL = CONSTANT+LNBOD

18 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.501
Squared Multiple R	0.251
Adjusted Squared Multiple R	0.157
Standard Error of Estimate	2.717

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.064	0.930	0.000		7.596	0.000
LNBOD	-1.851	1.131	-0.501	1.000	-1.637	0.140

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	19.794	1	19.794	2.681	0.140
Residual	59.062	8	7.383		

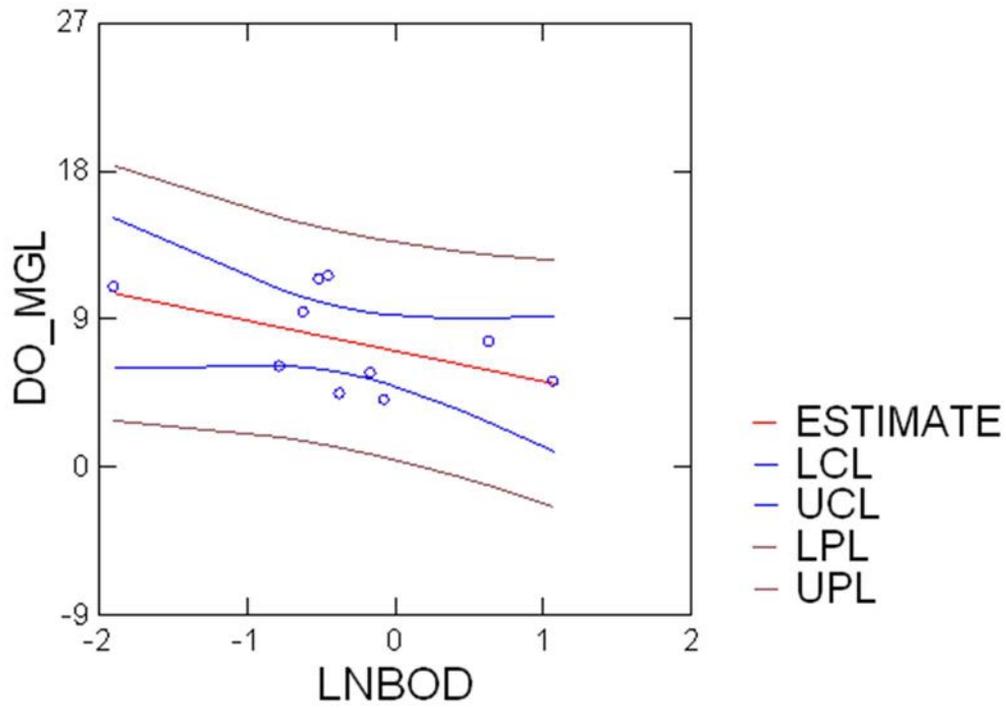
**WARNING**

Case 2 has large Leverage (Leverage : 0.534)

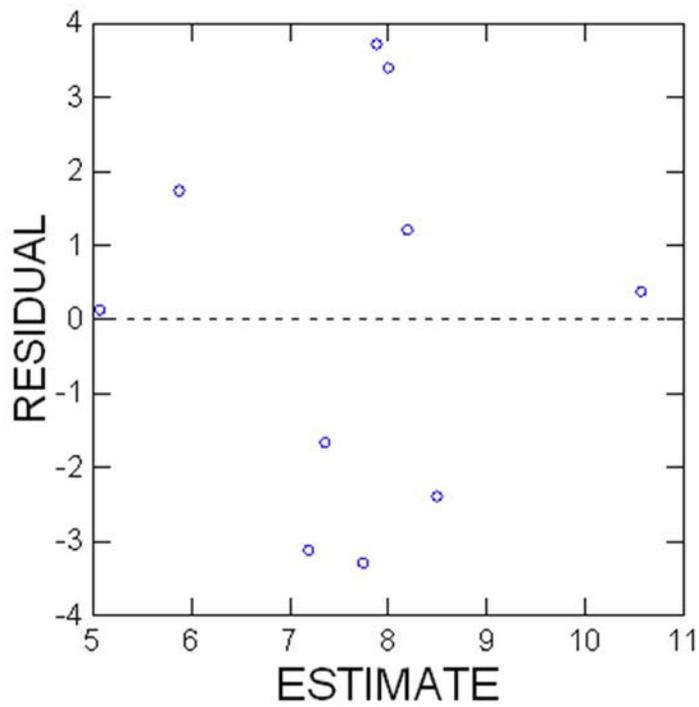
Durbin-Watson D Statistic	1.688
First Order Autocorrelation	0.131

Information Criteria	
AIC	52.139
AIC (Corrected)	56.139
Schwarz's BIC	53.046

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



## Appendix E

> REGRESS

> MODEL DO\_MGL = CONSTANT+TEMP\_DEGC+LNNOX+LNTKN+LNTN+LNTN+LNTN+LNNH3N+LNTURB

### Stepwise Selection of Variables

16 case(s) are deleted due to missing data.

Step number : 0  
 R : 0.949  
 R-square : 0.901

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.167	0.085	-0.507	0.374	1	3.884	0.120
3	LNNOX	2.655	3.184	0.822	0.026	1	0.695	0.451
4	LNTKN	2.396	8.768	0.657	0.004	1	0.075	0.798
5	LNTN	-4.503	11.975	-1.005	0.003	1	0.141	0.726
6	LNTN	0.029	0.290	0.020	0.652	1	0.010	0.925
7	LNNH3N	-2.684	1.098	-0.747	0.266	1	5.981	0.071
8	LNTURB	0.615	0.892	0.220	0.243	1	0.475	0.528

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
	none					

Information Criteria	
AIC	35.525
AIC (Corrected)	125.525
Schwarz's BIC	39.889

Dependent Variable : DO\_MGL  
 Minimum Tolerance for Entry into Model : 0.000  
 Backward Stepwise with Alpha-to-Enter : 0.150  
 Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1  
 R : 0.949  
 R-square : 0.901  
 Term Removed : LNTN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.166	0.076	-0.506	0.376	1	4.832	0.079
3	LNNOX	2.732	2.768	0.846	0.027	1	0.975	0.369
4	LNTKN	2.674	7.452	0.734	0.005	1	0.129	0.734
5	LNTN	-4.879	10.188	-1.090	0.004	1	0.229	0.652
7	LNNH3N	-2.736	0.866	-0.761	0.343	1	9.992	0.025
8	LNTURB	0.649	0.737	0.232	0.285	1	0.775	0.419

Appendix E

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
6	LNTP	0.050	0.652	1	0.010	0.925

Information Criteria	
AIC	33.555
AIC (Corrected)	81.555
Schwarz's BIC	37.434

Step number : 2  
R : 0.948  
R-square : 0.898  
Term Removed : LNTKN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.149	0.055	-0.455	0.602	1	7.331	0.035
3	LNNOX	1.764	0.569	0.546	0.548	1	9.618	0.021
5	LNTN	-1.239	0.882	-0.277	0.438	1	1.973	0.210
7	LNNH3N	-2.718	0.799	-0.756	0.344	1	11.574	0.014
8	LNTURB	0.746	0.635	0.267	0.329	1	1.380	0.285

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	0.158	0.005	1	0.129	0.734
6	LNTP	0.097	0.724	1	0.048	0.836

Information Criteria	
AIC	31.860
AIC (Corrected)	59.860
Schwarz's BIC	35.255

Step number : 3  
R : 0.935  
R-square : 0.875  
Term Removed : LNTURB

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.178	0.051	-0.542	0.745	1	12.192	0.010
3	LNNOX	2.087	0.511	0.646	0.715	1	16.664	0.005
5	LNTN	-1.365	0.899	-0.305	0.445	1	2.305	0.173
7	LNNH3N	-2.075	0.598	-0.577	0.649	1	12.058	0.010

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	0.291	0.005	1	0.554	0.485
6	LNTP	0.284	0.941	1	0.528	0.495
8	LNTURB	0.432	0.329	1	1.380	0.285

Appendix E

Information Criteria	
AIC	32.344
AIC (Corrected)	49.144
Schwarz's BIC	35.254

Step number : 4  
 R : 0.913  
 R-square : 0.833  
 Term Removed : LNTN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.211	0.050	-0.643	0.913	1	18.083	0.003
3	LNNOX	1.756	0.499	0.544	0.873	1	12.396	0.008
7	LNNH3N	-2.584	0.534	-0.719	0.946	1	23.446	0.001

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	-0.470	0.546	1	1.984	0.202
5	LNTN	-0.498	0.445	1	2.305	0.173
6	LNTTP	0.266	0.943	1	0.533	0.489
8	LNTURB	0.433	0.334	1	1.613	0.245

Information Criteria	
AIC	33.760
AIC (Corrected)	43.760
Schwarz's BIC	36.184

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	12
Multiple R	0.913
Squared Multiple R	0.833
Adjusted Squared Multiple R	0.771
Standard Error of Estimate	0.798

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	p-value
CONSTANT	5.513	1.992	0.000		2.768	0.024
TEMP_DEGC	-0.211	0.050	-0.643	0.913	4.252	0.003
LNNOX	1.756	0.499	0.544	0.873	3.521	0.008
LNNH3N	-2.584	0.534	-0.719	0.946	4.842	0.001

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	25.429	3	8.476	13.326	0.002

Analysis of Variance					
Source	SS	df	Mean Squares	F-ratio	p-value
Residual	5.089	8	0.636		

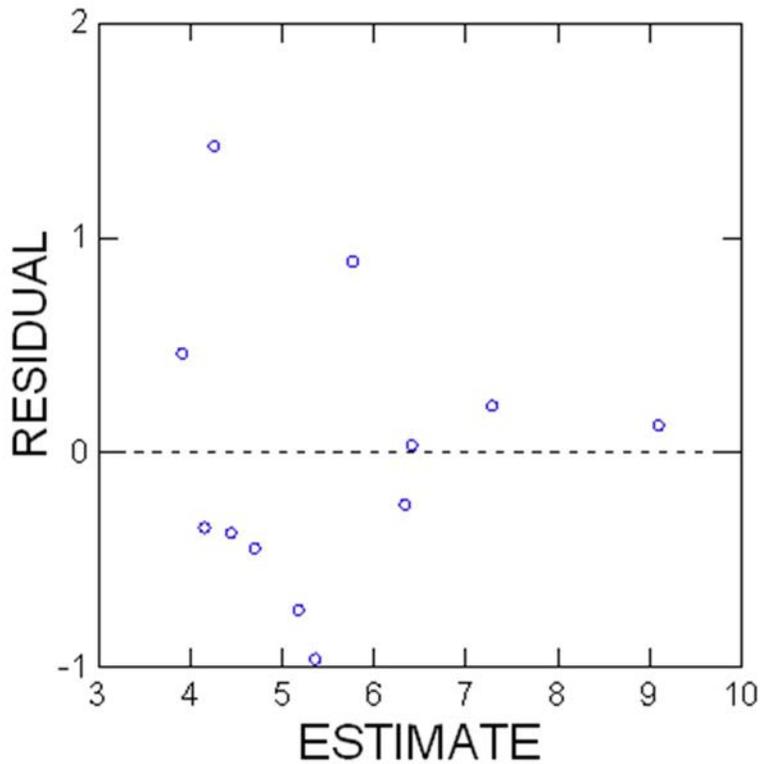
**WARNING**

Case 10 is an Outlier (Studentized Residual : 2.877)

Durbin-Watson D Statistic	2.523
First Order Autocorrelation	-0.344

Information Criteria	
AIC	33.760
AIC (Corrected)	43.760
Schwarz's BIC	36.184

Plot of Residuals vs Predicted Values



# **APPENDIX F**

---

## **Social Media Marketing Checklist**

# 7 Steps in Creating a Winning Social Media Marketing Strategy in 2018

Alex York

Just a few years ago, you could get away with building a social media marketing strategy on the fly. As long as you were present, you were doing more than your competitors—right?

Well it's 2018 and not much of the same logic applies today. With 30% of millennials saying they engage with a brand on social at least once a month (<https://sproutsocial.com/insights/data/q1-2017/>), your strategy can't be only about existence. Brands must be fully invested in their social media marketing strategies and focus on engagement. Otherwise, you'll lose out on real customers, which means serious effects on your bottom line.

We're not here to scare your brand into the world of social media. Instead, we want to provide your marketing team with the right steps to take toward a successful social strategy so your brand isn't left in the dust.

Here are the seven steps to create a winning social media marketing strategy in 2018 (<https://sproutsocial.com/insights/social-media-marketing-strategy/#infographic>):

## 1. Create Social Media Marketing Goals That Solve Your Biggest Challenges

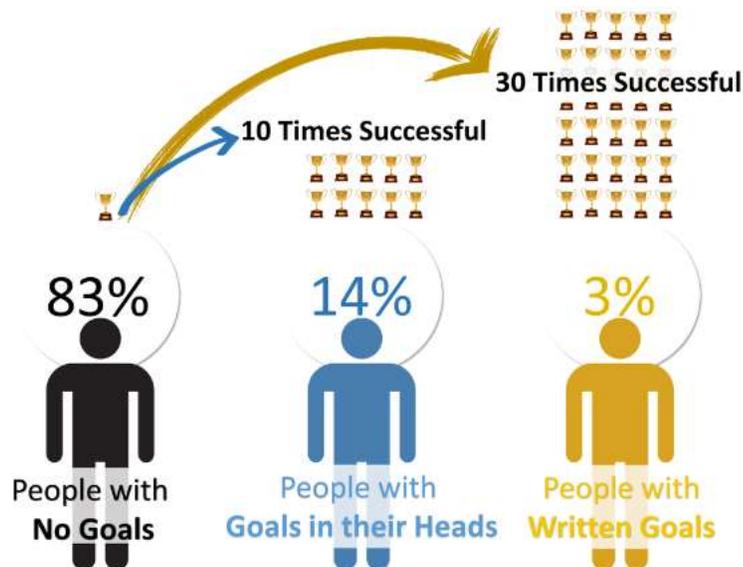
The first step to any strategy is to understand what you want out of your efforts. Social media marketing isn't about flipping a switch and calling it a day. Instead, social media planning should be looked at like cooking your favorite dish.

Once you have your ingredients, you follow a recipe and presto! But that's not always the case. What if you have guests and need to feed more people? What if someone is allergic to one of the ingredients? Suddenly, your goal goes from making a meal to ensuring it will feed enough people and be edible by all.

That's why creating goals is so critical to the first part of your social media strategy. At the same time, it's best to set goals that you know are attainable. Asking for 1 million new Instagram followers in 2018 is unrealistic. With achievable goals, you're more likely to stick to the original plan and continue to take on new hurdles as you complete old ones.

This is the same reason why brands should never take on every social media channel possible in their current marketing strategy. Try to choose the channels that have the most importance based on your brand's goals. Avoid over complicating a strategy with too many targets and objectives. Simplicity can take you a long way.

And also, don't forget to document your social media goals. Not only is it important to help you benchmark where you are, but it also improves your chances of achieving them. According to some statistics, people who write their goals down are 30 times more successful.



## Social Media Goals to Consider in 2018

Goal setting is a staple of all marketing and business strategies. Social media is no exception. Of course, with a range of social capabilities, it can be difficult to determine exactly what your objectives should be. For guidance, here are some common social media goals to consider:

- **Increase brand awareness:** To create authentic and lasting brand awareness, avoid a slew of promotional messages. Instead, focus on meaningful content and a strong brand personality through your social channels.
- **Higher quality of sales:** Digging through your social channels is nearly impossible without monitoring or listening to specific keywords, phrases or hashtags. Through more efficient social media targeting, you reach your core audience much faster.
- **Drive in-person sales:** Some retailers rely on social media marketing efforts to drive in-store sales. Is your brand promoting enough on social to reward those who come to you? What about alerting customers to what's going on in your stores?
- **Improve ROI:** There's not a brand on social media that doesn't want to increase its return on investment (ROI). But on social media, this goal is specific to performing a thorough audit of your channels and ensuring cost of labor, advertisements and design stay on track.
- **Create a loyal fanbase:** Does your brand promote user-generated content? Do your followers react positively without any initiation? Getting to this point takes time and effort with creating a positive brand persona on social.
- **Better pulse on the industry:** What are your competitors doing that seems to be working? What strategies are they using to drive engagement or sales? Having a pulse on

the industry could simply help you improve your efforts and take some tips from those doing well.

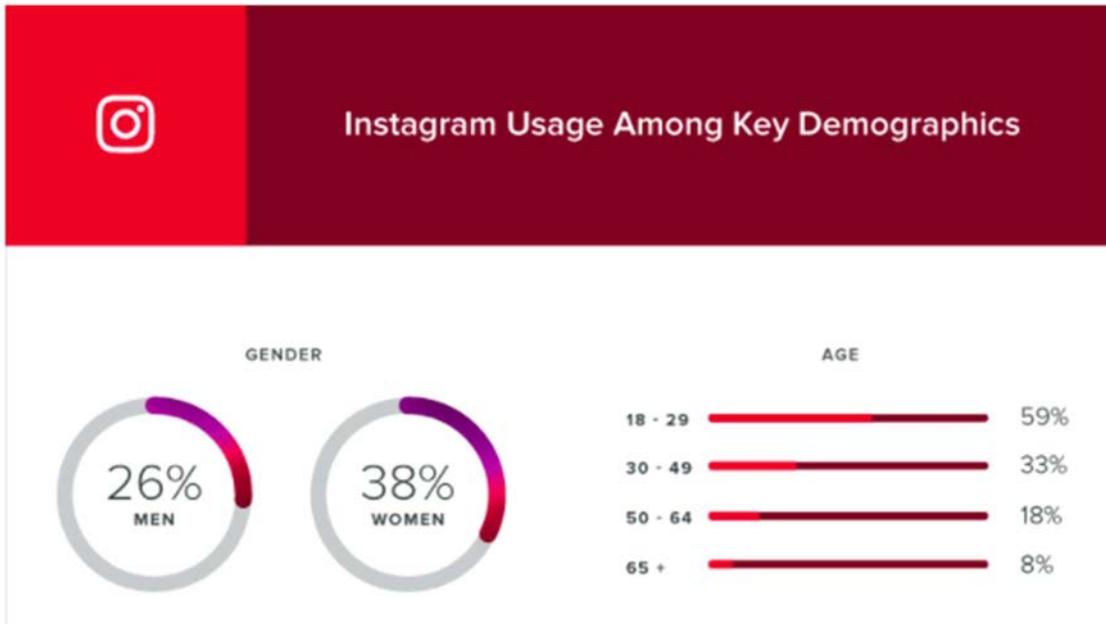
## 2. Research Your Social Media Audience

Approximately 79% of adults use Facebook—but are your customers actively engaging with your brand there? Understanding your audience is necessary to learn things like who buys your products, what age group is the toughest to sell and what income level makes up the most of your returning customers? As for social media, it's just as critical to know your audience.

First, your brand should look into the demographics of your most valuable social channels. Like we mentioned before, you should have a goal in mind for your social media marketing strategy. This is why you need to research the channels that correlate the most with your goals.

To help you find your focus channels: let's take a quick look at the essential demographics data for each major network:

- **Facebook's most popular demographics include:**
  - Women users (89%)
  - 18-29 year olds (88%)
  - Urban- and rural-located users (81% each)
  - Those earning less than \$30,000 (84%)
  - Users with some college experience (82%)
- **Instagram's most popular demographics include:**
  - Women users (38%)
  - 18-29 year olds (59%),
  - Urban-located users (39%)
  - Those earning less than \$30,000 (38%)
  - Users with some college experience (37%)



- **Twitter’s most popular demographics include:**
  - Women users (25%)
  - 18-29 year olds (36%)
  - Urban-located users (26%)
  - Those earning \$50,000-\$74,999 (28%)
  - Users with college experience or more (29%)
- **LinkedIn’s most popular demographics include:**
  - Men users (31%)
  - 18-29 year olds (34%)
  - Urban-located users (34%)
  - Those earning \$75,000 or more (45%)
  - Users with college experience or more (50%)
- **Snapchat and other auto-delete app’s most popular demographics include:**
  - Men users (24%)
  - 18-29 year olds (56%)
  - Those earning less than \$50,000 (27%)
  - Users with some college experience (27%)

See even more demographics data on our in-depth guide! (<https://sproutsocial.com/insights/new-social-media-demographics/>)

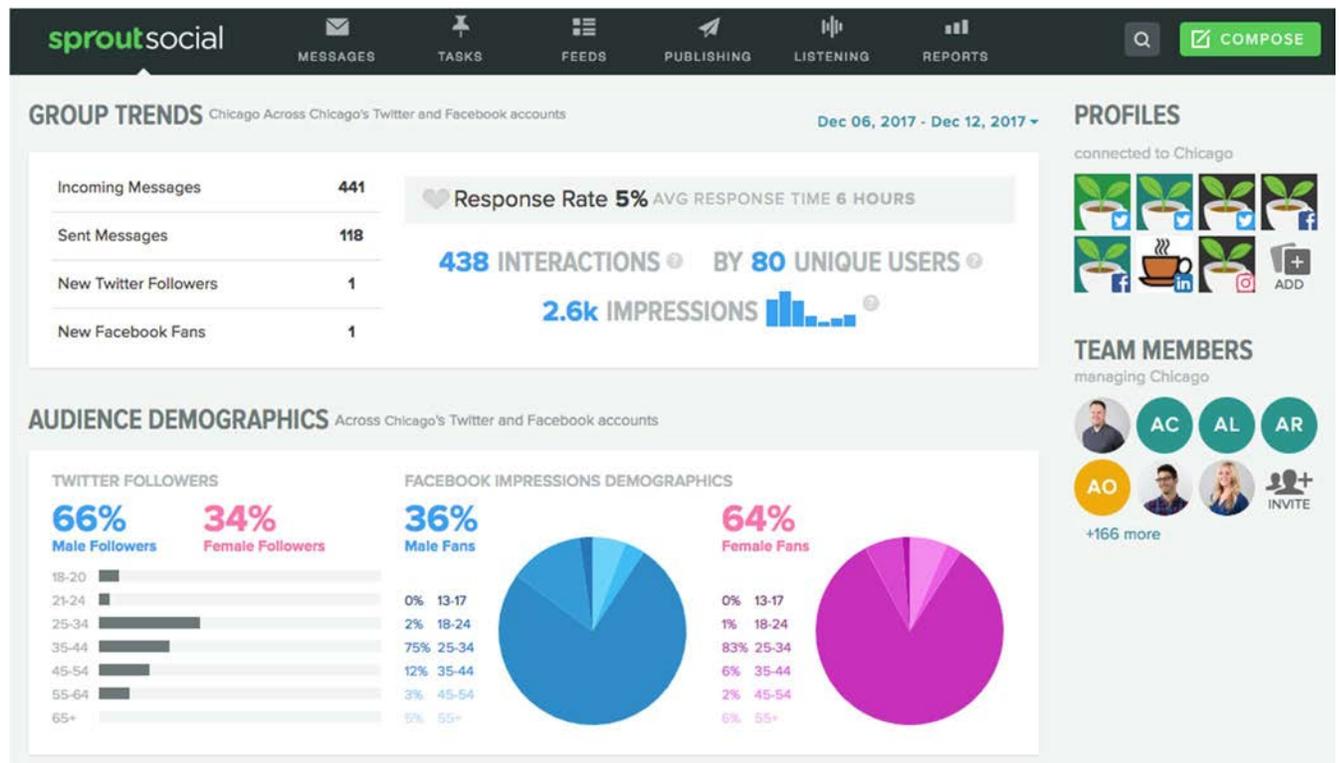
The best marketers you’ll come across don’t sleep until they have a better idea on their audience and segmentation strategy.

## Identifying Customer Demographics

While the demographics data above give you insight into each channel, what about your own customers? Further analysis has to be completed before you can truly know your customer demographics on social media.

That's why many brands use a social media dashboard (Figure) that can provide an overview of who's following you and how they interact with you on each channel. Most brands today are using at least some sort of dashboard. However, does your dashboard address your specific goals?

Whether you're an agency providing insights for your clients or an enterprise company discovering your own demographics, an all-in-one dashboard solution is critical.



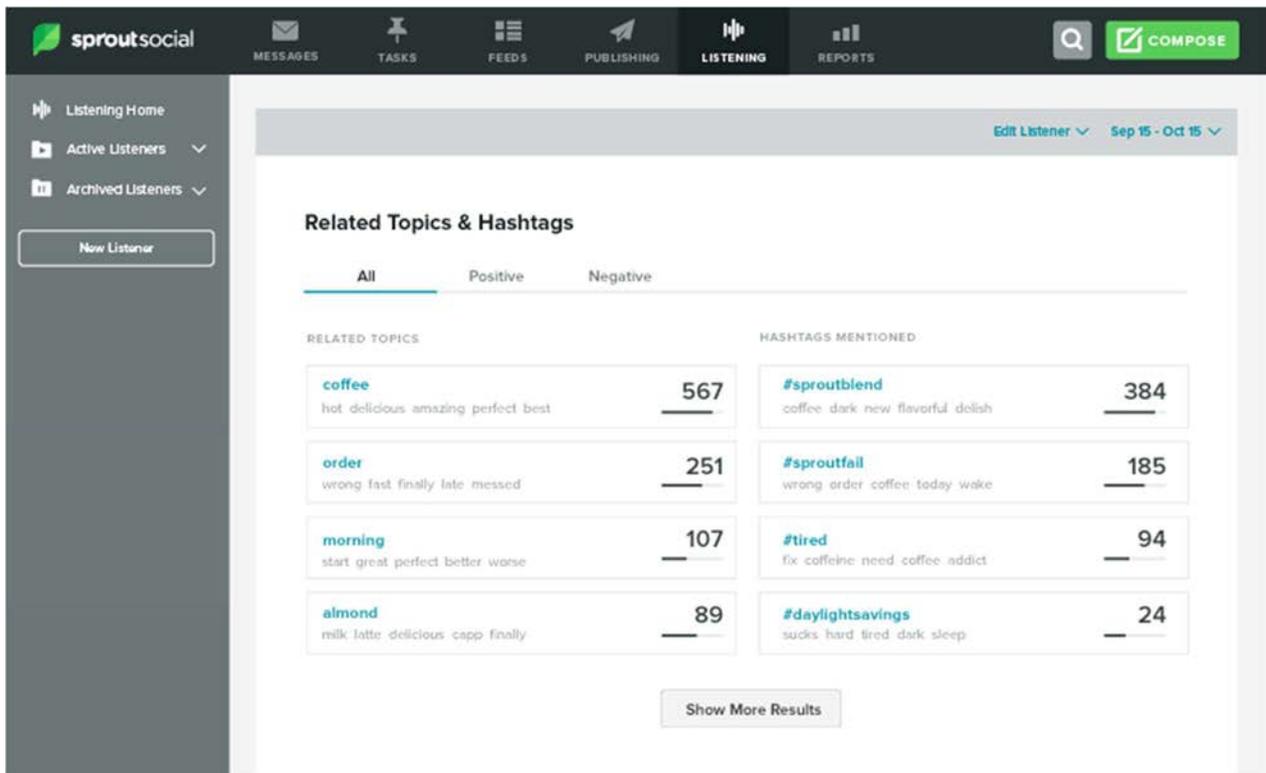
### 3. Establish Your Most Important Metrics

While your targeted social media metrics might be the most important step of a strategy, it's often the spot most veer off the path. Vanity metrics like follower count and likes are always good to measure, but does it tell you the **whole story of your brand** on social media?

We often get wrapped up in viewing followers and likes as the truth to a campaign, but it's smart to take a step back and evaluate the social metrics associated with your overall goals.

Engagement metrics sometimes paint a better picture, because as we've mentioned many times here, building lasting relationships works on social. Large audiences and likable content is absolutely great, but here are some other metrics you might want to pursue in 2018:

- **Reach:** Post reach is the number of unique users who saw your post. How far is your content spreading across social? Is it actually reaching user's feeds?
- **Clicks:** This is the amount of clicks on your content, company name or logo. Link clicks are critical toward understanding how users move through your marketing funnel. Tracking clicks per campaign is essential to understand what drives curiosity or encourages people to buy.
- **Engagement:** The total number of social interactions divided by number of impressions. For engagement, it's about seeing who interacted and if it was a good ratio out of your total reach. This sheds light on how well your audience perceives you and their willingness to interact.
- **Hashtag performance:** What were your most used hashtags on your own side? Which hashtags were most associated with your brand? Or what hashtags created the most engagement?



- **Sentiment:** This is the measurement of how users reacted to your content, brand or hashtag. Did customers find your recent campaign offensive? What type of sentiment are people associating with your campaign hashtag? It's always better to dig deeper and find what people are saying.
- **Organic and paid likes:** More than just standard Likes, these likes are defined from paid or organic content. For channels like Facebook, organic engagement is much harder to

gain traction, which is why many brands turn to Facebook Ads. However, earning organic likes on Instagram isn't quite as difficult.

## 4. Research Your Social Competitive Landscape

Before you start creating content (we promise we're almost there!), it's really smart to investigate your competitors. We put this before the content creation process because you often find new ways to look at content by analyzing what's making your competitors successful.

Again, we'll always believe you shouldn't steal your competitors' ideas, but instead learn and grow from their success and failures. So how do you find that information? The first step is to find out who's your competition in the first place.

The simplest way to find competitors is through a simple Google search. Look up your most valuable keywords, phrases and industry terms to see who shows up. For example, if you sold various soaps, "handmade natural soaps" would be a great keyword to investigate:

Shop for handmade natural soaps on Google Sponsored ⓘ

				
The Vermont Country Store ... <b>\$28.95</b> The Vermont C... Special offer	Free Shipping!! 5 Homemade ... <b>\$25.00</b> Etsy Free shipping	Handmade soap All natural Lot ... <b>\$19.99</b> Etsy	Lehman's Natural Handmade ... <b>\$6.99</b> Lehman's Special offer	Woodsmoke Goat Milk ... <b>\$0.99</b> Etsy

### Real Soaps Chicago | Natural & Handmade Soap, Bath & Body Products

<https://www.realsoaps.com/> ▼

Real Soaps Chicago | 100% Natural & Handmade Soap, Bath & Body Products. Soap Making Classes Available! Wholesale & Custom Orders Welcome!

### All Natural Soaps - 100% Junk Free - YUM! – Soaptopia

<https://soaptopia.com/collections/all-soaps> ▼

All Natural Soaps - 100% Junk Free - YUM! Soaptopia Handmade 100% Natural Artisan Soaps. Welcome to Soaptopia's hallmark soaps. We make soaps for all types of moods with distinct flavor families and our 100% JUNK FREE, all natural ingredients. We are known for our Citrus soaps, Flower Soaps, Earth Soaps, ...

### Abbey Brown Soap Artisan

<https://www.abbeybrown.com/> ▼

Ever wonder what a day in the life of Abbey Brown Soap Artisan looks like? Shoppe Video. Making Soap. Here you go, enjoy our journey as we make goodness for the skin. Be sure to check your local pbs listing for our episode of A Craftsman's Legacy! Airing on WTTW Chicago, Tuesday January 10th at 10:30 am and 4:30 ...

Our signature line · Olive Oil Soaps · Shea balms · BODY OILS

You can exclude the major retailers like Amazon and Bath & Body Works. Search for those who show up who are in your specific industry. Next you want to see who is active on social.

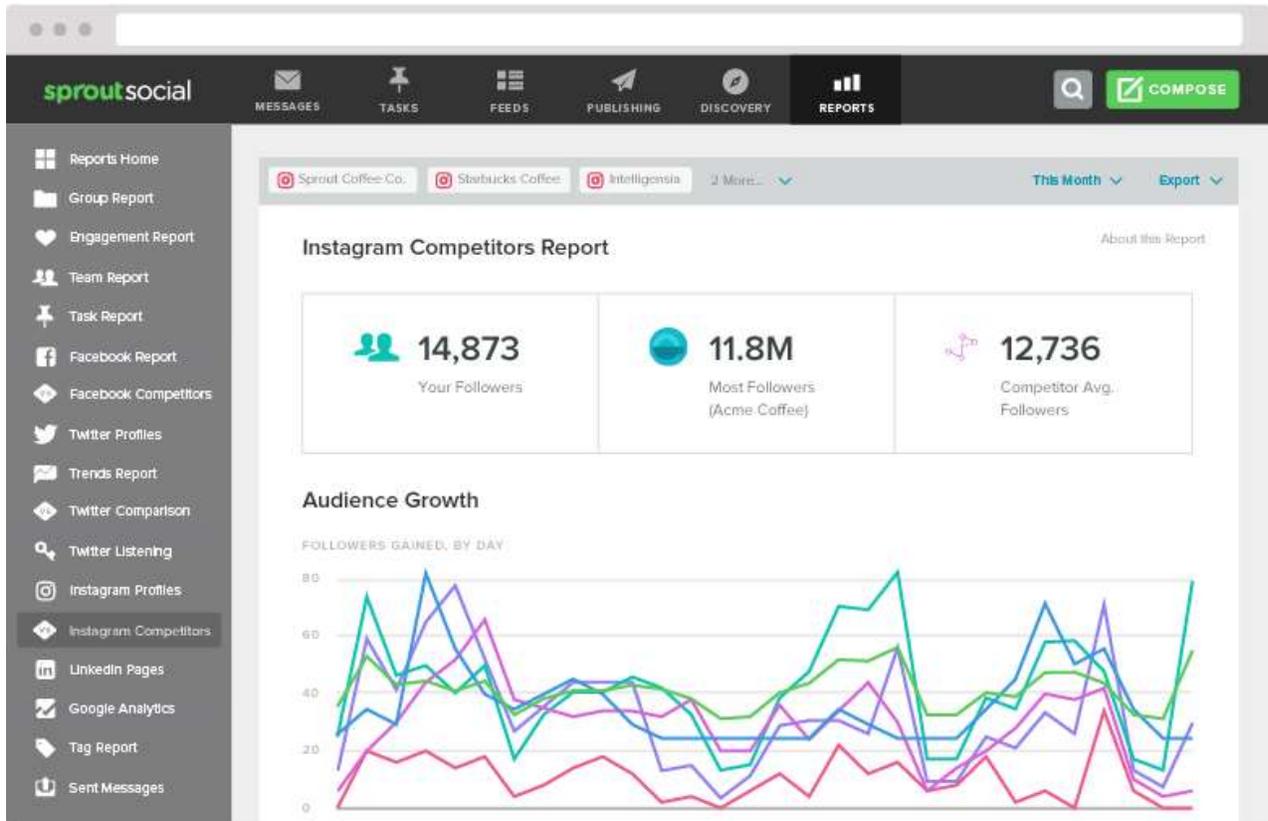


Questions? Give us a call. 512-272-4058 (9am-5pm CENTRAL) or [contact us online](#) anytime!



[home](#) [shop all](#) [get news](#) [wild about good](#) [why natural soap](#) [blog](#) [about](#) [policies](#) [store locator](#)

As you can see, Wild Soap has an active social presence, which means they're a great candidate to track. After gathering a handful of industry competitors, it's smart to use a social media competitive analysis tool like Sprout Social to track Facebook and Instagram content.



Here you can see post break downs of text, images and video to see what your competitors are doing to drive the most engagement. Once you dig through the competitive analysis, you'll have a better idea of what your potential customers want.

## **5. Build & Curate Engaging Social Media Content**

Did someone say content? It's no lie—social media content is extremely important to your marketing strategy. However, it's best to follow the previous steps before planning out content (we caught you, blog skippers!) so you can start building more effective themes.

For starters, we recommend creating content that fits to your brand's identity. This means you should avoid things like reaching out to your unpopular demographics without a complete strategy in place.

It's necessary to find the perfect balance between target content and being overly promotional as well. In fact, 46% of users say they'll unfollow a brand if there's too many promotional messages. Additionally, 41% of users say they'd unfollow a brand that shared too much irrelevant content (<https://sproutsocial.com/insights/data/q3-2016/>).

### **Video Content or Bust**

How important is video to your social media marketing strategy? Extremely—approximately 90% of online shoppers believe product videos help them make a purchasing decision (<https://www.forbes.com/sites/forbesagencycouncil/2017/02/03/video-marketing-the-future-of-content-marketing/#744d94af6b53>). Additionally, the average online video is completely watched end to end by 37% of viewers (<https://blog.hubspot.com/marketing/video-marketing-statistics#sm.0000f7ujhkwrs8sqa62aq63w23fi>).

These types of statistics should only enforce your reasoning to invest in social media video content. Brands can reach users through Instagram Stories, Facebook Live and other in-the-moment media.

### **Build Content Themes**

One of the toughest challenges to visual content is creating it on a day-to-day basis. A Venngage infographic showed 36.7% of marketers said their No.1 struggle with creating visual content was doing so consistently (<https://www.impactbnd.com/blog/visual-content-marketing-statistics-2017>).

This truly shows how important highly-visual content is to marketers and the people they want to reach. That's why building content themes is a great approach to sectioning out your content. Instagram is one your premier channels to work off visual themes.



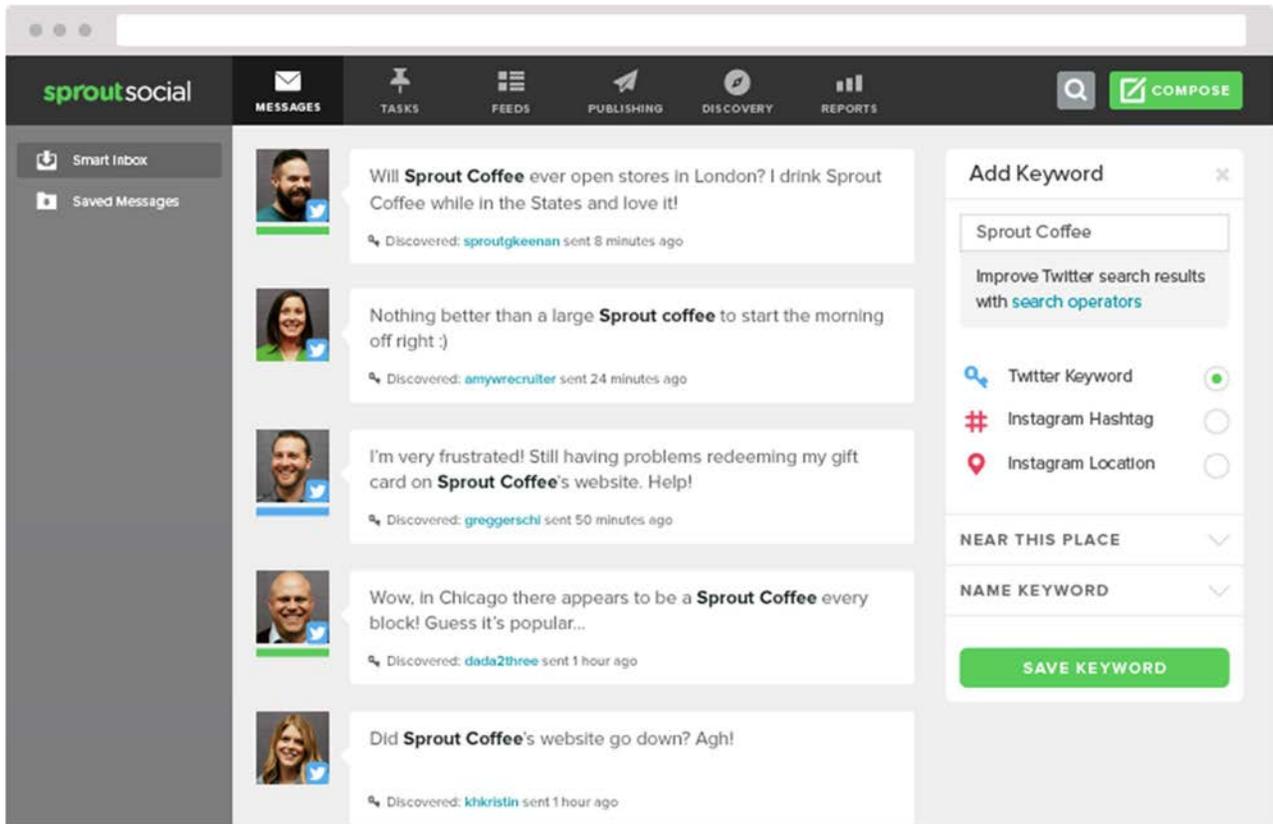
Anthropologie does an amazing job at keeping their Instagram feed consistent, colorful and eye-popping. Work in content themes to ensure you have a consistent schedule of excellent content to publish.

## 6. Engage With Your Audience & Don't Ignore

Social media channels are built as networks. This means their main purpose is to be a space to converse, discuss topics and share content. Your brand can't forget these core elements of "networking" and it takes effort to ensure conversations or engagement opportunities aren't left unattended.

Through social media, you gain respect as a brand by just being present and talking to your audience. That's why social customer care is so important to brands wanting to increase audience awareness. It's all about engagement.

For example, Seamless (<https://twitter.com/Seamless>) does a wonderful job of not only responding, but showing customer care is priority. Through the right social media monitoring tools, you can find instances across all your channels to interact, respond and gauge customer service inquiries.



Designating teams to specific tasks can help your staff run like a well-oiled social media team, whether you're a group of one or 100.

## Post at the Best Times to Engage

When is your brand available to engage and interact with customers? You might see some recommending times to post late in the evening. But if your brand isn't there to communicate, what's the point of posting at the preferred time?

Instead, try to ensure your social media or community managers are available and ready to answer any product questions or concerns when you tweet or post. It's smart to learn the best times to post on social media, but it's just as critical to engage after posting.

## People's Wait Time Expectation vs. Brand Response Time on Social



CONSUMER  
EXPECTATION



AVERAGE BRAND  
RESPONSE TIME

sproutsocial

[sproutsocial.com/index](https://sproutsocial.com/index)

According to our Index, a brand's average response time is around 10 hours. But did you know that most users believe brands should respond to social media messages within four hours?

With all the updated algorithms, organic content has a tough time reaching the majority of your audience. The last thing you want to do is ignore those who engage and lose out on sending more down your marketing funnel.

## 7. Track Your Efforts & Always Improve

So, how well did you do on your social media marketing strategy? Without continuously analyzing your efforts, you'll never know how one campaign did over another. Having a bird's-eye-view of your social media activity helps put things into perspective.



You've got down your most important goals, network preferences and metrics—now it's time to make sure you made the right decisions. Knowing you've made the right choices is still a difficult task in social media.

In fact, 46% of B2B marketers are unsure if their social strategy actually created revenue for their brand (<https://www.business2community.com/social-media/47-superb-social-media-marketing-stats-facts-01431126#HT07K2mwjfUGsG2Z.99>). But marketers are always trying and looking for the perfect connection. That's why the most commonly used metric (80%) for marketers is engagement.

If you work at building lasting relationships, there's a lot less room for failure with your social media marketing strategy.

## Use a Tool to Track Success

Sprout Social was created with social media marketing in mind. Our social media tools offer a full suite of analytics and reporting features to help you pinpoint exactly which posts, messages and hashtags perform the best.

It's easy to connect other critical tools to our dashboard like Google Analytics, which helps you see which posts drove the most traffic, conversions and overall revenue.

# Social Media Marketing Strategy Checklist

We wanted to give our readers a few resources to use moving forward. That's why we put together this 7-step social media marketing strategy checklist to help all of our readers creating and auditing their own strategies.

We encourage you to share it with colleagues or use the embed code to put it on your own site!

## Social Media Checklist

### What are your social media goals?

- Increase brand awareness
- Community engagement and education
- Increase volunteerism/public recruitment
- Fundraising
- Others?

### Where will you reach your social media audience?

- Facebook
- Instagram
- Twitter
- Linked In
- Snapchat
- YouTube
- Google

### What are your core demographics?

- Age (18-29; 30-49; 50-65; 65+)
- Gender (M, F)
- Location (urban, suburban, rural)
- Income (\$30K-49.9K; 50K-75K; 75K+)
- Education (High School or less; some college; college+)

### What are your core metrics?

- No. of clicks
- Reach (how broadly discussed)
- Hashtag performance
- Engagement (total no of clicks or reviews/demographic core goals)
- Shares
- Retweets

**What type of content will you produce?**

- Videos (YouTube)
- Webinars
- Blogs
- Photos
- Case studies
- Gated guides
- Post other nonprofits that promote your effort

**What are your best times to post on media?**

- Facebook (Day, Time of day)
- Instagram (Day, Time of day)
- Twitter (Day, Time of day)
- Linked In (Day, Time of day)
- Snapchat (Day, Time of day)

**How often will you assess your metrics?**

- Daily
- Weekly
- Monthly
- Annually

**Who is going to monitor and maintain the social media platform?**

- ANRC
- Nonprofit partner
- Contract
- Other

# **APPENDIX G**

---

**Calculations of Cost Estimates for Implementation of Management Practices**

## APPENDIX G COST ESTIMATE CALCULATIONS

### 1.0 MANAGEMENT PRACTICES FOR PASTURE AND HAYLAND IN LOWER SALADO CREEK SUBWATERSHED

Table G.1. Estimates of amount of practices required to achieve 21% reduction of nitrogen load in Lower Salado Creek Subwatershed.

Practice	Practice reduction efficiency <sup>a</sup>	Percentage of source to treat to achieve 21% reduction target <sup>b</sup>	Estimated amount of source present	Estimated extent of practice to achieve 21% reduction <sup>c</sup>
Forest riparian buffer	70%	30%	141,768 feet <sup>d</sup>	42,530 feet of 50-foot-wide buffer = 49 acres
Herbaceous riparian buffer	50%	42%	141,768 feet <sup>d</sup>	59,453 feet of 50-foot-wide buffer = 68 acres
Controlled access (fence)	60%	35%	283,536 feet <sup>e</sup>	99,000 feet of fence
Controlled access (alternate water supply)	60%	35%	283,536 feet <sup>e</sup>	99 water tanks <sup>f</sup>
Prescribed grazing	20%	100%	7,009 acres of pasture <sup>g</sup>	7,000 acres

<sup>a</sup> from Table 6.7 in Task 3 report

<sup>b</sup> calculated as target reduction (21%) divided by practice reduction efficiency

<sup>c</sup> Values calculated as the amount of source present (column 4) multiplied by percentage of source to treat to achieve 21% reduction target (column 3). Values rounded to two significant digits.

<sup>d</sup> GIS analysis of 2011 land use data identified 26.85 miles of stream associated with pasture. Based on 2017 aerial imagery, assumed 50% of pasture streams do not have adequate riparian buffer = 13.42 miles = 70,884 feet, multiplied by two streambanks = 141,768 feet.

<sup>e</sup> GIS analysis of 2011 land use data identified 26.85 miles of stream associated with pasture = 141,768 feet, multiplied by two streambanks = 283,536 feet.

<sup>f</sup> Assume 1 tank for every 1,000 feet of fence

<sup>g</sup> based on 2011 National Land Cover Database (Homer, et al. 2015)

Table G.2. Estimated cost for practices to reduce nitrogen load in Lower Salado Creek by 21%.

Practice	Extent/Amount of Practice <sup>a</sup>	Unit Cost <sup>b</sup>	Total Cost <sup>c</sup>
Forest riparian buffer	49 acres	\$2,000 per acre	\$98,000
Herbaceous riparian buffer	68 acres	\$400 per acre	\$27,000
Controlled access (fence)	99,000 feet	\$1.75 per foot	\$170,000
Controlled access (alternate water supply)	99 water tanks	\$1,500 per tank	\$150,000
Prescribed grazing	7,000 acres	\$70 per acre	\$490,000

<sup>a</sup> From Table B.1

<sup>b</sup> Based on EQIP reimbursement values for 2017

<sup>c</sup> Calculated as practice amount (column 2) multiplied by unit cost (column 3). Values rounded to two significant digits.

## 2.0 MANAGEMENT PRACTICES FOR RESIDENTIAL AND DEVELOPED AREAS IN LOWER SALADO CREEK SUBWATERSHED

Unit construction costs for urban stormwater management practices are reported as cost per cubic meter of runoff treated (see Table 8.2). Runoff from several developed catchments within the Lower Salado Creek subwatershed was estimated using information from the USGS StreamStats utility program (<https://streamstats.usgs.gov/ss/>) and the following equations from Claytor and Schueler (1996) reported in Weis, Gulliver, and Erickson (2007):

$$\text{Water Quality Volume (in cubic meters)} = 100 * \text{rainfall depth (in centimeters)} * \text{ratio of runoff to rainfall} * \text{watershed area (in hectares),}$$

and

$$\text{Ratio of Runoff to Rainfall} = 0.05 + 0.009 * \text{percent impervious area (0-100).}$$

The inputs and results from these calculations are shown in Table G.3.

Table G.3. Estimates of runoff from impervious areas for a 1-inch (2.54 centimeter) rainfall depth.

Stream	Drainage area		Percent impervious <sup>a</sup>	Ratio of runoff to rainfall	Water quality volume (cubic meters) <sup>c</sup>
	(square miles) <sup>a</sup>	(hectares) <sup>b</sup>			
Double Branch	4.87	1,261	5%	0.095	30,000
Tributary to Caney Creek	1.21	313	8%	0.122	9,700
Ladd Branch	0.69	179	4%	0.086	3,900
<b>Total</b>					<b>44,000</b>

<sup>a</sup> Estimated using USGS StreamStats,

<sup>b</sup> converted by multiplying area in square miles by 259

<sup>c</sup> values rounded to two significant digits

Table G.4 shows the calculations used to estimate the cost of implementing selected urban stormwater management practices, using the total water quality volume from Table G.3, 44,000 cubic meters.

Table G.4. Estimates of cost to reduce nitrogen load in storm runoff by 21%.

Practice	Practice reduction efficiency <sup>a</sup>	Percentage of volume to treat to achieve 21% reduction target <sup>b</sup>	Volume to treat (cubic meters) <sup>c</sup>	Cost per cubic meter treated <sup>d</sup>	Total Cost <sup>e</sup>
Media filter	25%	84%	37,000	\$18	\$660,000
Constructed wetland	20%	100%	44,000	\$15	\$660,000
Pond	22%	95%	42,000	\$7	\$290,000
Porous pavement	40%	52%	23,000	\$5	\$120,000

<sup>a</sup> From Table 6.6 in Task 3 report

<sup>b</sup> calculated as target reduction (21%) divided by practice reduction efficiency

<sup>c</sup> Values calculated as the runoff volume (44,000 cubic meters) multiplied by percentage of source to treat to achieve 21% reduction target (column 3). Values rounded to two significant digits.

<sup>d</sup> Based on costs reported in Table 8.2 of this report

<sup>e</sup> Calculated as volume to treat (column 4) multiplied by unit cost (column 5). Values rounded to two significant digits.

### 3.0 REFERENCES

- Claytor, Richard A., and Thomas R. Schueler. 1996. *Design of stormwater filtering systems*. Silver Spring, MD: Center for Watershed Protection.
- Homer, CG, JA Dewitz, L Yang, S Jin, P Danielson, G Xian, J Coulston, ND Herold, JD Wickham, and K Megown. 2015. *Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information*. *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5 345-354.
- Weiss, Peter T, John S Gulliver, and Andrew J Erickson. 2007. *Cost and pollutant removal of storm-water treatment practices*. *Journal of Water Resources Planning and Management (American Society of Civil Engineers)* 218-229.