

**Alabama Water Resources Research Institute
Annual Technical Report
FY 2015**

Introduction

The Alabama Water Resources Research Institute (AL WRC) was created in 1964 by the Alabama Legislature. In 2007, the AL WRC was combined with the newly created Auburn University Water Resources Center (AU WRC) and in 2008 it was designated as part of the Auburn University Center of Excellence for Watershed Management. In 2013, the AU WRC and the AL WRC were re-organized and funded under the auspices of Auburn University's Alabama Agricultural Experiment Station (AAES) and the Alabama Cooperative Extension System (ACES).

The mission of the AU WRC is to facilitate successful collaboration among Auburn University faculty and staff on multidisciplinary water-related research, outreach, and teaching; and to facilitate the active involvement of private citizens in the stewardship of water resources. The AL WRC is one of 54 water resources institutes nationwide authorized by the federal Water Resources Research Act and retains membership in the National Institutes for Water Resources (NIWR). The AL WRC serves the state of Alabama at large in administering the funding provided under the Water Resources Research Act that is administered by the US Geological Survey.

To achieve this mission, the AU WRC consists of interdisciplinary teams of research, teaching, and Extension outreach faculty and staff who address all types of water related issues in Alabama, the Southeast, and around the globe. The research activities are funded through the AL WRC, the AAES, and a wide variety of extramural sources. The Extension and outreach activities are carried out through the ACES, extramural sources and through two longstanding AU WRC programs, Alabama Water Watch (AWW) and Global Water Watch (GWW).

AWW is a statewide program developed by Auburn University and dedicated to promoting community-based watershed stewardship through developing citizen volunteer monitoring of Alabama's streams, rivers, lakes and coastal waters, and has a successful history exceeding twenty years. The AWW Program became part of the AU WRC in 2013. The 4-H AWW Program, included in the AWW Program, is a statewide youth volunteer water quality monitoring program created through a partnership between AWW and Alabama 4-H, the youth development program of ACES. Qualified volunteers and educators lead students in water data collection and watershed stewardship activities that promote environmental literacy and science education.

GWW is a worldwide network of citizen groups developed by Auburn University, promoting community-based, science based watershed stewardship. GWW is committed to spreading environmental literacy, and monitoring of streams, rivers, lakes and coastal waters to achieve improvements in water quality, water policy and public health. The GWW Program has a successful history of more than twenty years and became part of the AU WRC in 2013.

The AU WRC and AL WRC are led by the Center's Director, Dr. Puneet Srivastava. Dr. Srivastava has a 50% administrative and 50% research appointment, and manages a rigorous research program in addition to the aforementioned three programs within the AU WRC.

2015 Accomplishments Due to the reorganization of the AU WRC in 2013 and technological changes and advances of the university it was important to pull all pre-existing web-based data and information for AWW, GWW, 4-H AWW and the AU WRC into new web portals organized within a newly-designed, mobile-friendly AU WRC website, <https://aes.auburn.edu/wrc/>.

Annual Alabama Water Resources Conference For the past 29 years, the AU WRC has organized the Annual Alabama Water Resources Conference to engage local, state, and federal agencies; community-based citizen groups; researchers; and undergraduate and graduate students to discuss water issues in the state and to share

new knowledge being developed. Our 2015 conference occurred in September and saw record registrations. More than 100 oral and poster presentations were delivered at this conference. The post-conference survey indicated that the registrants found great value in both networking and information exchange through their participation in the conference.

Alabama Water Resources Research Institute (AL WRC) AU WRC manages the AL WRC Program. One of the activities of the AL WRC is to develop a Request for Proposals, solicit research proposals, arrange a review-and-selection committee to determine proposals to recommend for funding, and then distribute funding for the annual USGS 104 (b) Grant Program. In 2015, duties of this program were successfully executed and three proposals were funded.

National Integrated Drought Information System (NIDIS) webinars Funded by NIDIS, AU WRC hosts monthly, Apalachicola-Chattahoochee-Flint River Basin Drought Early Warning webinars. The webinar presentations are posted on the US Drought portal at <https://www.drought.gov/drought/dews/acf-river-basin>.

Governor's Taskforce on Water At the request of Governor Bentley, state agencies in Alabama created a number of Focus Area Panels (FAPs) to discuss the possibility of developing a state water management plan. The AU WRC Director, Dr. Puneet Srivastava was asked by Governor Bentley to serve on two FAPs which met several times in 2015.

With the passage of the Food Safety Modernization Act (FSMA), the AU WRC sees an opportunity for the development of a bacteriological monitoring program specifically focused on produce farmers. The AWW protocol for citizen training in bacteriological monitoring appears to be an ideal method for assisting Alabama farmers in meeting FSMA's Produce Safety Rule. The AU WRC continues to monitor this situation and seek funding via the Center for Produce Safety for the research component of this new initiative.

Research Program Introduction

Research Program Introduction The essential ingredient for determining proper policies and practices is factual information. Often such information must be obtained by means of scientific research. The Alabama Water Resources Institute (AL WRI) conducts a program that stimulates, sponsors, and provides funding for research, investigation, and experimentation in the fields of water and of resources as they affect water, and encourages the training of scientists in the fields related to water.

Objectives of the AU WRC and AL WRI are:

1. To plan, conduct and otherwise arrange for competent research that fosters (a) the entry of new research scientists into the water resources fields, (b) the training and education of future water scientists, engineers and technicians, (c) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (d) the dissemination of research results to water managers and the public.
2. To identify major research needs and develop for Alabama and the Southeastern Region short- and long-term research priorities.
3. To encourage research applying to other environmental resources closely associated with water.
4. To maintain close consultation and collaboration with governmental agencies, public groups, and cooperate closely with other colleges and universities in the state that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designed to resolve state and regional water and related land problems.

Water Policy and Law in Alabama

Basic Information

Title:	Water Policy and Law in Alabama
Project Number:	2014AL166B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	7
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Water Use
Descriptors:	None
Principal Investigators:	Bennett Bearden, Heather Elliott

Publication

1. This project has produced a 345 page treatise on Alabama water resources law and policy with the following chapters: Alabama’s Water Resources; Alabama’s Ownership of and Regulatory Authority over Its Water Resources; The Law and Policy Governing Alabama Surface Water; The Law and Policy Governing Alabama Groundwater; Water Quality Regulation in Alabama; Instream Flow Science in Alabama; Interbasin Transfers in Alabama; Alabama Public Rights in Water; Alabama Drought Management; Alabama Watershed Management; Special Issues for Water Use by Alabama Municipalities; Special Issues for Water Use by Alabama Irrigators; Water Issues for Non-Hydropower Energy Producers and for Resources Extraction Industries in Alabama; The Apalachicola-Chattahoochee-Flint Dispute; The Alabama-Coosa-Tallapoosa Dispute. These chapters are completed but not yet published.

ANNUAL TECHNICAL REPORT SYNOPSIS

- A. PROJECT TITLE: Water Policy and Law in Alabama
- B. PRIMARY PI: Heather Elliott, Professor of Law, University of Alabama School of Law
- C. OTHER PI(s): William L. Andreen, Edgar L. Clarkson Professor of Law, University of Alabama School of Law
Bennett L. Bearden (Co-PI), Director, Water Policy and Law Institute, University of Alabama
Patrick E. O'Neil (Co-PI), Director, Ecosystems Investigations Program, Geological Survey of Alabama
- D. START DATE: March 1, 2014
- E. END DATE: February 28, 2015
- F. PROJECT OVERVIEW/SUMMARY: Alabama's current water-law regime, because it is primarily a judicially created common-law regime, is nowhere clearly explicated; such explication is necessary to determine its strengths and failings as the state faces growing pressure on its water resources. This project provides a clear explication of Alabama water law and policy, covering the following topics: surface water rights, groundwater rights, irrigation, municipal water uses, instream flows, interbasin transfers, water quality, watershed management, and drought management. A second phase of the project will compare Alabama water resources law to that of its neighboring states, Florida, Georgia, Mississippi, and Tennessee, as well as other states that generally follow riparian doctrine.
- G. PROJECT OBJECTIVE(s): The objective of this project is to produce the definitive statement of Alabama water resources law and policy, including a comparison with the water resources law and policy of other states.
- H. METHODOLOGIES: The methodology of this project focuses on gathering existing case law and statutory materials governing Alabama water resources law and policy and formulating a definitive statement of the Alabama law.
- I. PRINCIPAL FINDINGS/RESULTS: This project has produced a 345 page treatise on Alabama water resources law and policy with the following chapters: Alabama's Water Resources; Alabama's Ownership of and Regulatory Authority over Its Water Resources; The Law and Policy Governing Alabama Surface Water; The Law and Policy Governing Alabama Groundwater; Water Quality Regulation in Alabama; Instream Flow Science in Alabama; Interbasin Transfers in Alabama; Alabama Public Rights in Water; Alabama Drought Management; Alabama Watershed Management; Special Issues for Water Use by Alabama Municipalities; Special Issues for Water Use by Alabama Irrigators; Water Issues for Non-Hydropower Energy Producers and for Resources Extraction Industries in Alabama; The Apalachicola-Chattahoochee-Flint Dispute; The Alabama-Coosa-Tallapoosa Dispute

J. NOTABLE AWARDS AND ACHIEVEMENTS. N/A

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	0
Book Chapters	0*
Theses and Dissertations	0
Water Resources Institute Reports	0
Articles in Conference Proceedings	0
Other Publications	0

* We have an agreement in principle to publish the results of the research as a treatise published by the University of Alabama Press.

L. PRESENTATIONS MADE:

Bennett Bearden, Interbasin Transfers in Alabama, Alabama Water Resources Conference, September 5, 2014

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	
Ph.D.	1 Ph.D. candidate, 17 J.D. candidates
Post Doc	
Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	0
Ph.D. Dissertations	0

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
	Biological Sciences
	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
X	Social Sciences
	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
X	LAW, INSTITUTIONS, & POLICY	LIP
X	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU

	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: Water Law (268), Water Rights (278), Law (140), Policy Analysis (180), Planning (175), Resource Planning (199), Institutional Relationships (124)

Water Policy and Law in Alabama (Year Two)

Basic Information

Title:	Water Policy and Law in Alabama (Year Two)
Project Number:	2015AL167B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	7
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, None
Descriptors:	None
Principal Investigators:	Heather Elliott, Bill Andreen

Publication

1. We have an agreement in principle to publish the results of the research as a treatise published by the University of Alabama Press with the following chapters: 1. Alabama's Water Resources 2. Alabama's Ownership of and Regulatory Powers over Its Waters 3. The Law and Policy Governing Alabama Surface Water 4. The Law and Policy Governing Alabama Groundwater 5. Water Quality Regulation in Alabama 6. Instream Flow Science in Alabama--Water Resources Policies and Management 7. Interbasin Transfers in Alabama 8. Alabama Public Rights in Water 9. Alabama Drought Management 10. Watershed Management in Alabama 11. Special Issues for Water Use by Municipalities 12. Water Issues for Irrigators 13. Special Water Issues Relating to Mining and Energy Industries 14. Alabama's Dams and Impoundments 15. Special Water Issues for Indian Tribes 16. The Dispute over the Apalachicola-Chattahoochee-Flint River Basin 17. The Dispute over The Alabama-Tallapoosa-Coosa River Basin 18. Potential Water Disputes with Mississippi 19. Nuisance And Trespass as Forms Of Water Regulation 20. Climate Change and Its Likely Effects on Alabama's Water Resources 21. Florida's Water Experience – Highlights and Mistakes 22. Water Regulation in Georgia 23. Louisiana Water Law 24. Mississippi Water Law 25. North Carolina Water Law 26. South Carolina's Water Resources 27. Tennessee Water Law and Policy 28. Transitions from Common-Law to Regulatory Regimes: Lessons From South Carolina And Georgia

ANNUAL TECHNICAL REPORT SYNOPSIS

PROJECT TITLE: Water Policy and Law in Alabama: A Comparative Treatise

- A. PRIMARY PI: Heather Elliott, Professor of Law, University of Alabama School of Law
- B. OTHER PI(s): William L. Andreen, Edgar L. Clarkson Professor of Law, University of Alabama School of Law
Bennett L. Bearden (Co-PI), Director, Water Policy and Law Institute, University of Alabama
Patrick E. O'Neil (Co-PI), Deputy Director, Geological Survey of Alabama
- C. START DATE: March 1, 2014
- D. END DATE: February 29, 2016
- E. PROJECT OVERVIEW/SUMMARY: Alabama's current water-law regime, because it is primarily a judicially created common-law regime, is nowhere clearly explicated; such explication is necessary to determine its strengths and failings as the state faces growing pressure on its water resources. This project, completed over two years, provides a clear explication of Alabama water law and policy, covering the following topics: surface water rights, groundwater rights, irrigation, municipal water uses, instream flows, interbasin transfers, water quality, watershed management, drought management, and comparison of Alabama water resources law to that of other Southern states Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.
- F. PROJECT OBJECTIVE(s): The objective of this project is to produce the definitive statement of Alabama water resources law and policy, including a comparison with the water resources law and policy of other states.
- G. METHODOLOGIES: The methodology of this project focuses on gathering existing case law and statutory materials governing Alabama water resources law and policy and formulating a definitive statement of the Alabama law.
- H. PRINCIPAL FINDINGS/RESULTS: This project has produced a 694 page draft treatise on Alabama water resources law and policy with the following chapters:
1. Alabama's Water Resources
 2. Alabama's Ownership of and Regulatory Powers over Its Waters
 3. The Law and Policy Governing Alabama Surface Water
 4. The Law and Policy Governing Alabama Groundwater
 5. Water Quality Regulation in Alabama
 6. Instream Flow Science in Alabama--Water Resources Policies and Management
 7. Interbasin Transfers in Alabama
 8. Alabama Public Rights in Water
 9. Alabama Drought Management
 10. Watershed Management in Alabama
 11. Special Issues for Water Use by Municipalities
 12. Water Issues for Irrigators
 13. Special Water Issues Relating to Mining and Energy Industries

14. Alabama’s Dams and Impoundments
15. Special Water Issues for Indian Tribes
16. The Dispute over the Apalachicola-Chattahoochee-Flint River Basin
17. The Dispute over The Alabama-Tallapoosa-Coosa River Basin
18. Potential Water Disputes with Mississippi
19. Nuisance And Trespass as Forms Of Water Regulation
20. Climate Change and Its Likely Effects on Alabama’s Water Resources
21. Florida’s Water Experience – Highlights and Mistakes
22. Water Regulation in Georgia
23. Louisiana Water Law
24. Mississippi Water Law
25. North Carolina Water Law
26. South Carolina’s Water Resources
27. Tennessee Water Law and Policy
28. Transitions from Common-Law to Regulatory Regimes: Lessons From South Carolina And Georgia

I. NOTABLE AWARDS AND ACHIEVEMENTS. N/A

J. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
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Theses and Dissertations	0
Water Resources Institute Reports	0
Articles in Conference Proceedings	0
Other Publications	0

* We have an agreement in principle to publish the results of the research as a treatise published by the University of Alabama Press.

K. PRESENTATIONS MADE:

Bennett Bearden, Interbasin Transfers in Alabama, Alabama Water Resources Conference, September 5, 2014

Samantha Pline, Transitions from Common-Law to Regulatory Regimes: Lessons From South Carolina And Georgia, Alabama Water Resources Conference, September 11, 2015

L. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	1
Ph.D.	1 Ph.D. candidate, 32 J.D. candidates
Post Doc	
Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	0
Ph.D. Dissertations	0

M. RESEARCH CATEGORIES: (In column 1 mark all that apply)

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	Biological Sciences
	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
X	Social Sciences
	Water Quality
	Other: Explain

N. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

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	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE

	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
X	LAW, INSTITUTIONS, & POLICY	LIP
X	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

O. DESCRIPTORS: Water Law (268), Water Rights (278), Law (140), Policy Analysis (180), Planning (175), Resource Planning (199), Institutional Relationships (124)

Final Report
for
Water Resources Research Institute Program
under
Section 104, Water Resources Research Act of 1984
to the
Alabama Water Resources Research Institute

in support of the
Research Project

WATER POLICY AND LAW IN ALABAMA

by

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FINAL REPORT ON RESEARCH PROJECT WATER POLICY AND LAW IN ALABAMA

Project Summary

The Water Resources Research Institute Program funded a two-year research project, Water Policy and Law in Alabama, beginning March 1, 2014 and ending February 29, 2016.

The project fell under the Focus Categories Law, Institutions, and Policy (LIP) and Management and Planning (M&P); it involved the keywords Water Law (268), Water Rights (278), Law (140), Policy Analysis (180), Planning (175), Resource Planning (199), and Institutional Relationships (124).

The Principal Investigator was Heather Elliott, Professor of Law at the University of Alabama School of Law in Tuscaloosa, AL, which is located in the 7th Congressional District. Co-PIs were William Andreen, the Edgar L. Clarkson Professor of Law at the University of Alabama School of Law; Bennett L. Bearden, the Director of the Water Policy and Law Institute at the University of Alabama; and Patrick E. O'Neil, the Deputy Director of the Geological Survey of Alabama.

The project was approved in recognition of the major and expanding water crisis facing the State of Alabama. Population growth and economic development are putting increasing pressure on water resources already strained by recent droughts, and such droughts are likely to become more frequent and more severe in the future. Disputes with neighboring states over shared water resources threaten Alabama's use of interstate waters to meet future needs. Alabama's current water-law regime, because it is primarily a judicially created common-law regime, is nowhere clearly and exhaustively explicated; such explication is necessary to determine its strengths and failings.

The project has produced a treatise on Alabama water law and policy, a draft of which is submitted with this report. The treatise comprises the following chapters:

1. Alabama's Water Resources
2. Alabama's Ownership of and Regulatory Powers over Its Waters
3. The Law and Policy Governing Alabama Surface Water
4. The Law and Policy Governing Alabama Groundwater
5. Water Quality Regulation in Alabama
6. Instream Flow Science in Alabama--Water Resources Policies and Management
7. Interbasin Transfers in Alabama
8. Alabama Public Rights in Water
9. Alabama Drought Management
10. Watershed Management in Alabama
11. Special Issues for Water Use by Municipalities
12. Water Issues for Irrigators
13. Special Water Issues Relating to Mining and Energy Industries
14. Alabama's Dams and Impoundments
15. Special Water Issues for Indian Tribes
16. The Dispute over the Apalachicola-Chattahoochee-Flint River Basin
17. The Dispute over The Alabama-Tallapoosa-Coosa River Basin

18. Potential Water Disputes with Mississippi
19. Nuisance And Trespass as Forms Of Water Regulation
20. Climate Change and Its Likely Effects on Alabama's Water Resources
21. Florida's Water Experience – Highlights and Mistakes
22. Water Regulation in Georgia
23. Louisiana Water Law
24. Mississippi Water Law
25. North Carolina Water Law
26. South Carolina's Water Resources
27. Tennessee Water Law and Policy
28. Transitions from Common-Law to Regulatory Regimes: Lessons From South Carolina And Georgia

The treatise is nearly 700 manuscript pages and reflects the work of nearly 40 people over two years. The treatise fills a void: there is no other such treatise, or anything approaching such a document. Among the benefits of the project:

- The treatise thoroughly describes Alabama's surface- and groundwater resources.
- The treatise provides an exhaustive and definitive statement of virtually every aspect of Alabama water law and policy.
- The treatise highlights the strengths and failings of Alabama water law and policy.
- The treatise compares Alabama water law and policy to that of its Southeastern neighbors, some of whom have adopted strategies that may inform Alabama policy choices.
- The treatise explains existing and potential conflicts over water resources with neighboring states.
- The treatise investigates the possible effect global climate change may have on Alabama's water resources and, as a result, on Alabama water law and policy.

The treatise, it is to be hoped, will prove valuable to policymakers as they determine what, if any, changes need to be made to Alabama water law and policy to meet future challenges.

The University of Alabama Press has agreed in principle to publish the treatise. (The Board of the Press is permitted to vote on a publishing contract only after seeing a completed manuscript.) Thus the treatise will have behind it the expert technical and promotional assistance of a major university press.

FINAL REPORT ON RESEARCH PROJECT WATER POLICY AND LAW IN ALABAMA

Nature, Scope, and Objectives; Need for Project

1. Nature of the Research

As is generally true among the humid states east of the 100th meridian, Alabama adopted and modified the “riparian” common-law doctrine of England to regulate surface waters. Similarly, like many other American states, Alabama abandoned the English law governing groundwater and adopted the “American reasonable use rule.” Unlike many of the humid states, Alabama has never adopted a modern statute to regulate water use comprehensively. The primary water-rights statute, the Alabama Water Resources Act (AWRA), disavows any intent to change existing water rights, which are conferred by common law.

Because Alabama has always relied on a common-law method, where judges determine the law on a case-by-case basis, there has been no clear and exhaustive statement of the content of Alabama’s water law. The treatise that accompanies this report fills this void.

The need for such a statement is manifest. First, without a clear statement of existing law, it is difficult or even impossible to determine what existing water rights are. While various treatises on the law give overviews of Alabama water-rights law, their national focus allows coverage of Alabama law that is necessarily summary. No existing treatise provides the detailed statement necessary to guide Alabama lawyers and policymakers in understanding the full content of Alabama water law. Some of these treatises even conflict with each other (compare, e.g., A. DAN TARLOCK, *LAW OF WATER RIGHTS & RESOURCES* § 3:56 (2013) (suggesting that Alabama may still follow the natural flow doctrine), with William L. Andreen, *Alabama Water Law* in *WATERS AND WATER RIGHTS AL-1 to AL-36* (Amy K. Kelley ed., LexisNexis/Matthew Bender 2016) (describing Alabama as state that follows common-law riparian doctrine)). The definitive statement of Alabama water law and policy provided by this treatise resolves these conflicts and gives the details necessary to provide legal and policy guidance.

Second, we must know the current status of the law to determine what changes might be desirable: Alabama is one of the minority of eastern states that still relies almost exclusively on the common law as a source for water rights. Many other humid states have adopted at least some measure of statutory regulation of water resources to arrive at a doctrine called “regulated riparianism.” Alabama is currently considering such a move, with the Alabama Water Agencies Working Group and the Joint Legislative Committee on Water Policy taking steps to determine what the appropriate water policy should be. The definitive statement of Alabama water law and policy provided by the treatise permits those governmental entities to work from solid legal ground.

2. Scope of the Research

The treatise covers Alabama’s water resources law and policy in comparative perspective. The first portion of the treatise was written from March 1, 2014, to February 28, 2015, and explored existing Alabama law and policy governing the ownership of the waters of the state, rights to surface water and groundwater (including non-riparian issues such as access to water for irrigation and water supply), irrigation issues, instream flows, interbasin transfers, water quality, watershed management, and drought management. In that first year, efforts were also made to

address specific issues that arise for agricultural irrigators, energy producers, and municipal water systems, and to delineate the interstate conflicts that Alabama faces over water resources . The second half of the project, begun on March 1, 2015 and largely completed by February 29, 2016, expands on the topics already listed; adds several Alabama topics, including special issues for Alabama’s Indian tribes and the law governing dams and impoundments; undertakes to compare Alabama’s water resources regime to the regimes of Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee; and investigates what happened in Georgia and South Carolina when those states moved from common-law to statutory regulation of water (because they are the most recent states in the Southeast to do so, we concluded they might provide the most salient comparisons).

3. Objectives of the Research

The main purpose of the treatise is to produce a clear statement of Alabama’s current water law and policy, with comparisons to Georgia, Florida, Tennessee, Mississippi, Louisiana, North Carolina, and South Carolina law.

Specifically, the treatise exhaustively describes existing law and policy in both Alabama and the other identified Southern states regarding:

- Ownership of the waters of Alabama;
- Water supply issues;
- Surface water rights;
- Groundwater rights;
- Non-riparian issues (including access to water for irrigation and water supply);
- Interbasin transfers;
- Irrigation issues;
- Instream flows;
- Water quality;
- Drought management;
- Watershed protection; and
- Other issues that arise in connection with these issues.

4. Need for the Project

No one has completed a truly comprehensive study of Alabama water policy and law. Water law treatises contain only summaries of the law, some of which are truly inadequate, e.g., A. DAN TARLOCK, *LAW OF WATER RIGHTS & RESOURCES* § 3:56 (2010), and some of which are accurate, broad-ranging, but necessarily compressed, e.g., William L. Andreen, *Alabama Water Law* in *WATERS AND WATER RIGHTS AL-1 to AL-36* (Amy K. Kelley ed., LexisNexis/Matthew Bender 2016). The Alabama Law Institute compiled all Alabama laws relevant to water, but that compilation contains relatively little analysis. *ALABAMA WATER LAWS* (Ala. Law. Inst. 2007). Several recent authors have written about Alabama water law and policy, but none of these pieces are comprehensive. E.g., Heather Elliott, *Alabama’s Water Crisis*, 63 ALA. L. REV. 383 (2012); W. Barron A. Avery, *Disenfranchising the Non-Riparian: Alabama’s Water Resource Management Program*, 39 CUMB. L. REV. 437, 441–42 (2009); Larry O’Neil Putt, *Water Resource Protection in Alabama: The Need for a Paradigm Change*, 7 JONES L. REV. 1 (2003).

The best articles in the field are long out of date. *E.g.*, Harry Cohen, *Water Legislation Perspectives for Alabama*, 26 ALA. L. REV. 177 (1973); Harry Cohen, *Water Law in Alabama—A Comparative Survey*, 24 ALA. L. REV. 453 (1972).

More attention has been paid to Alabama's dispute with Georgia and Florida over the Apalachicola-Chattahoochee-Flint system. Andreen, *supra*, at AL-17 to AL-32; Stephen E. O'Day et al., *Wars Between the States in the 21st Century: Water Law in an Era of Scarcity*, 10 VT. J. ENVTL. L. 229 (2009); Robert Haskell Abrams, *Broadening Narrow Perspectives and Nuisance Law: Protecting Ecosystem Services in the ACF Basin*, 22 J. LAND USE & ENVTL. L. 243 (2007); Natasha Meruelo, *Considering a Cooperative Water Management Approach in Resolving the Apalachicola–Chattahoochee–Flint River Basin Water War*, 18 FORDHAM ENVTL. L. REV. 335 (2007); Joseph W. Dellapenna, *Interstate Struggles over Rivers: The Southeastern States and the Struggles over the 'Hooch*, 12 N.Y.U. ENVTL. L.J. 828, 828 (2005); Benjamin L. Snowden, *Bargaining in the Shadow of Uncertainty: Understanding the Failure of the ACF and ACT Compacts*, 13 N.Y.U. ENVTL. L.J. 134, 146 (2005); Andrew Thornley, *A Tale of Two River Basins: The Southeast Finds Itself in a Rare Interstate Water Struggle*, 9 U. DENV. WATER L. REV. 97, 102 & n.31 (2005); Christine A. Klein, *On Integrity: Some Considerations for Water Law*, 56 ALA. L. REV. 1009 (2004); Douglas L. Grant, *Interstate Allocation of Rivers Before the United States Supreme Court: The Apalachicola–Chattahoochee–Flint River System*, 21 GA. ST. U. L. REV. 401, 401 (2004); Joseph Dellapenna, *Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. ARK. LITTLE ROCK L. REV. 9 (2002); Mary R. Hawk, Comment, *Interstate Compacts: Allocate Surface Water Resources from the Alabama–Coosa–Tallapoosa River Basin Between Georgia and Alabama; Allocate Surface Water Resources from the Apalachicola–Chattahoochee–Flint River Basin Among Alabama, Florida, and Georgia*, 14 GA. ST. U. L. REV. 47, 54–55 (1997); Carl Erhardt, *The Battle over "The Hooch": The Federal-Interstate Water Compact and the Resolution of Rights in the Chattahoochee River*, 11 STAN. ENVTL. L.J. 200 (1992). In general, however, these articles do not provide the comprehensive and in-depth statement of Alabama water resources law that is needed.

FINAL REPORT ON RESEARCH PROJECT WATER POLICY AND LAW IN ALABAMA

Methods, Procedures, and Facilities

1. Methods and Procedures

The drafting of the treatise proceeded in several distinct phases, all supervised and managed by Principal Investigator Heather Elliott using research assistants (RAs). All RAs were selected based on background in water law, interest in water law, and/or excellence of writing and research skills.

Professor Elliott applied for the WRRRI grant in Fall 2013. She was notified of the approval of the grant in Spring 2014, and the funds became available in May 2014. Professor Elliott advertised for research assistants in April 2014, hiring three law students to work as research assistants (RAs) starting in May 2014. The work was assigned as follows:

- RA Colin Kruger, a rising third-year law student (3L) who had taken Water Resources Law, began drafting material on Alabama's common law doctrine, statutes, and regulations governing surface and groundwater use.
- RA Axel Buchwalter, a rising second-year law student (2L), began drafting material on Alabama and federal statutes and regulations governing surface water quality.
- RA Kevin Bartz, a rising 2L, began drafting material on Alabama common-law doctrine, statutes, and regulations governing drought management and watershed management.

Professor Elliott met regularly with the RAs, read and closely edited drafts of their work, gave extensive comments and guidance for continued work, connected the RAs with experts in the areas on which they were working, and ensured that the RAs were submitting appropriate and reasonable hours for payment under the grant.

In addition, Co-PI Bennett Bearden began to draft the chapter on interbasin transfers, and Co-PI Patrick O'Neil began to draft the chapter on instream flows.

In August 2014, RA Kruger became unable to continue with the project. RAs Buchwalter and Bartz continued their assigned work and attended the Alabama Water Resources Conference in Orange Beach, Alabama in September 2014 with Professor Elliott.

In late August 2014, Professor Elliott hired additional research assistants to continue to draft material for the treatise. At this point, only 3L students would have had the opportunity to take water resources law, because it was not offered in Fall 2014, Spring 2015, or Fall 2015. The work was assigned as follows:

- RA Shawn Carter, a graduate student in the Geography Department of the University of Alabama, began drafting material describing Alabama's surface water resources.
- RA Lauren Breland, a 3L who had taken Water Resources Law, took over the drafting of the material on surface water use.
- RA Kara Deal, a 3L who had taken Water Resources Law, took over the drafting of the material on groundwater use.
- RA Aleksandra Matuszewski, a 2L, began drafting material on public rights in Alabama's water resources, including navigation, recreation, fishing, and hunting, as well as material on the public trust doctrine more generally.

- RA Michael Morris, a 3L, began drafting material on Alabama's dams and the law that governs them.
- RA Chase Chesser, a 2L, began drafting material on Alabama's dispute with Georgia and Florida over the Apalachicola-Chattahoochee-Flint river systems.
- RA Joseph Mammone, a 2L, began drafting material on Alabama's dispute with Georgia over the Alabama-Coosa-Tallapoosa river systems.

As during the summer, Professor Elliott continued to hold meetings, review and closely edit drafts, set new paths for research, and ensure that RAs were completing their assigned work in a timely and efficient manner.

The work described above continued throughout the Fall semester. In November 2014, Professor Elliott applied for the second year of funding through the WRI program.

At the end of the Fall semester, RAs Chesser, Deal, and Matuszewski ended their work on the project. In December 2014, as the remaining RAs continued their assigned work, Professor Elliott hired several more RAs to work on additional material and to begin reviewing, editing, and cite-checking existing material, and assigned new tasks to existing RAs:

- RA Mammone and RA Manley Cummins, a 2L, began drafting material on state ownership of and regulatory authority over water resources.
- RA Chris Lee, a JD/MBA student who had taken Water Resources Law, began drafting material on issues faced by the agricultural industry and by small farmers in obtaining water to pursue agricultural activities.
- RA John Gamble, a 3L who had taken Water Resources Law, began drafting material on issues faced by the energy production and resource extraction industries in obtaining water to pursue their businesses.
- RAs Stephen McKitt, a 2L, Emily Vande Lune, a 2L, and Erin Hardin, a 2L, began working as editors and cite-checkers.
- RA Buchwalter began coordinating the work of the editors and cite-checkers, working closely with Professor Elliott.

Despite the extensive work done by the RAs, in January 2015, it became clear that substantial funds remained from the 2014-15 grant. Professor Elliott sought and obtained a no-cost extension for those funds from the WRI at Auburn University. At the same time, the second year of funding under the WRI program was approved.

The work described above continued throughout Spring 2015 under Professor Elliott's close supervision. RA Cummins took on the additional task of researching North Carolina's approach to water resources management.

In March 2015, Professor Elliott advertised for a number of new RA positions commensurate with the scope of the project remaining. The following RAs were hired to work on additional material and to continue reviewing, editing, and cite-checking existing material, and existing RAs continued their work or were assigned new tasks:

- RA Buchwalter established a comprehensive task management system to make sure that all material was being drafted, edited, cite-checked, and finalized in a timely way and began to serve largely as project manager and assistant to Professor Elliott.

- RAs Bartz, Cummins, Gamble, Lee, Mammone, and Morris continued their assigned tasks.
- RA McKitt began drafting material on how the common law of nuisance and trespass apply to water resources.
- RA Breland began drafting material on potential disputes over shared water resources with Mississippi.
- RA Vande Lune began drafting material on Georgia's and Mississippi's approaches to groundwater management.
- RA Hardin began drafting material on Mississippi's approach to surface water management.
- RA Greg Pierce, a graduate student in the Geography Department of the University of Alabama, replaced RA Carter in drafting material describing Alabama's surface water resources.
- RA Alyssa Leard, a rising 2L, began drafting material on how global climate change will affect Alabama's water resources.
- RA Trent Dressen, a rising 3L, began drafting material on the application of Fifth Amendment and Fourteenth Amendment takings law to changes in the legal regimes regulating water resources.
- RA David Terry, a rising 3L, did substantial additional work drafting and editing the chapters on Alabama's common-law doctrine governing groundwater management and North Carolina's approach to water resources management.
- RA Jonathan Pivetz, a rising 2L, did substantial additional work drafting and editing the chapter on public rights in water resources.
- RA Ethan Wilkinson, a rising 3L, began drafting material on Alabama and federal statutes and regulations governing groundwater quality.
- RA Brian Padgett, a graduating law student, began drafting material on the special issues that face municipalities as they seek to provide water to their citizens.
- RA Vikram Bhatia, a rising 2L, began drafting material on Florida's approach to water resources management.
- RA Bridget Harris, a rising 2L, began drafting material on Georgia's approach to surface water management.
- RA Sarah Jackson, a rising 2L, began drafting material on Louisiana's approach to water resources management.
- RA Brandi Soper, a graduating law student, began drafting material on South Carolina's approach to water resources management.
- RA J.T. Salmon, a rising 2L, began drafting material on Tennessee's approach to water resources management.
- RA Samantha Pline, a rising 2L, began drafting material on the political processes that led Georgia, South Carolina, Florida, and other states, to move from common-law to statutory regimes of water resources management.
- RA James Rodgers, a rising 2L, completed cite-checking and editing tasks.

Professor Elliott held regular group meetings with the RAs to facilitate communication among those working on similar topics, as well as continuing her usual supervisory tasks.

The work of RAs Breland, Gamble, Morris, Padgett, and Soper terminated in late July 2015 (as graduated students, they were permitted to work for the University only up to the Bar Exam, which is always given in the last week of July). RAs Bhatia, Dressen, Leard, Rodgers, Salmon, Terry, Vande Lune, and Wilkinson ended their work in mid-August, having sought only summer employment. RA Pivetz ended his work in October 2015 for family reasons.

RAs Bartz, Buchwalter, Cummins, Mammone, McKitt, Pierce, and Pline attended the Alabama Water Resources Conference in Orange Beach, Alabama in September 2015. RA Pline made a presentation to the conference on the processes followed by Georgia and South Carolina in moving from a common-law to a statutory regime of water resources management.

In early Fall 2015, Marlon Cook of the Geological Survey of Alabama agreed to draft material describing Alabama's groundwater resources. The following additional RAs were also hired:

- Bethanie Blair, a 3L, and Catie Malone, a 2L, began editing and cite-checking work.
- Robert Carter, a 2L, continued the research and drafting of the chapter on interbasin transfers and began editing and cite-checking work.
- Reid Harris, a 2L, undertook research into how states other than Alabama regulate instream flows and performed editing and cite-checking work.
- Jay Malone, a 3L, continued the research and drafting of the chapter on dams, as well as performing editing and cite-checking work.

RAs Bartz, Blair, Buchwalter, Carter, Cummins, Hardin, B. Harris, R. Harris, Jackson, Lee, C. Malone, J. Malone, Mammone, McKitt, and Pline continued to work in various capacities until the end date of the grant, February 29, 2016.

In the end, 35 different research assistants worked on the treatise under the supervision of Professor Elliott. Of these, thirty-two were students at the University of Alabama School of Law, one was a joint-degree student in law and business at the University of Alabama, and two were graduate students in the Geography Department of the College of Arts and Sciences at the University. Twenty-three were men and twelve were women; five identify as persons of color. Co-PI Bearden of the Water Policy and Law Institute, Co-PI O'Neil of the Geological Survey of Alabama, and Marlon Cook of the GSA also contributed material to the treatise.

2. Facilities

The research was done through the University of Alabama School of Law, using its library and computing resources, through the Water Policy and Law Institute at The University of Alabama, and through the Geological Survey of Alabama.

FINAL REPORT ON RESEARCH PROJECT
WATER POLICY AND LAW IN ALABAMA

Investigator Qualifications

Heather Elliott, J.D., M.A. (P.I.)

Heather Elliott is a Professor of Law at the University of Alabama School of Law. She has over ten years of experience teaching water law and related topics, as well as supervising J.D. student research in water law and environmental law topics more generally. She received her J.D., Order of the Coif, from the University of California, Berkeley School of Law (Boalt Hall), with environmental law certificate. After clerking for Justice Ruth Bader Ginsburg at the United States Supreme Court and for Judge Merrick B. Garland at the United States Court of Appeals for the District of Columbia Circuit, Elliott practiced appellate litigation in the D.C. office of WilmerHale. She is admitted to the Bar in Washington, D.C., and California.

William L. Andreen, J.D. (Co-P.I.)

William L. Andreen is the Edgar L. Clarkson Professor of Law at the University of Alabama School of Law, where he teaches environmental law, international environmental law, and administrative law. He holds a J.D. degree from Columbia University School of Law. Prior to joining the law school, he served as Assistant Regional Counsel of the U. S. Environmental Protection Agency, Region 4. He is a past Chair of the Environmental Law Section of the American Association of Law Schools, and currently serves on the Environmental Law Commission of the World Conservation Union and in many similar capacities. Professor Andreen publishes widely on water pollution law and water management, as well as on other environmental and administrative law topics.

Bennett L. Bearden, J.D., LL.M., J.S.D. (Co-P.I.)

Bennett Bearden's legal, political and negotiating experiences have placed him squarely in the center of one of Alabama's most important natural resources issues: water policy. He is Director of the Water Policy and Law Institute at the University of Alabama. In April 2012, Governor Robert Bentley appointed Bearden chair of the Alabama Water Agencies Working Group, the task force charged with developing policy options for a comprehensive water management plan for the State. As chair, he has provided the AWA WG with constructive resolution of emerging challenges at the intersection of water policy and law, emphasizing strategic counseling, crisis management, creative dispute resolution and enhanced relations with stakeholders and community groups. He currently serves as Special Counsel on Water Law and Policy for the Office of the Governor of the State of Alabama. He is a former Special Counsel on Water Law and Policy for the Office of the State Geologist and General Counsel for the Geological Survey of Alabama.

Bearden received B.S. in Geology and M.S. (geology) degrees from the University of Alabama. He received his Juris Doctor (J.D.) degree from Birmingham School of Law (ranked no. one academically in his class) and his Master of Laws (LL.M.) degree in Commercial and Corporate Law (with honors) from the University of London. Bearden also has a post-graduate Certificate

in Watershed Management from the University of British Columbia. He earned his doctorate (J.S.D. degree, legal education's counterpart to the Ph.D.) in water law and policy at McGeorge School of Law, University of the Pacific, in Sacramento, California, where he was the recipient of the 2008 Slater International Water Law Award.

Bearden is a member of the Alabama State Bar, the Washington DC Bar and is admitted to the Roll of Solicitors in England and Wales. He is a member of the American Bar Association (ABA) Section of Environment, Energy, and Resources (SEER) Water Resources Committee, the Executive Committee of the Environmental Section of the Alabama State Bar, the Alabama Section of the American Water Resources Association (AWRA), the Organizing Committee of the Alabama Water Resources Conference and the International Water Association (IWA).

Bearden was an Adjunct Professor at Birmingham School of Law where he taught water law, environmental law, contracts, equity, and trial advocacy. He also taught water resources management, law and policy at the University of Alabama. His work has been published in *Water Policy*, the official journal of the World Water Council.

Patrick E. O'Neil, Ph.D. (Co-P.I.)

Patrick E. O'Neil currently serves as Deputy Director of the Geological Survey of Alabama (GSA), a State agency that conducts geologic, energy, water, and biological research directed at managing and conserving Alabama's resources while providing information for their prudent development. His responsibilities are to supervise GSA Managers including program and budget development, funding, training, and employee evaluation and performance. He oversees the GSA publication program including development of technical reports, publications, maps, and other materials and reviews contract reports and other technical and administrative documents to ensure completeness and technical accuracy. Serves as a technical liaison between GSA programs and other administrative departments including budget and finance, information technology, and personnel and represents the agency at meetings, on boards and councils, and works with the State Geologist in formulating, implementing, and administering departmental programs, research, and policies. Supervises/conducts hydrological, biological, and water-related research as needed to evaluate the state's natural resources and provide information to the public.

He has worked in Alabama on numerous water-related research projects for nearly 40 years. He attended the University of Alabama where he received B.S. and M.S. degrees in Biology, and a Ph.D. degree in Civil Engineering emphasizing water quality, water supply, and wastewater treatment. He was employed by the Geological Survey of Alabama in 1979 as a staff Biologist/Hydrologist and is currently Deputy Director of the agency. During his career at the Survey Pat has conducted water resource investigations, watershed studies, and biological surveys throughout the State and collected thousands of water and biological samples. He has authored or coauthored numerous reports and publications dealing with Alabama's water resources and unique aquatic fauna. His current work at the Survey can be summarized in three areas: (1) applying the principals of aquatic biomonitoring to assess stream water quality and integrating the methods of hydrology, biology, geology, and engineering into the field he calls "interdisciplinary watershed science" for investigating Alabama's watersheds and water resources; (2) developing strategic initiatives to restore and recover Alabama's aquatic biodiversity, and (3) working with a wide array of stakeholders to update Alabama's water policies.

HEATHER ELLIOTT

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EXPERTISE

A leading expert in Alabama water resources law and U.S. water law more generally. Teaches water resources law, land use planning, and comparative environmental law at the University of Alabama School of Law. Has written articles on Alabama water law and U.S. water law.

PROFESSIONAL PREPARATION

J.D. with Environmental Law Certificate, Order of the Coif, University of California School of Law (Boalt Hall), 2000

M.A., M. Phil., Political Science, Yale University, 1994

B.A., *magna cum laude*, Political Science, Philosophy, Duke University, 1990

PROFESSIONAL APPOINTMENTS

University of Alabama School of Law, Full Professor August 2014-present; Associate Professor, August 2010-August 2014 (tenure effective August 16, 2012); Assistant Professor, June 2008-August 2010; Hugo Black Faculty Fellow, August 2002-July 2003

Columbus School of Law, The Catholic University of America, Assistant Professor, 2005- 2008

Law clerk, Justice Ruth Bader Ginsburg, Supreme Court of the United States, 2001-2002

Law clerk, Judge Merrick B. Garland, United States Court of Appeals for the District of Columbia Circuit, 2000-2001

RELEVANT PUBLICATIONS

Alabama's Water Crisis, 63 ALA. L. REV. 383 (2012)

We Face a Water Emergency, CAPSTONE LAWYER (2012)

WATER LAW 101 (ABA May 20, 2010) (with Christine Klein)

Water as Development Resource: Lessons from the Southeastern United States and the U.S.-Mexico Border, in 2 COMPARATIVE PERSPECTIVES ON THE LAW: PORTUGAL & THE UNITED STATES ((Dário Moura Vicente ed., 2010)

SYNERGISTIC ACTIVITIES

Speaks at conferences, at colleges and universities, and to community groups about water resources issues:

American Bar Association Annual Water Law Conference

Alabama Water Resources Symposium
Alabama Bar Association Annual Meeting
League of Women Voters
Pomona College, Department of Political Science
University of Alabama, Department of Geography
Georgia Tech Bar Association
Universidade de Lisboa, Faculdade de Direito

Has served as a consultant to the Alabama Office of Water Resources on water resources issues.

WILLIAM ANDREEN

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EXPERTISE

A leading expert on the federal Clean Water Act and on Alabama water resources law. Has taught administrative law, environmental law, international environmental law, comparative environmental law, Ethiopian environmental law, and water pollution law.

PROFESSIONAL PREPARATION

J.D., Columbia University School of Law, New York, New York, 1977

B.A., College of Wooster, Wooster, Ohio, 1975

PROFESSIONAL APPOINTMENTS

The University of Alabama School of Law, Edgar L. Clarkson Professor of Law (1992-present); Professor of Law (1989-1992); Associate Professor of Law (1986-1989); Assistant Professor of Law (1983-1986); Director, University of Alabama/Australian National University Reciprocal Summer School Program (2000-present)

The Australian National University, Adjunct Professor of Law (2006-2015)

RELEVANT PUBLICATIONS

Editor, ALABAMA WATER LAWS (2007) (two volumes; produced for the Alabama Office of Water Resources and published by the Alabama Law Institute).

Editor, ENVIRONMENTAL LAW AND REGULATION IN ALABAMA (1990 ed.) (Bradley Arant Rose & White).

Water Law and the Search for Sustainability: A Comparative Analysis, in WATER RESOURCES PLANNING AND MANAGEMENT: CHALLENGES AND SOLUTIONS 155-174 (Quentin Grafton & Karen Hussey, eds., Cambridge University Press) (2011).

Alabama Water Law in WATERS AND WATER RIGHTS AL-1 to AL-36 (Amy K. Kelley ed., LexisNexis/Matthew Bender 2016), and also in Volume 4 of WATERS AND WATER RIGHTS (Amy Kelley, ed., LexisNexis (2013), and in Volume 6 (2005 and 1994 editions) (Robert Beck, ed., LexisNexis) and Annual Supplements 1996-2004; 2007-2012.

Success and Backlash: The Remarkable (Continuing) Story of the Clean Water Act, 4 GEORGE WASHINGTON JOURNAL OF ENERGY AND ENVIRONMENTAL LAW 25-37 (2013).

Motivating Enforcement: Institutional Culture and the Clean Water Act, 24 PACE ENVIRONMENTAL LAW REVIEW 67-98 (2007)

Developing a More Holistic Approach to Water Management in the United States, 36 ENVIRONMENTAL LAW REPORTER (Environmental Law Institute) 10,277-10,289 (2006) (published as part of a special edition on “Sustainable Water Management in Australia, Europe, and the United States”)

The Evolution of Water Pollution Control in the United States: State, Local and Federal Efforts, 1789-1972: Part II, 21 STANFORD ENVIRONMENTAL LAW JOURNAL 215-294 (2003)

The Evolution of Water Pollution Control in the United States: State, Local and Federal Efforts, 1789-1972: Part I, 21 STANFORD ENVIRONMENTAL LAW JOURNAL 145-200 (2003)

SYNERGISTIC ACTIVITIES

Member, University of Alabama Freshwater Studies Center

Senior Fulbright Specialist in Law, The Australian National University, Canberra (Fall 2005), convened the International Symposium on Sustainable Water Management: Comparative Perspectives from Australia, Europe and the United States at the National Museum of Australia (September 15-16, 2005).

Scholar, Center for Progressive Reform, Washington D.C.

Commission on Environmental Law, International Union for the Conservation of Nature (IUCN) (1997-present)

Advisory Committee, Natural Resources Defense Council (NRDC) Project on Clean Water Act Implementation and Enforcement (2012-13).

BENNETT BEARDEN

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EXPERTISE

Serves as Director of the Water Policy and Law Institute at the University of Alabama (UA) under the Vice President for Research; responsible for the development and management of the UA water policy and law initiative; develops relationships with federal and state agencies involved in water policy and coordinates the expertise resident at the UA to provide these agencies with information and guidance related to water policies and laws; coordinates with the science centers and institutes at the UA to integrate science with policy and law.

Serves as Special Counsel on Water Law and Policy for the Office of the Governor; provides the forward-thinking Executive Division with constructive resolution of emerging environmental challenges and water resources issues at the intersection of law and policy; emphasizes strategic counseling, crisis management, creative dispute resolution and enhanced relations with stakeholders and community groups in order to ensure compliance with mandates under Senate Joint Resolution No. 28, creating the Alabama Permanent Joint Legislative Committee on Water Policy and Management, in the development of the Alabama Water Management Plan to recommend to the Governor and Legislature courses of action to address the State's long-term and short-term water resources challenges

Serves as Chairman (appointed by Governor Robert Bentley on April 18, 2012) of the Alabama Water Agencies Working Group, a five-member coalition of state agencies (Alabama Department of Environmental Management (ADEM), Alabama Department of Conservation and Natural Resources (DCNR), Alabama Department of Agriculture and Industries (AGI), Geological Survey of Alabama (GSA) and Alabama Office of Water Resources (OWR)) charged with developing water policy and a comprehensive water management plan for the State of Alabama.

PROFESSIONAL PREPARATION

Doctor of Juridical Science (J.S.D., legal education's counterpart to the Ph.D.) in International Water Resources Law, McGeorge School of Law, University of the Pacific, December 2011, Dissertation: Following the Proper Channels: Tributaries in the Mekong Legal Regime (selected portions of dissertation published in *Water Policy* journal and forthcoming book entitled *The UN Watercourse Convention In Force-Strengthening International Law for Transboundary Water Management* (London, Earthscan 2013) with Alistair Rieu-Clarke and Sokhem Pech

Master of Laws (LL.M.) in Commercial and Corporate Law, (with Merit (honors)) University of London, November 2006

Post-Graduate Certificate in Watershed Management, University of British Columbia, Institute for Resources, Environment and Sustainability, December 2004

Juris Doctor (J.D.) degree, Birmingham School of Law, May 1992

Master of Science degree (Geology), University of Alabama, December 1984 (Thesis published in the American Association of Petroleum Geologists (AAPG) Bulletin, Vol. 69, No. 3, March 1985, Petroleum Geology of the Carter Sandstone (Upper Mississippian), Black Warrior Basin, pages 361-377)

Bachelor of Science in Geology degree (45 hour specialized degree), University of Alabama, May 1981

Bachelor of Science degree (Geography), University of Alabama, May 1980

PROFESSIONAL APPOINTMENTS

Chair, Alabama Water Agencies Working Group

Special Counsel on Water Law and Policy to the Governor of Alabama

Member of Executive Committee of the Environmental Law Section of the Alabama State Bar

RELEVANT PUBLICATIONS

Bearden, B. L., 2012, Following the proper channels: tributaries in the Mekong legal regime: *Water Policy*, v. 14, no. 6, p. 991-1014.

Bearden, B. L., 2012, Water Policy in Alabama: An Idea Whose Time Has Come? (abstract): 26th Annual Alabama Water Resources Conference and Symposium, September 5-7, 2012, Orange Beach, Alabama.

Bearden, B.L., 2012, Water Policy and Law Update: The Alabama Water Agencies Working Group (abstract): 26th Annual Alabama Water Resources Conference and Symposium, September 5-7, 2012, Orange Beach, Alabama.

Bearden, B. L., 2011, Bridging the Science, Policy and Law Interface: Examples from the Water Resources Spectrum (abstract): 25th Annual Alabama Water Resources Conference and Symposium, September 7-9, 2011, Orange Beach, Alabama.

Bearden, B.L., 2011, Emerging Water Resources Issues in Alabama, Louisiana and Mississippi: Update on Alabama Water Resources Issues: Alabama, Louisiana and Mississippi State Bar Associations Environmental Law Sections, 20th Annual Beach and Bar Symposium, Environmental Regulation 2011: Turmoil, Catastrophes, and New Realities, June 17, 2011, Sandestin Beach Resort, Destin, Florida, 24 p.

Bearden, B.L., 2010, The legal regime of the Mekong River: a look back and some proposals for the way ahead: *Water Policy*, v. 12, no.6, p. 798-821.

Bearden, B.L., Update on Water Issues, 2010 Alabama Oil and Gas Seminar, October 29, 2010, University of Alabama School of Law, Tuscaloosa, Alabama, 20 p.

Bearden, B.L., 2010, What Goes Around, Flows Around: An Overview of Instream Flow Laws and Regulations in the Southeastern United States (abstract): 24th Annual Alabama Water Resources Conference, September 8-10, 2010, Orange Beach, Alabama.

Bearden, B.L. Bearden, 2009, The Legal Regime of Water Resources in Alabama (abstract): 23rd Annual Alabama Water Resources Conference, September 9-11, 2009, Orange Beach, Alabama.

Bearden, B.L., 2009, Alabama Water Rights: Environmental Challenges at the Intersection of Law and Policy (abstract), Alabama Department of Environmental Management (ADEM) 20th Annual Nonpoint Source Conference Summary of Presentations, p. 24.

Bearden, B.L., 2006, Water Rights in Alabama: Emerging Environmental Challenges at the Intersection of Law and Policy: The EnLaw, Official Newsletter of the Environmental Law Section of the Alabama State Bar, v. 13, No. 3, p. 10-14.

Bearden, B.L., 2003, A Lawsuit Runs Through It: The Clean Water Act Storm Water Phase II Regulations: Alabama Bar Institute for Continuing Legal Education, Seminar-What Every Real Estate Lawyer Needs to Know, October 10, 2003, 25 p.

Bearden, B. L., 2003, Storm Water Phase II Regulations: Impacts on Local Governments: Proceedings of the Alabama Association of Municipal Attorneys Annual Law Seminar, 84 p.

SYNERGISTIC ACTIVITIES

Provides forward-thinking institutions, organizations and governments with constructive resolution of emerging environmental challenges at the intersection of law and policy; emphasizes strategic counseling, crisis management, creative dispute resolution and enhanced relations with stakeholders and community groups.

PATRICK E. O'NEIL

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EXPERTISE

Proposal preparation and grant solicitation, personnel management, conduct independent research, budget preparation and management, information presentation and publication/report development. Technical skills and interests include: ichthyology, limnology, aquatic ecology, water quality, hydrology, wastewater disposal and management, environmental regulation, environmental engineering practices, watershed assessment and monitoring. Recent work has focused on developing stream bioassessment procedures using fish communities and implementation of instream flow principles into water policy.

PROFESSIONAL PREPARATION

Ph.D. Civil Engineering, University of Alabama, 1993
M.S. Environmental Engineering, University of Alabama, 1990
M.S. Biology, University of Alabama, 1980
B.S. Biology, University of Alabama, 1977

PROFESSIONAL APPOINTMENTS

Alabama Water Agencies Working Group
Clean Water Partnership Board of Directors

RELEVANT PUBLICATIONS

O'Neil, P.E., and Shepard, T.E., 2010, Calibration of the Index of Biotic Integrity for the Tennessee Valley Ichthyoregion in Alabama: Alabama Geological Survey Open-File Report 1004, 126 p.

O'Neil, P.E., McGregor, S.W., and Wynn, E.A., 2010, Watershed assessment of the North River system for recovery and restoration of rare mussel species: Alabama Geological Survey Bulletin 183, 65

O'Neil, P.E., and Shepard, T.E., 2010, Biological assessment of the Little Choctawhatchee River watershed in Alabama, Geological Survey of Alabama, Open-File Report 1105, 35 p.

O'Neil, P.E., and Shepard, T.E., 2011, Calibration of the Index of Biotic Integrity for the Ridge and Valley/Piedmont Ichthyoregion in Alabama: Alabama Geological Survey Open-File Report 1109, 140 p.

O'Neil, P.E., and Shepard, T.E., 2011, Calibration of the Index of Biotic Integrity for the Plateau Ichthyoregion in Alabama: Alabama Geological Survey Open-File Report 1111, 117 p.

O'Neil, P.E., and Shepard, T.E., 2011, Calibration of the Index of Biotic Integrity for the Hills and Coastal Terraces Ichthyoregion in Alabama: Alabama Geological Survey Open-File Report 1116, 135 p.

Wynn, E.A., O'Neil, P.E., McGregor, S.W., Powell, J.R., Pritchett, J.M., Ford, A.D., and Johnson, P.D., 2012, Strategic habitat and river reach units for aquatic species of conservation concern in Alabama: Alabama Geological Survey Special Map 248.

O'Neil, P.E., and Johnson, C.J., Wynn, E.A., and Smith, J.B., 2013, Evaluation of sedimentation risk and habitat threat severity for stream crossings and critical habitat in the North River Strategic Habitat Unit, Alabama: Alabama Geological Survey Bulletin ---, in press.

SYNERGISTIC ACTIVITIES

Works closely with the Alabama Department of Conservation and Natural Resources to evaluate instream flow methodologies, explore instream flow policy options, and develop plans for instream flow research.

Works as part of the Alabama Water Agencies Working Group to evaluate Alabama's water issues, provide policy options and develop recommendations for the Governor of Alabama.

Works as part of the Alabama Rivers and Streams Network to investigate water quality, habitat conditions, and biological quality with regard to restoration and recovery of imperiled aquatic species. The goal of this group is to investigate Alabama's water resources in a comprehensive, scientific way and encourage responsible resource development so all users benefit.

Works closely with many state agencies, conservation organizations, universities, businesses and industries to better understand our impacts to aquatic resources and how best to implement improvement through a watershed understanding and approach.

FINAL REPORT ON RESEARCH PROJECT
WATER POLICY AND LAW IN ALABAMA

Training Results

This project used law student and graduate student research assistants. Thirty-five different research assistants worked on the treatise under the supervision of Professor Elliott. Of these, thirty-two were students at the University of Alabama School of Law, one was a joint-degree student in law and business at the University of Alabama, and two were graduate students in the Geography Department of the College of Arts and Sciences at the University. Twenty-three were men and twelve were women; five identify as persons of color.

The research tasks included

- Describing Alabama's water resources and creating maps to show these resources;
- Finding all Alabama case law regarding water resources and water rights;
- Finding all Alabama statutes regarding water resources and water rights;
- Writing analyses of Alabama case law and statutes;
- Determining the content of Georgia, Florida, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee water policy and law;
- Writing analyses comparing Alabama water law to the laws of these other states;
- Researching the political processes that led states other than Alabama to adopt water resources statutes;
- Researching the law of other states involving state ownership of water and the application of the Interstate Commerce Clause, the Dormant Commerce Clause, and Fifth Amendment and Fourteenth Amendment takings law to water issues.

Most of the research assistants will receive author credit on the chapters that they assisted in drafting. Several of the research assistants may also publish in law reviews, as authors or co-authors, articles that arise from their research on the treatise.

FINAL REPORT ON RESEARCH PROJECT
WATER POLICY AND LAW IN ALABAMA

Budget Results

The USGS provided \$80,000 over two years to the Water Policy and Law project. The vast majority of those funds – \$75,037.77 – went to pay student research assistants. Of the remainder, \$3432.15 went to pay for PI Elliott and several students to attend the Alabama Water Resources Conference in Orange Beach, Alabama, in both 2014 and 2015. The remaining \$1530.08 was paid to the University of Alabama Press to help fund the color illustrations for the ultimate book.

Student Research Assistants	75,037.77
Travel to Water Resources Conferences 2014 and 2015	3432.15
Partial payment of color printing costs, UA Press	1530.08
TOTAL	80,000.00

Identification of pollution sources on agricultural farms and evaluation of new fecal indicators for surface water quality monitoring

Basic Information

Title:	Identification of pollution sources on agricultural farms and evaluation of new fecal indicators for surface water quality monitoring
Project Number:	2015AL169B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Agriculture, Water Quality, Non Point Pollution
Descriptors:	None
Principal Investigators:	Luxin Wang, Eric Reutebuch

Publications

1. Yuan, Jing; Eric Reutebuch; and Luxin Wang. In Press. Comparison of different enumeration protocols for Enterococci, *Journal of Microbiology Method*.
2. Yuan, Jing; 2016, Evaluation of the efficiency of different indicator microorganism enumeration protocols for water quality monitoring, MS, Department of Animal Science, Auburn University, Auburn, AL, 84 pp.

ANNUAL TECHNICAL REPORT SYNOPSIS
Alabama Water Resources Research Institute

A. PROJECT TITLE:

Identification of pollution sources on agricultural farms and evaluation of new fecal indicators for surface water quality monitoring

B. PRIMARY PI(s): Name(s), Title(s) & Academic Rank(s)

Luxin Wang, Ph.D., Assistant Professor in the Department of Animal Sciences, AU

Eric Reutebuch, M.S., Director of Alabama Water Watch in the Water Resources Center, AU

C. OTHER PI(s): Name(s), Title(s) & Academic Rank(s) – N/A

D. START DATE: March 1, 2015

E. END DATE: February 29, 2016

F. PROJECT OVERVIEW/SUMMARY:

The determination of the sources of fecal pollution is a critical issue in complying with the Clean Water Act (Federal Water Pollution Control Act amendments of 1973 and 1977). It is necessary to have the ability to differentiate fecal microbial contamination of water runoff from animal operations versus that from human sources. *Escherichia coli* (*E. coli*) has been used as an indicator microorganism for fecal source tracking because it is easily cultured and is used as the primary regulatory indicator for pathogen contamination in recreational waters (Simposon et al., 2002; U.S. EPA, 2002). However, there are problems associated with using *E. coli* as a source identifier. These problems include a high degree of genetic diversity not attributable to a specific host animal source, the potential for *E. coli* to replicate outside the host, and geographic and temporal visibilities (U.S. EPA, 2005).

A recent study conducted by Wang and Reutebuch (unpublished) found that the *E. coli* concentrations downstream of cattle farms were significantly higher than the *E. coli* concentrations upstream of the farms. These results indicated that on-farm management and good agricultural practices need to be improved in order to lower the fecal contamination of surface water. The genus *Bacteroides* has been suggested as an alternative fecal indicator to replace *E. coli* or fecal coliforms because they make up a significant portion of the fecal bacterial population (Fiksdal et al., 1985; Kreader, 1998). Most importantly, *Bacteroides* are host specific and can be used as to track the contamination sources (Layton et al., 2006). **Objective 1 of this research was to identify water contamination sources by collecting and analyzing surface water samples (upstream and downstream) from different farms and detecting host specific *Bacteroides* groups via real-time PCR assays.**

Due to the concerns with using *E. coli* as the indicator organisms, several other genera have been proposed for use as an alternative indicator for fecal contamination of surface waters. One of them is *Enterococcus*. An epidemiological study performed by U.S. EPA demonstrated a direct relationship between the density of *E. coli* and *Enterococci* in surface waters and an increase in swimmer-associated gastroenteritis (U.S. EPA, 1986). For freshwater, the current single-sample advisory limits are 235 CFU/100 ml for *E. coli* and 61 CFU/100 ml for *Enterococci* (U.S. EPA, 2000). Another recent study conducted by Wang and Reutebuch (unpublished) found that the concentrations of *Enterococci* present in recreational waters were higher than *E. coli*, which indicates that *Enterococcus* may serve as a better indicator microorganism for monitoring fecal contamination in fresh waters, and a better indicator for AWW volunteer monitors to use. Because the higher the concentration of the indicator microorganisms, the better the chance of recovering them, we feel that *Enterococcus* may make AWW enumeration more reliable. Therefore, **Objective 2 of this research was to develop a water monitoring protocol that is credible and easy-to-use for AWW water quality monitoring groups using *Enterococci* as the indicator microorganism.**

G. PROJECT OBJECTIVE(S):

Objective 1 of this research was to identify water contamination sources by collecting and analyzing surface water samples (upstream and downstream) from different farms and detecting host specific *Bacteroides* groups via real-time PCR assays.

Objective 2 of this research was to develop a water monitoring protocol that is credible and easy-to-use for AWW water quality monitoring groups using *Enterococci* as the indicator microorganism.

H. METHODOLOGIES: Briefly explain the research methodology used.

1. Conducting Bacteriological Sampling on farm

Water samples from upstream and downstream of four farms was collected in the spring, summer, fall, and winter. These water samples were kept on ice and delivered to Wang's microbiology lab located on the Auburn University campus.

2. Enumeration of *E. coli*

The AWW Coliscan Easygel method was used to enumerate the number of *E. coli* present in the water samples. Concentrations of *E. coli* measured in the water column were interpreted relative to human health by comparison with USEPA and Alabama Department of Environmental Management water quality criteria (USEPA 2012; ADEM 2012).

3. Enumeration of *Enterococci* and Comparison of different *Enterococci* enumeration methods.

Three *Enterococci* enumeration methods were evaluated:

Method 1: Enterolert® Method

One pack of Enterolert® reagent was added to each 100-ml water sample. The mixture was poured into a Quanti-Tray and the tray was sealed and incubated at 41°C for 24 hours. *Enterococci* present in the water react with the Enterolert® reagent and release 4-methylumbelliferone that exhibit fluorescence. The results were read under a UV lamp at 365nm and the data was interpreted following the 51-well Quanti-Tray MPN table.

Method 2: Membrane Filtration Agar Method

A 100-ml water sample was filtered through a 0.45 µm membrane. Following filtration, the membrane was placed on mEI agar (membrane- *Enterococcus* Indoxyl-β-D-Glucoside Agar) and incubated at 41°C for 24 h. All colonies with blue haloes (regardless of color) were recorded as suspect *Enterococci* colonies. To confirm the suspect colonies, 10 well-isolated colonies were taken and transferred onto Bile Esculin Agar (BEA). Gram staining was conducted as well. Colonies were confirmed as *Enterococci* by being gram-positive cocci, and growth and hydrolysis of esculin on BEA.

Method 3: Quantitative Polymerase Chain Reaction (qPCR) Assay

Every 100-ml water sample was filtered through a 0.45 µm membrane. After that, the membrane containing the bacterial cells was used for DNA extraction following the protocol described by Zhao et al., 2013. Forward primer: 5'-GAGAAATTCCAAACGAACTTG-3' and Reverse primer: 5'-CAGTGCTCTACCTCCATCATT-3' was synthesized by Integrated DNA Technologies, Inc. (Coralville, USA). SYBR® Green Master Mix (Life technologies, USA) was used and the reaction conditions followed the Wang lab protocol.

4. Water contamination source tracking A TaqMan®-based real-time PCR assay was modified and adopted for the contamination source tracking. The DNA extraction step followed the protocol by Zhao et al. 2013. Reaction conditions followed Layton et al. 2006.

I. PRINCIPAL FINDINGS/RESULTS:

Results show that there were no differences among the three *E. coli* enumeration methods ($P > 0.05$). Therefore, the Coliscan® Easygel agar plates method (used by the Alabama Water Watch) was used to evaluate the impact of sampling times and sample types on the enumeration of *E. coli*. Field sampling results show that both the sampling times and sample types may impact the enumeration results ($P < 0.05$), regardless of the indicator microorganisms used. When samples were collected in the afternoon, the surface water samples contained more indicator microorganisms than samples collected in the morning. Sediments contained more indicator microorganisms than the surface water ($P < 0.05$) and impacted the surface water monitoring results. The comparison of four *Enterococci* enumeration protocols show that while the Easygel cards™ method has the lowest price (\$1 per sample), the USEPA qPCR method 1611 ranks the highest among all tested methods based on the shorter processing time needed (~ 4 hours) and the widest detection range (2.47-8.47 log CFU/mL for surface water and 2.47-8.47 log CFU/g for sediment). Because of this, different DNA extraction methods were tested and compared to

prepare samples for the qPCR protocol. Results show that, for surface water samples, the PrepMan® boiling procedure can substitute for the DNA extraction procedure used by the USEPA qPCR method 1611, however, for sediment samples, the PowerSoil® DNA Isolation Kit cannot be replaced by the PrepMan® boiling procedure. The results also show that the USEPA qPCR method 1611 is an efficient method for enumerating *Enterococcus* both in surface water and sediment.

J. NOTABLE AWARDS AND ACHIEVEMENTS:

N/A

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	1 (in press)
Book Chapters	0
Theses and Dissertations	1
Water Resources Institute Reports	1
Articles in Conference Proceedings	2
Other Publications	0

PROVIDE A CITATION FOR EACH PUBLICATION USING THE FOLLOWING FORMATS:

1. Articles in Refereed Scientific Journals Citation

Yuan, Jing; Eric Reutebuch; and Luxin Wang. In Press. Comparison of different enumeration protocols for Enterococci, Journal of Microbiology Method.

2. Book Chapter Citation

N/A

3. Dissertations Citation

Yuan, Jing; 2016, Evaluation of the efficiency of different indicator microorganism enumeration protocols for water quality monitoring, MS, Department of Animal Science, Auburn University, Auburn, AL, 84 pp.

4. Water Resources Research Institute Reports Citation

***This report.*

5. Conference Proceedings Citation

Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the International Association for Food Protection Annual Meeting, Portland, OR.

Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the Alabama Water Resources Conference, Alabama Water Resources Center, Orange Beach, AL.

6. Other Publications Citation

N/A

L. PRESENTATIONS MADE:

Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the International Association for Food Protection Annual Meeting, Portland, OR, July 24-28, 2015.

Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the Alabama Water Resources Conference, Alabama Water Resources Center, Orange Beach, AL. September 9-11, 2015.

M. STUDENTS SUPPORTED:

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	0
Masters	1
Ph.D.	0
Post Doc	0
Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	1
Ph.D. Dissertations	0

N. RESEARCH CATEGORIES:

	Research Category
X	Biological Sciences

	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
	Social Sciences
X	Water Quality
	Other: Explain

O. FOCUS CATEGORIES:

	ACID DEPOSITION	ACD
X	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
	MANAGEMENT & PLANNING	M&P
X	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
X	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
X	SURFACE WATER	SW

	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
X	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS:

Indicator microorganism, Enterococcus, Escherichia coli, E. coli, Enterococci, water quality, Alabama Water Watch, citizen monitoring

EVALUTATION OF THERMAL AND DISSOLVED OXYGEN STRESS TO FRESHWATER MUSSELS IN A SAFE HARBOR / CRITICAL HABITAT REACH OF AN ALABAMA STREAM.

Basic Information

Title:	EVALUTATION OF THERMAL AND DISSOLVED OXYGEN STRESS TO FRESHWATER MUSSELS IN A SAFE HARBOR / CRITICAL HABITAT REACH OF AN ALABAMA STREAM.
Project Number:	2015AL170B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	3
Research Category:	Biological Sciences
Focus Category:	Water Quality, Hydrology, None
Descriptors:	None
Principal Investigators:	James Stoeckel

Publications

There are no publications.

ANNUAL TECHNICAL REPORT SYNOPSIS

- A. PROJECT TITLE: Evaluation of thermal and dissolved oxygen stress to freshwater mussels in a Safe Harbor/Critical Habitat reach of an Alabama Stream
- B. PRIMARY PI(s): James Stoeckel, Associate Professor
- C. OTHER PI(s): Cliff Webber, Visiting Professor; Dennis DeVries, Professor; Rusty Wright, Extension Specialist Associate Professor.
- D. START DATE: March 1, 2015
- E. END DATE: Feb 29, 2016
- F. PROJECT OVERVIEW/SUMMARY: Provide a brief narrative overview or summary of the project.

Due to global climate change, much of the southeastern United States is expected to face warmer temperatures and increasingly frequent and lengthy droughts in the coming decades. Human demands for water also continue to grow, further exacerbating the effects of drought on freshwater ecosystems. The coupling of climate change and increasing water demands for multiple uses (often requiring construction of dams and reservoirs) is particularly problematic for conservation of our natural resources because the southeastern United States harbors the highest species diversity of stream biota in North America, including fish, mussels, and crayfish.

Increasing temperatures and decreased stream flow, can greatly influence life history strategies, health, and survivorship of aquatic organisms. Dams, common in southeastern river systems, can alter temperature and DO of downstream reaches even in the absence of drought, and these impacts can be further exacerbated by increased temperatures and decreased natural flow. When water is being stored behind dams, downstream flow is diminished or even halted altogether. Temperature can increase and DO decline – particularly during the hot summer months. Effects of altered discharge and DO on aquatic organisms play a large role in determining regulations applied to dams with regards to minimum flow requirements. Understanding the interrelationships between climate change, altered discharge patterns, and aquatic community health is of increasing importance to state and federal management agencies.

- G. PROJECT OBJECTIVE(s): Briefly explain the project objectives.

Use the project funds as seed money to begin addressing the following questions:

- 1) Whether the current minimum flow requirements in the Safe Harbor reach of Chewacla Creek are sufficient to protect mussel populations from thermal and dissolved oxygen stress.

2) Whether the ETS thermal tolerance assay recently proposed by Simcic et al (2014) has potential as a rapid screening tool for thermal tolerance of freshwater mussels.

H. METHODOLOGIES: Briefly explain the research methodology used.

Laboratory study: Mussels of two species, *Lampsilis teres* and *Villosa lienosa* were acclimated to six experimental temperatures, and then held without food for 24-48 hrs, in open glass aquaria. Three tissue plugs were extracted from the foot of each mussel, and homogenized in liquid nitrogen with a pestle and mortar. ETS enzyme activity of the homogenate was measured using the same methodology described in Simcic et al. (2014). Thermal tolerance was assessed via the relationship between ETS activity and temperature where Optimal Temperature = temperature of maximal ETS activity, and Optimal Range = temperature range at which ETS activity is at or above 90% of maximum activity. *This portion of the study is still ongoing, now supported by funding from other sources.*

Field study: To verify that the relationships between ETS activity and temperature from the laboratory study are representative of natural conditions, we PIT-tagged 18 mussels of the two study species and place them in a representative reach within the Safe Harbor reach of Chewacla Creek. Temperature loggers were placed along the Safe Harbor reach in representative pool, riffle, and run habitats to record ambient water temperature every 15 minutes. Dissolved oxygen (concentration and % saturation) was measured at the site of each temperature logger every 1-2 weeks throughout the study period. Every two weeks, from June through December, mussels were located via a waterproof PIT tag antennae. A tissue plug was collected from one mussel / species, immediately frozen in liquid nitrogen, and returned to the lab (~18 samples per species). *This portion of the study is still ongoing, now supported by funding from other sources. ETS activity of each tissue plug will be determined as previously described. ETS activity will then be plotted against the average water temperature of the collection site during the 24 hour period prior to collection of the plug. We will then graph ETS activity vs temperature for each species to verify that the relationship is consistent between laboratory and field.*

I. PRINCIPAL FINDINGS/RESULTS: Explain the results of findings of this research project.

Results thus far indicate the ETS Assay has potential as a rapid screening tool for thermal tolerance of freshwater mussels. For both species, ETS enzyme activity initially increased with increasing temperature. However, the relationships between ETS activity and temperature suggests a potential for strong differences in optimal temperature and thermal tolerance between the two species. For *Lampsilis teres*, ETS activity peaked at 23.5° C and subsequently declined, yielding an estimated optimal temperature range of ~20 – 27° C (Fig. 1 top panel). Conversely, ETS activity of *Villosa lienosa* continued to increase with maximum activity recorded at the highest temperature tested thus far (~30° C), yielding an estimated optimal temperature range of ~25° - >30° C (Fig. 2 top panel). Additional experiments are currently being conducted at higher temperatures to determine the upper bound of this species thermal optima. We are

planning additional experiments to directly examine lethal and sublethal effects of temperature on the two mussel species and to determine whether results of the ETS assay can predict these effects with increasing temperature.

Temperatures recorded in the Safe Harbor reach of Chewacla Creek just downstream of Lake Ogletree dam indicate that the level of heat stress experienced by the mussel community differed among species. Based on ETS activity, *L. teres* is less tolerant of high temperatures than *V. lienosa*, and experienced heat stress from June – September 2015, as water temperatures rose and remained above 27° C (Fig. 1 bottom panel). Conversely, *V. lienosa* was not heat stressed during this period as its estimated optimal temperature range exceeded 30° C (Fig. 2 bottom panel).

Minimum discharge requirements from Lake Ogletree are intended to provide a sufficient flow of water with adequate temperature and dissolved oxygen profiles to support native mussel fauna below the dam, with particular emphasis on the federally threatened *Hamiota altilis*. Because of its threatened status and rarity, *H. altilis* was not utilized in the current study. However, results of the study appear strong enough to justify using the non-lethal ETS assay to assess its thermal tolerance in subsequent studies. Because the majority of water supplied to this protected stretch of the creek is siphoned from Lake Ogletree, and water temperature varies with reservoir depth, estimates of thermal tolerance can be used to inform managers as to the optimal siphon depth for water withdrawal from the reservoir. Similarly, ETS activity can be used to determine which common mussel species could be used as surrogates for investigating effects of high temperatures on T&E species such as *H. altilis*. For example, if the ETS activity profile of *H. altilis* is similar to that of *V. lienosa*, the current siphon depth and flow rate may be sufficient to protect *H. altilis* from thermal stress. However, if the ETS activity profile is more similar to that of *L. teres*, managers should consider manipulating siphon depth and flow rate to reduce downstream temperatures during the hot summer months.

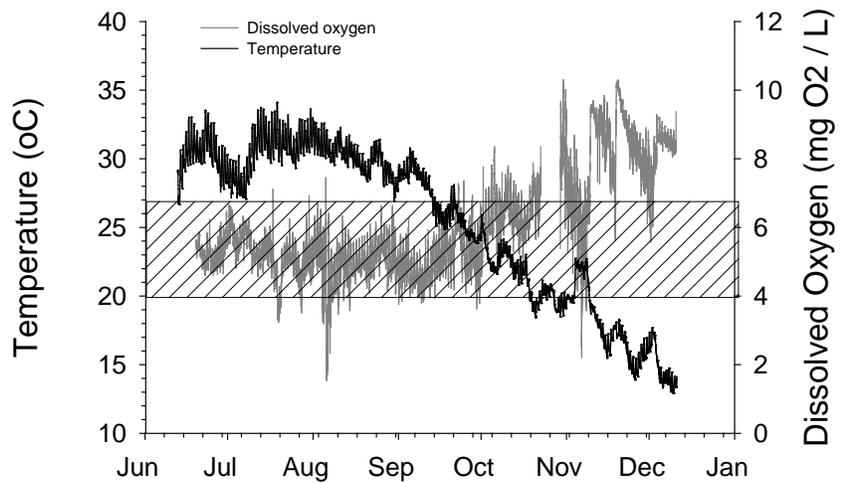
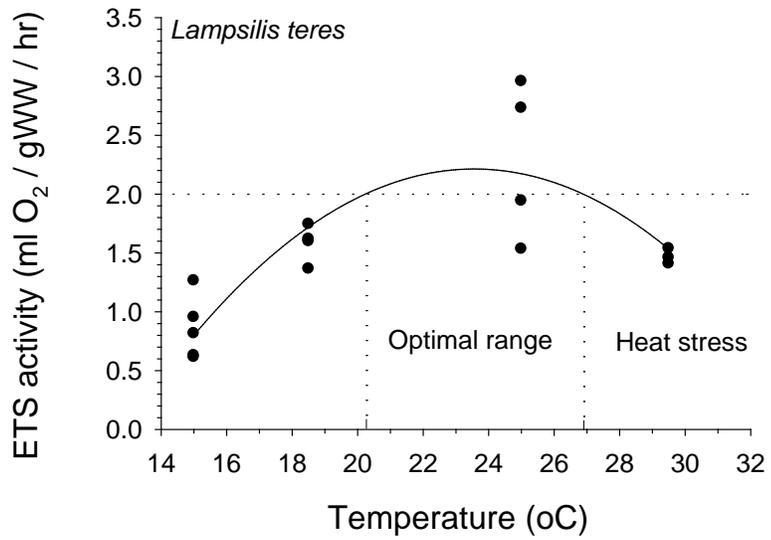


Figure 1. Upper Panel: Relationship between ETS activity and water temperature for *Lampsilis teres*. Horizontal dotted line indicates ETS activity at 90% of maximum. Vertical dotted lines indicate the upper and lower temperature bounds (optimal thermal range) between which ETS activity is at or above 90% of the maximum. Lower Panel: Temperature and dissolved oxygen through time in the Safe Harbor Reach (pool habitat) below Lake Ogletree Dam. Diagonal lines indicate optimal the thermal range for *L. teres* as determined from the upper panel.

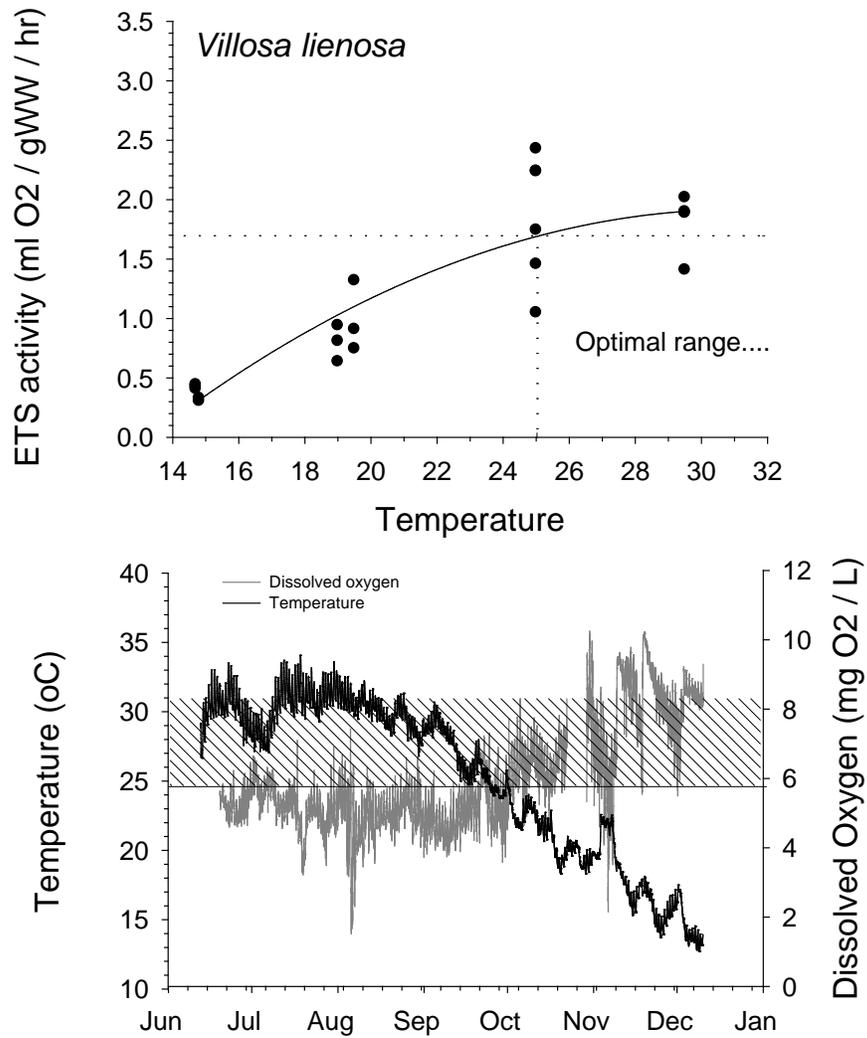


Figure 2. Upper Panel: Relationship between ETS activity and water temperature for *Villosa lienosa*. Horizontal dotted line indicates ETS activity at 90% of maximum. Vertical dotted line indicates the lower temperature bound above which ETS activity is at or exceeds 90% of the maximum (optimal thermal range). The upper bound has yet to be determined. Lower Panel: Temperature and dissolved oxygen through time in the Safe Harbor Reach (pool habitat) below Lake Ogletree Dam. Diagonal lines indicate optimal the thermal range for *V. lienosa* as determined from the upper panel.

J. NOTABLE AWARDS AND ACHIEVEMENTS. List any awards or recognitions for this research

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	
Book Chapters	
Theses and Dissertations	
Water Resources Institute Reports	
Articles in Conference Proceedings	
Other Publications	

PROVIDE A CITATION FOR EACH PUBLICATION USING THE FOLLOWING FORMATS:

1. Articles in Refereed Scientific Journals Citation

Author (first author; last name, first name; all others; fist name, last name), Year, Title, Name of Journal, Volume(Number), Page Numbers.

2. Book Chapter Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of chapter, "in" Name(s) of Editor "ed.", Title of Book, City, State, Publisher, Page Numbers.

3. Dissertations Citation

Author (last name, first name), Year, Title, "MS (Ph.D.) Dissertation," Department, College, University, City, State, Number of Pages.

4. Water Resources Research Institute Reports Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, Name of WRRI, University, City, State, Number of Pages.

5. Conference Proceedings Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of Presentation, "in" Title of Proceedings, Publisher, City, State, Page Numbers.

6. Other Publications Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, other information sufficient to locate publications, Page Numbers (if in publication) or Number of Pages (if monograph).

L. PRESENTATIONS MADE:

Presenter(s) (last name, first name; all others presentation authors: first name, last name), Year, Title, other information sufficient to identify the venue in which the presentation was made.

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	
Ph.D.	1
Post Doc	
Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	
Ph.D. Dissertations	in progress

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
x	Biological Sciences
x	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
	Social Sciences
x	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
x	CLIMATOLOGICAL PROCESSES	CP
x	CONSERVATION	COV
x	DROUGHT	DROU
x	ECOLOGY	ECL

	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
x	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
x	MANAGEMENT & PLANNING	M&P
x	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
x	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
x	WATER QUALITY	WQL
x	WATER QUANTITY	WQN
x	WATER SUPPLY	WS
x	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: (Enter keywords of your choice, descriptive of the work)

Thermal tolerance, unionid, freshwater mussel, electron transport system, dams, minimum flow, conservation, altered flow, regulation.

Information Transfer Program Introduction

Information Transfer Primary venues for information transfer of findings from AL WRRI-funded research projects are the AU WRC website (<http://aes.auburn.edu/wrc>) and the Annual Alabama Water Resources Conference (<http://aes.auburn.edu/wrc/extension-outreach/awrc-conference/>). The Auburn University Water Resources Conference (AU WRC) website is regularly updated with research findings and publications generated from AL WRRI-funded research projects (click the RESEARCH menu). Other information transfer outlets include presentations at other conferences.

For the past 29 years, AU WRC has organized the Annual Alabama Water Resources Conference to engage local, state, and federal agencies; community-based citizen groups; researchers; and undergraduate and graduate students to discuss water issues in the state and to share new knowledge being developed. Our 2015 conference occurred in September and saw record registrations. More than 100 oral and poster presentations were delivered at this conference. The post-conference survey indicated the registrants found great value in participating in the conference.

Presentations of findings from AL WRRI-funded research projects at the 2015 Alabama Water Resources Conference included: 1. Samantha Pline, Transitions from Common-Law to Regulatory Regimes: Lessons From South Carolina And Georgia, Alabama Water Resources Conference, September 11, 2015 2. Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the Alabama Water Resources Conference, Alabama Water Resources Center, Orange Beach, AL. September 9-11, 2015.

Presentations of findings from AL WRRI-funded research projects at other conferences included: 1. Yuan, Jing; Eric Reutebuch; and Luxin Wang. 2015. Comparison of different enumeration protocols for indicator microorganisms in water and sediment; in the Proceedings of the International Association for Food Protection Annual Meeting, Portland, OR, July 24-28, 2015.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	0	0	0	0
Masters	2	0	0	0	2
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	4	0	0	0	4

Notable Awards and Achievements