Water Resource Inventory and Assessment
Cahaba River National Wildlife Refuge
Bibb County, Alabama

U.S. Department of the Interior
U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

December 2013

Water Resource Inventory and Assessment
Cahaba River National Wildlife Refuge
Bibb County, Alabama

Theresa A. Thom
U.S. Fish and Wildlife Service, Inventory and Monitoring Network
Savannah Coastal Refuge Complex, 694 Beech Hill Lane
Hardeeville, SC 29927

Rebecca E. Burns
Atkins North America, Inc.
5200 Seventy Seven Center Drive, Suite 500
Charlotte, NC 28217

John Faustini
U.S. Fish and Wildlife Service, Southeast Region
1875 Century Blvd., Suite 200
Atlanta, GA 30345

Kirsten J. Hunt
Atkins North America, Inc.
1616 East Millbrook Road, Suite 310
Raleigh, NC 27609

December 2013
U.S. Department of the Interior, U.S. Fish and Wildlife Service

Please cite this publication as:
Thom, T.A., R.E. Burns, J. Faustini and K.J. Hunt. 2013. Water Resource Inventory and Assessment (WRIA): Cahaba River National Wildlife Refuge, Bibb County, Alabama, U.S. Fish and Wildlife Service, Southeast Region. Atlanta, Georgia. 102 pp. + appendices.

COVER PHOTO: View of the Cahaba River, the heart of Cahaba River National Wildlife Refuge, 2012. Photo credit: Theresa Thom / USFWS. Used by permission.

Acknowledgements

This work was completed in part through contract PO# F11PD00794 between the U.S. Fish and Wildlife Service and Atkins North America, Inc. Information for this report was compiled through coordination with multiple state and federal partners and non-governmental agencies, including the U.S. Fish and Wildlife Service (USFWS), Alabama Department of Environmental Management (ADEM), the Cahaba River Society (ADEM), the Geological Survey of Alabama (GSA), The Nature Conservancy (TNC), the Alabama Aquatic Biodiversity Center (AABC), and the Alabama Innovation Engine. Significant input and support of this process was provided by Sarah Clardy, the refuge manager for Cahaba River NWR, Mountain Longleaf NWR and Watercress Darter NWR. The authors thank Taylor Griswell (ADEM), Randy Haddock (CRS), Eric Spadgenske (USFWS), Jeff Powell (USFWS), Dwight Cooley (USFWS), Pat O'Neil (GSA), Paul Johnson (AABC), and Jim Williams (USGS) for their comments on earlier drafts of this report, and for generously sharing their time, expertise, and knowledge.

Table of Contents

1 Executive Summary 1

1.1 Findings 1

1.2 Key Water Resources Issues of Concern 3

1.3 Needs and Recommendations 3

2 Introduction 4

3 Facility Information 6

4 Natural Setting 12

4.1 Region of Hydrologic Influence (RHI) 12

4.2 Topography and Landforms 12

4.3 Geology 15

4.4 Soils 17

4.5 Hydrology and Geomorphology 21

4.6 Anthropogenic Landscape Changes 21

4.7 Climate 26

4.7.1 Historical Climate 26

4.7.2 Climate Change Projections 32

5 Inventory Summary and Discussion 35

5.1 Water Resources 35

5.1.1 Rivers/Streams/Creeks 35

5.1.2 Lakes/Ponds 37

5.1.3 Springs and Seeps 37

5.1.4 Wetlands 37

5.1.5 Groundwater 40

5.2 Infrastructure 40

5.2.1 Water Supply Wells 40

5.2.2 Water Control Structures and Impoundments 41

5.2.3 Other Water Resources Infrastructure 41

5.3 Water Monitoring 41

5.3.1 Surface Water 41

5.3.2 Groundwater 51

5.4 Water Quantity and Timing 53

5.4.1 Historical Streamflows 53

5.4.2 Hydrologic Alterations 56
5.4.3 Land Use Activities Affecting Water Quantity and Timing 60
5.5 Water Quality Conditions 61
5.5.1 State Water Quality Regulations 62
5.5.2 Impaired Waters, TMDLs and NPDES Permits 64
5.5.3 Groundwater Quality 67
5.5.4 Land Use Activities Affecting Water Quality 68
5.6 Water Law/Water Rights 70
5.6.1 State Water Law Overview 70
5.6.2 Aspects of State Water Law That May Negatively Affect the Station 71
5.6.3 Existing Formal Water Rights 72
6 Assessment 73
6.1 Water Resource Issues of Concern 73
6.1.1 Urgent/Immediate Issues 73
6.1.2 Longer-Term Issues 76
6.2 Needs and Recommendations 80
7 Literature Cited 83
8 Appendices 102

Appendices

Appendix A August 14, 2012 WRIA Kick-off Meeting Agenda, Summary, and Participant List
Appendix B Listed and Petitioned Species within the Cahaba Basin (8-Digit HUC - 03150202)
Appendix C Piper II Mine Reclamation Plan
Appendix D Selected USGS and GSA Surface and Groundwater Quantity Monitoring Sites in the RHI
Appendix E Selected USGS and ADEM Surface Water Quality Monitoring Sites in the RHI
Appendix F USGS Surface Water Quality Monitoring Data for USGS 02423647 gage on the Cahaba River near West Blocton, AL (period of record 1976 – 1983)
Appendix G GSA Groundwater Well Hydrographs from wells within or near the RHI
Appendix H USGS Groundwater Quality Monitoring Sites in the RHI
Appendix I Water Availability in Bibb County, Alabama, Geological Survey of Alabama Map 144 (Causey et al. 1978)
Appendix J GSA Permits for Oil and Gas Wells within the Refuge Acquisition Boundary
Appendix K NPDES Permits within the RHI

List of Figures

Figure 1. Location of Cahaba River NWR in relation to USFWS Region 4 Landscape Conservation Cooperative boundaries. .... **Error! Bookmark not defined.**

Figure 2 . Cahaba River Basin 8-digit Hydrologic Unit boundary and bordering 8-digit Hydrologic Units. .. 8

Figure 3. Cahaba River NWR showing the approved acquisition boundary, and the boundary of land acquired as of April 2013. 9

Figure 4. Cahaba River NWR in relation to Alabama physiographic provinces and districts..................... 13

Figure 5. Generalized geology within the RHI based on GSA (2006a) data. 16

Figure 6. Soil types within Cahaba River NWR acquisition boundary based on SSURGO soils data........... 20

Figure 7. Mean and distribution of monthly temperature for 1916 – 2013 for NWS Stations at Centreville and Brent, AL.. 27

Figure 8. Average daily maximum, mean, and minimum temperature by water year (1895 – 2010) at Selma, AL (USHCN Station 017366). 27

Figure 9. Mean and distribution of monthly precipitation (1916 – 2013) at Centreville and Brent, AL..... 29

Figure 10. Total annual precipitation by water year (1895 – 2010) at Selma, AL (USHCN Station 017366). 29

Figure 11. Average monthly discharge from the Cahaba River near Centreville, AL. From data collected between 1901– 2011. 31

Figure 12. Percent of average annual flow on Cahaba River near Centreville, AL: 1901-2011. 31

Figure 13. Region of Hydrologic Influence and named creeks and streams within the Cahaba River NWR acquisition boundaries... 36

Figure 14. National Wetlands Inventory (NWI) land cover within or in the vicinity of the Cahaba River NWR acquisition boundary. 39

Figure 15. Regional USGS and GSA water quantity monitoring within the Region of Hydrologic Influence and in the vicinity of the Cahaba River NWR. 43

Figure 16. Long-term USGS and GSA surface and groundwater quantity monitoring sites within and near the Region of Hydrologic Influence. Numbered sites are listed in Table 8.. 44

Figure 17. Regional USGS and ADEM surface and groundwater quality monitoring sites within the Region of Hydrologic Influence and in the vicinity of the Cahaba River NWR acquisition boundary. 46

Figure 18. Monthly average discharge at Cahaba River near West Blocton, AL (1975 – 1984). 54

Figure 19. Total annual flow as a percentage of the average for Cahaba River near West Blocton, AL (1976 – 1984)... 55

Figure 20. Oil and gas wells, flow diversions, and dams/weirs within the Region of Hydrologic Influence and proximal to the Cahaba River NWR. 59

Figure 21. Impaired and assessed streams and NPDES permits within the Region of Hydrologic Influence for the Cahaba River NWR. 65

List of Tables

Table 1. Hydric classes of soils within Cahaba River NWR acquisition boundary. 18

Table 2. Soils types within Cahaba River NWR acquisition boundary. 18

Table 3. Descriptions of soil map units within Cahaba River NWR acquisition boundary. 19

Table 4. PRISM Monthly Normals (1971-2000) for precipitation and maximum and minimum temperature at Cahaba NWR. 28

Table 5. Miles of named and unnamed streams within the Region of Hydrologic Influence for Cahaba River NWR. 35

Table 6. Named creeks and streams with mileage inside the Cahaba River NWR acquisition boundary 35

Table 7. Wetland habitat delineated by the National Wetland Inventory inside the Cahaba River NWR acquisition boundary. 38

Table 8. Regional USGS and GSA long-term surface and groundwater quantity monitoring sites within or in the vicinity of the Cahaba River NWR acquisition boundary 42

Table 9. Regional USGS surface and groundwater quality monitoring sites within or in the vicinity of the Cahaba River NWR acquisition boundary 47

Table 10. Mean of mean daily discharge values (cfs) for each day for 85 - 88 years of record (1900-2012) at Centreville, AL (USGS 0242000). 55

Table 11. Existing Total Maximum Daily Loads (TMDLs) for impaired streams within the Region of Hydrologic Influence. 66

Table 12. NPDES permittees within the Cahaba River NWR acquisition boundary. 67

1 Executive Summary

This Water Resource Inventory and Assessment (WRIA) Summary Report for Cahaba River National Wildlife Refuge (Cahaba River NWR or the refuge) summarizes available information relevant to refuge water resources, provides an assessment of refuge water resource needs and issues of concern, and makes recommendations to address the identified water resources needs and concerns. Major topics addressed in this report include the natural setting of the refuge (topography, climate, geology, soils, hydrology), impacts of development and climate change, significant water resources and associated infrastructure within the refuge, past and current water monitoring activities on and near the refuge, water quality information, and state water use regulatory framework. Information was compiled from publicly available reports, databases, and geospatial datasets from federal, state, and local agencies; published research reports; websites maintained by government agencies, academic institutions, and non-governmental organizations; and from files and GIS data layers maintained by the refuge. For the purposes of this assessment, the area considered (the Region of Hydrologic Influence or RHI) was defined as the upper portion of the Cahaba River subbasin (HUC 03150202) that includes four watersheds (Headwaters Cahaba River [0315020201], Buck Creek-Cahaba River [0315020202], Shades Creek [0315020203], and Little Cahaba River [0315020204]). These geographic delineations are based on the National Watershed Boundary Dataset (WBD).

1.1 Findings

- Cahaba River NWR in Bibb County, Alabama currently includes approximately 3,681 acres within the 7,600-acre approved acquisition boundary. The current acquisition boundary of the refuge encompasses 8.3 miles of the Cahaba River and several tributary streams. Key terrestrial habitats present on the refuge include mesic hardwood forest, dry hardwood forest, floodplain forest, dry longleaf pine forest, cliffs and rockhouses, artificial habitats, and caves and mines (USFWS 2007). Key aquatic habitats include flowing rivers and streams, rocky shoals, pools, riffles, and forested riparian habitat.
- The Cahaba River drainage area lies entirely within the state of Alabama and encompasses approximately 1,824 square miles, including portions of St. Clair, Jefferson, Shelby, Bibb, Tuscaloosa, Perry, Chilton, and Dallas Counties (ADEM 2012a; CRBCWP undated).
- Although described as Alabama's longest free-flowing river, the Cahaba River technically contains the longest stretch of free-flowing river in Alabama, an approximately 150-mile stretch of free-flowing water from the Highway 280 diversion dam to the river's confluence with the Alabama River.
- Alabama Department of Environment Management (ADEM) recognizes sections of the Cahaba River (including portions that flow through the refuge) as Outstanding Alabama Waters: from the Alabama River upstream to Shelby County Road 52, from the dam near U.S. Highway 280 to Grant's Mill Road, and from U.S. Highway 11 upstream to the source of the Cahaba River (ADEM 2012b). The Little Cahaba River in Bibb County is also designated an Outstanding Alabama Water from its source downstream 16.54 miles to its confluence with the Cahaba (ADEM 2012b).
- Within the Cahaba River basin, 32 federally listed species are known to occur, or have historically occurred (Appendix B with citations). Biological surveys conducted within refuge boundaries have documented 12 of these species. In addition to listed species, the Cahaba River supports a wide diversity of endemic plants and animals.

- The Region of Hydrologic Influence (RHI) for the Cahaba River NWR includes a total of 2,089.2 miles of named and unnamed streams (Table 5, Figure 13). Within the refuge acquisition boundary, there are eight named creeks and rivers, totaling 17.6 miles, as well as an additional 15.0 miles of unnamed streams (Table 5, Table 6, Figure 13).
- According to the National Wetlands Inventory (NWI), less than 5% of the land within the acquired boundary of the refuge, and less than 4% of land within the acquisition boundary is classified as wetlands. The wetlands are primarily Riverine, with some Palustrine wetlands, small areas of freshwater forested/shrub wetlands, and freshwater ponds. Two of the wetland areas identified from NWI are associated with current mine reclamation work.
- Mooty and Kidd (1997) estimate that baseflow from groundwater discharge supplies approximately 48% of the mean annual discharge of the Cahaba River at Centreville, AL, although stream discharges at multiple sites on the Cahaba River were sustained entirely from baseflow during periods of sustained drought.
- Birmingham, AL draws water from both the Black Warrior River and the Cahaba River systems. During periods of drought, nearly all of the flow of the Cahaba River is removed at the Birmingham intake point (at the Birmingham Water Works Cahaba Heights Pump Station) and only a portion is returned downstream as treated wastewater. The remainder is emptied into the Black Warrior River Basin as an inter-basin transfer (Howard et al. 2002).
- There are 1,138 National Pollutant Discharge Elimination System (NPDES) permittees within the RHI for the Cahaba basin (Figure 21, Appendix K). ADEM issues NPDES permits for point source discharges from facilities such as wastewater treatment plants, mines and other commercial and industrial activities, which require the implementation of best management practices (BMPs) to reduce pollution, as well as periodic monitoring.
- Wastewater treatment plant discharges influence the Cahaba River. One quarter of Alabama's population draws its water from, and/or discharges treated wastewater into, the Cahaba River watershed. There are 12 major and 19 minor permitted wastewater discharge points upstream of the refuge, over 100 industrial discharge permits in the upper watershed of the Cahaba River, and over 40,000 septic systems within the watershed (ADEM 2006b). Approximately 27 million gallons of treated wastewater are released into the watershed daily, with additional permitted capacity to allow over 43 million gallons/day. Permit violations at major discharge locations for nutrient or nutrient related parameters have occurred (Howard et al. 2002).
- Within the Cahaba River watershed there are 185 miles of streams that do not support, or only partially support, their designated uses (ADCNR 2005). U.S. Environmental Protection Agency (EPA) designated §303(d) waters include 106 miles of the Cahaba River. Major Cahaba River tributaries such as Shades Creek (55 miles impaired), Little Shades Creek, Patton Creek, and Buck Creek are also impaired. Causes of impairment include excessive nutrients and organic enrichment, pathogens, turbidity, and siltation.
- The national non-profit conservation organization, American Rivers, selected the Cahaba River as one of the ten most endangered rivers in North America in 1990, primarily due to the threat of coalbed methane mining and energy development in the watershed (American Rivers 1990).
- Significant man-made alterations to the landscape surrounding the refuge include mining and logging activities, energy development, groundwater and surface water diversions, and urbanization. The impact of increased urbanization, along with associated mining and industrial

development in the upper Cahaba River Basin, have degraded water quality and threaten the future of the diverse biological communities in the basin (ADCNR 2005).

1.2 Key Water Resources Issues of Concern

For many freshwater aquatic systems like those protected by Cahaba River National Wildlife Refuge, water quality and water quantity are the two most critical factors influencing the ability of managers to meet the primary purposes of refuge establishment. Specific issues are outlined in Section 6.1.

Rapid urbanization and commercial development in the area south and southeast of Birmingham (Jefferson, Shelby and St. Clair counties) are the primary forces shaping water quality conditions and biological communities both directly in the upper Cahaba River drainage and indirectly in the lower Cahaba River drainage through material and pollutant transport (CRBCWP undated).

Water quality concerns on the refuge include upstream impacts from urban development (e.g., excess sediment and nutrients, water withdrawals, run-off, altered flows, point source and nonpoint source pollution), wastewater discharge from treatment plants, and impacts to both surface water and groundwater from legacy, current, and future energy development in the watershed.

Water quantity concerns on the refuge include urban development, population growth, surface water and groundwater withdrawals, alteration of the natural flow regime ecological flows, and large-scale and long-term impacts from climate change on multiple factors influencing water quantity and quality.

1.3 Needs and Recommendations

Highlights of the needs and recommendations for Cahaba River NWR are summarized below. A more in-depth discussion of needs and recommendations is provided in Section 6.2.

- In order to most effectively manage and protect the Cahaba River, continued, enhanced, and expanded future support of existing and future partnerships is critical.
- Critical water quantity data for both surface water and groundwater are needed for the refuge – specifically to document the magnitude, frequency, timing, duration and rate of ecological flows needed (with seasonal, temporal, and spatial variability) – to carry out the refuge's four primary purposes. Critical data needs include maintaining existing USGS stream gage and groundwater well data, and adding gages and wells where necessary.
- Specific water monitoring objectives for the refuge should be developed and implemented, ideally supplementing existing monitoring occurring in the watershed. Water monitoring efforts are tied to baseline information needs in the adaptive management framework, targeting ecological integrity while meeting refuge level, Regional and National level Water Resources Inventory and Monitoring Goals and Objectives (USFWS 2010a; USFWS 2013).
- Barriers to aquatic fauna movement within the basin should be evaluated and either replaced or removed based on successful removal of historic dams and barriers. Efforts to evaluate the effectiveness of fish passage structures and strategies currently being implemented at large dams within the Alabama River and Mobile basin should continue. Although outside the refuge boundary, these downstream dams affect production and distribution of numerous species at various trophic levels within the Cahaba drainage.

2 Introduction

This Water Resource Inventory and Assessment (WRIA) Summary Report for Cahaba River National Wildlife Refuge (NWR) inventories relevant hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations to address the identified water resource needs and concerns. The information compiled as part of the WRIA process will ultimately be housed in an online WRIA database currently under development by the U.S. Fish and Wildlife Service Natural Resources Program Center (NRPC), which is expected to be operational by mid-2014. Together, the WRIA Summary Report and the accompanying information in the online WRIA database are intended to be a reference to help guide on-going and adaptive water resource management. This WRIA Summary Report was developed in conjunction with the refuge manager, and numerous internal and external partners with extensive knowledge about the Cahaba River basin. The document incorporates existing hydrologic information compiled between April 2012 and June 2013.

The WRIA database and summary reports provide a reconnaissance-level inventory and assessment of water resources on and adjacent to National Wildlife Refuges and National Fish Hatcheries nationwide. Achieving a greater understanding of existing refuge water resources will help identify potential concerns or threats to those resources and will provide a basis for wildlife habitat management and operational recommendations to refuge managers, wildlife biologists, field staff, Regional Office personnel, and Department of Interior managers. A national team composed of Water Resource staff, Environmental Contaminants Biologists, and other Service employees developed the standardized content of the national interactive online WRIA database and summary reports.

The long term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on NWRS water quantity and quality in order to acquire, manage, and protect adequate supplies of clean and fresh water. An accurate water resources inventory is essential to prioritize issues and tasks, and to take prescriptive actions that are consistent with the established purposes of the refuge. Reconnaissance-level water resource assessments evaluate water rights, water quantity, known water quality issues, water management, potential water acquisitions, threats to water supplies, and other water resource issues for each field station.

WRIAs are recognized as an important part of the NWRS Inventory and Monitoring (I&M) initiative and are prioritized in the National I&M Operational Blueprint as Task 2a (USFWS 2010a). In addition, this WRIA work supports the Water Resources Inventory and Monitoring (WRIM) Operational Goal, as well as Objective WRIM 1.0, and Task WRIM 1.4 within the National I&M Seven Year Plan (USFWS 2013). The seven-year plan outlines a strategic, focused, measureable and prioritized plan directly tied to the I&M Operational Blueprint. Hydrologic and water resource information compiled during the WRIA process can facilitate the development of other key documents for each refuge including Hydrogeomorphic Analyses (HGMs), Comprehensive Conservation Plans (CCPs), Habitat Management Plans (HMPs) and Inventory and Monitoring Plans (IMPs). In addition, water quality and pollutant source information compiled as part of this WRIA informed the Contaminant Assessment Process (CAP) and helped to streamline the CAP effort for the refuge.

A CCP for the refuge was initiated in 2011 and is anticipated to be completed in 2014 (USFWS 2011). In April of 2013, the CAP was initiated for Cahaba River National Wildlife Refuge and was completed in October 2013. Preliminary water resource assessments conducted within Region 4 by the US Fish and Wildlife Service beginning in 2007, as well as hydrologic and climate change vulnerability assessments conducted by the USFWS and USGS in 2009, identified Cahaba River National Wildlife Refuge as one of six top priority sites within Region 4 recommended for detailed hydrologic characterization. This hydrologic characterization conducted by USGS was expanded in FY2010 and is still on-going, although hydrologic data summaries for Cahaba River NWR were received in November 2011. Key issues outlined for the refuge in these assessments highlighted water quantity and water quality factors, primarily related to the high biodiversity and endemism of aquatic species in the drainage and the specific natural history requirements of these species. Land use impacts in the watershed relating to urban sprawl, timber operations, and mining and gas industry operations were prioritized as major impacts to both water quantity and quality. Upstream and downstream dams on the Alabama River were identified as greatly impacting fish migration, spawning and critical aquatic habitat in the Cahaba River. Predicted climate related impacts were specifically mentioned, along with the possibility to exacerbate existing threats to the Cahaba River basin (USFWS 2009a). Following this work, the WRIA process was initiated in August 2010 with a kick-off meeting and site visit held on August 25, 2010. Due to staff turn-over, the process halted and was re-initiated on August 14, 2012 with a kick-off meeting held in Birmingham, AL. A summary of the meeting and attendees is provided in Appendix A.

3 Facility Information

Cahaba River National Wildlife Refuge is located in central Alabama, in Bibb County near the town of West Blocton, approximately 30 miles southwest of Birmingham and 65 miles northwest of Montgomery. It is located in the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC), just southwest of the Appalachian LCC boundary (Figure 1, Figure 2). The refuge was established September 25, 2002 under the authority of the Cahaba River National Wildlife Refuge Act, Public Law 106-331 and the National Wildlife Refuge System Administration Act of 1996, as amended (16 U.S.C., 668dd-668ee). It was established to serve four primary purposes: (1) to conserve, enhance and restore native aquatic and terrestrial community characteristics of the Cahaba River; (2) conserve, enhance and restore habitat to maintain and assist in the recovery of plants and animals that are listed as threatened or endangered species; (3) to ensure that hunting, fishing, wildlife observation, wildlife photography, and environmental education and interpretation are the priority general public uses of the refuge when providing opportunities for compatible fish- and wildlife-oriented recreation; and (4) to encourage the use of volunteers and to facilitate partnerships among the Service, local communities, conservation organizations, and other non-federal entities when promoting public awareness of the refuge's resources and those of the National Wildlife Refuge System (USFWS 2007).

As of April 2013, the refuge had acquired 3,681 acres within a 7,600-acre approved acquisition area (Figure 3) (USFWS 2010b; 2011). Key terrestrial habitats present on the refuge include mesic hardwood forest, dry hardwood forest, floodplain forest, dry longleaf pine forest, cliffs, rockhouses and caves, as well as artificial habitats including mines (USFWS 2007). The current acquisition boundary of the refuge encompasses 8.3 miles of the Cahaba River, as well as several tributary streams.

The word Cahaba, historically “Cahawba,” from which the river takes its name is thought to come from either the Creek Indian word for the native cane that historically covered the river valleys, or it may be a corruption of the Choctaw words for "water above" (TCF 2013). The Cahaba River drainage area lies entirely within the state of Alabama and encompasses approximately 1,824 square miles including portions of St. Clair, Jefferson, Shelby, Bibb, Tuscaloosa, Perry, Chilton, and Dallas Counties (ADEM 2012a; CRBCWP undated). The Cahaba River flows for approximately 191 miles and includes Alabama’s longest stretch of free-flowing river (approximately 150 miles, from the Highway 280 diversion dam to its confluence with the Alabama River). The Alabama Department of Environmental Management (ADEM) recognizes sections of the Cahaba River and the entire Little Cahaba River in Bibb County as Outstanding Alabama Waters (ADEM 2012b). The U.S. Environmental Protection Agency (EPA) currently lists the Cahaba River basin as a priority watershed for the Southeast Region (EPA 2013), and The Nature Conservancy highlighted the Cahaba River as a hotspot for aquatic diversity – one of 87 watersheds in the continental United States harboring 10 or more imperiled fish and mussel species (Master et al. 1998).

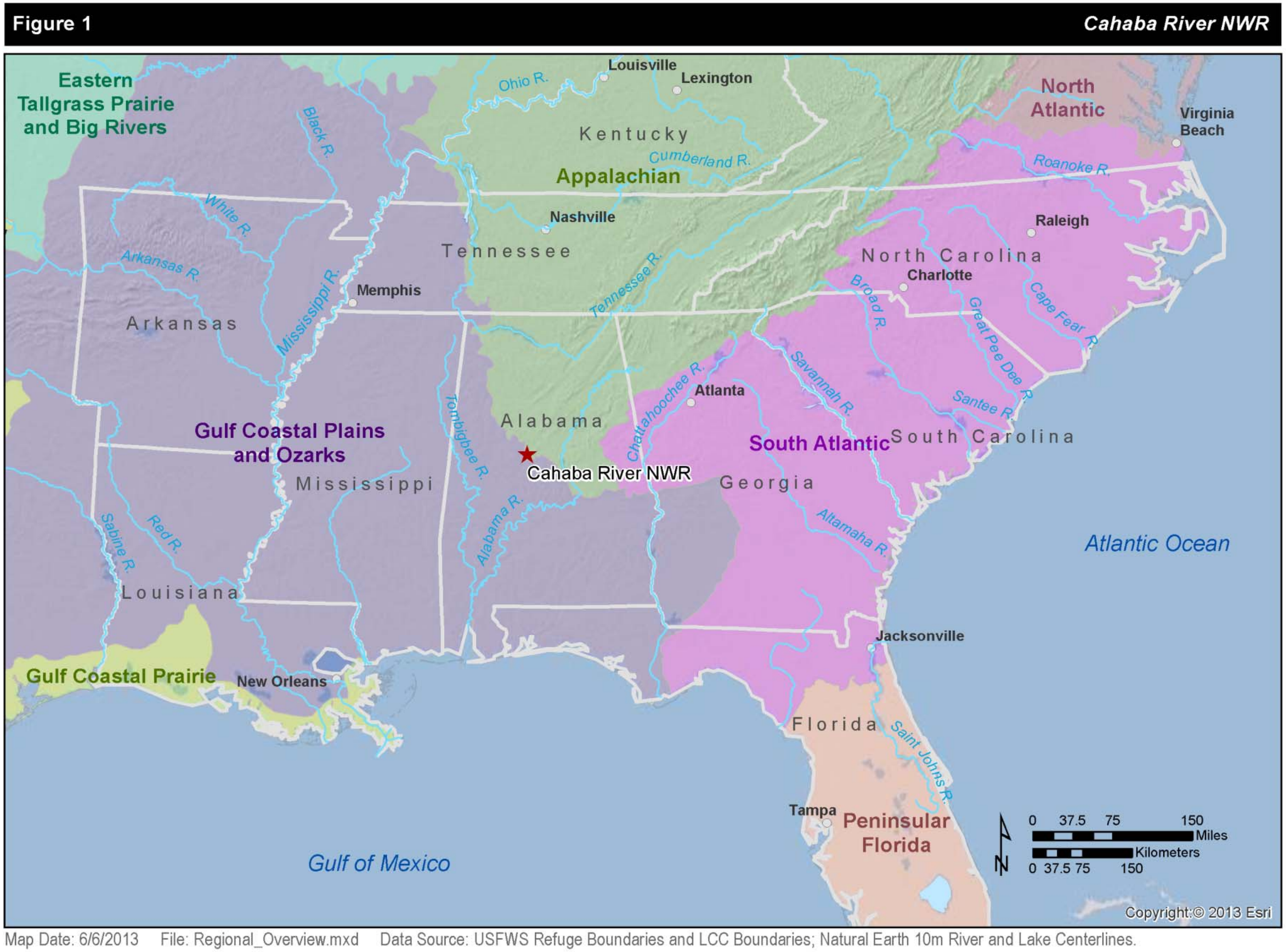


Figure 1. Location of Cahaba River NWR in relation to USFWS Region 4 Landscape Conservation Cooperative boundaries.

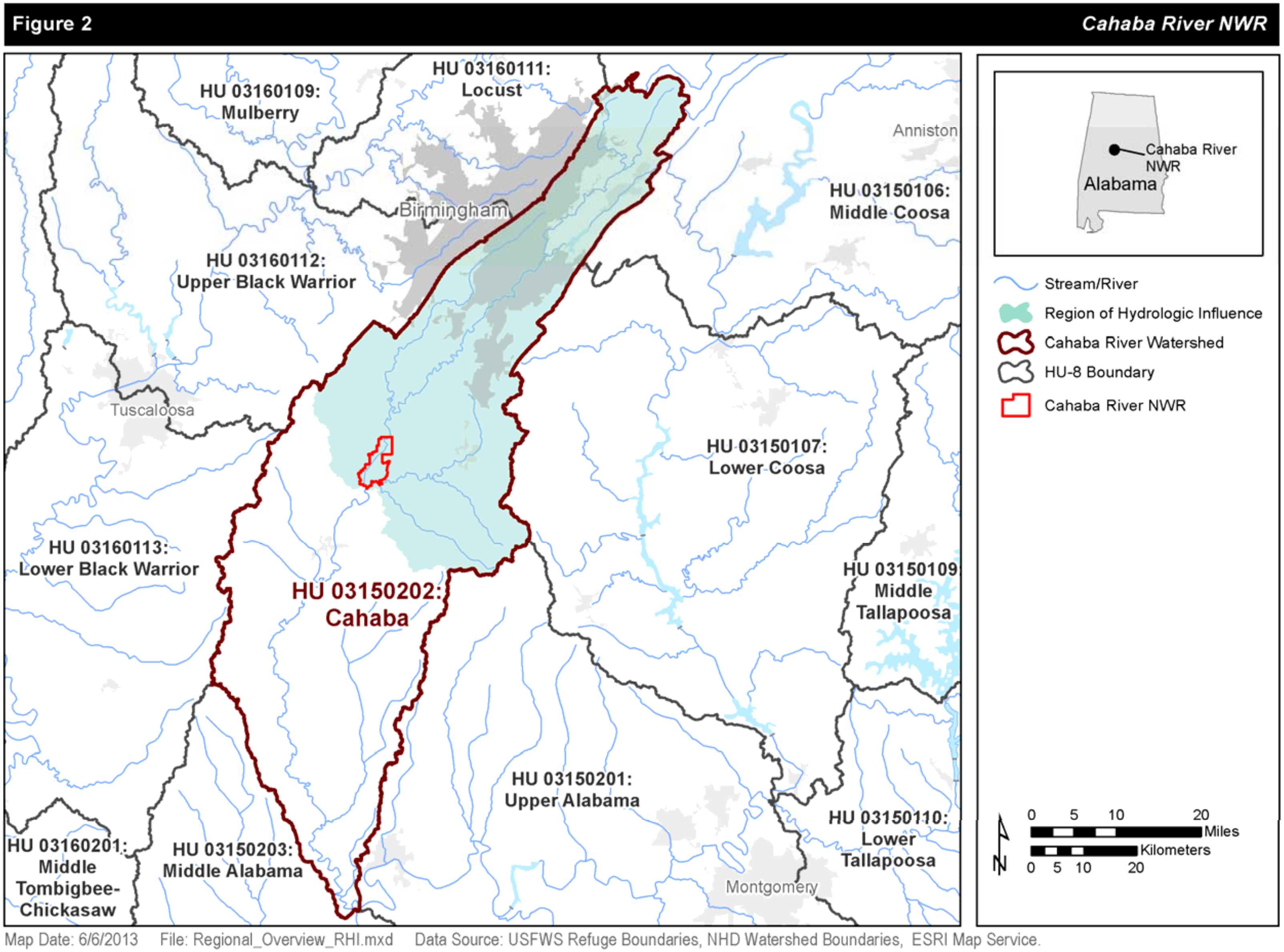


Figure 2 . Cahaba River Basin 8-digit Hydrologic Unit boundary and bordering 8-digit Hydrologic Units.

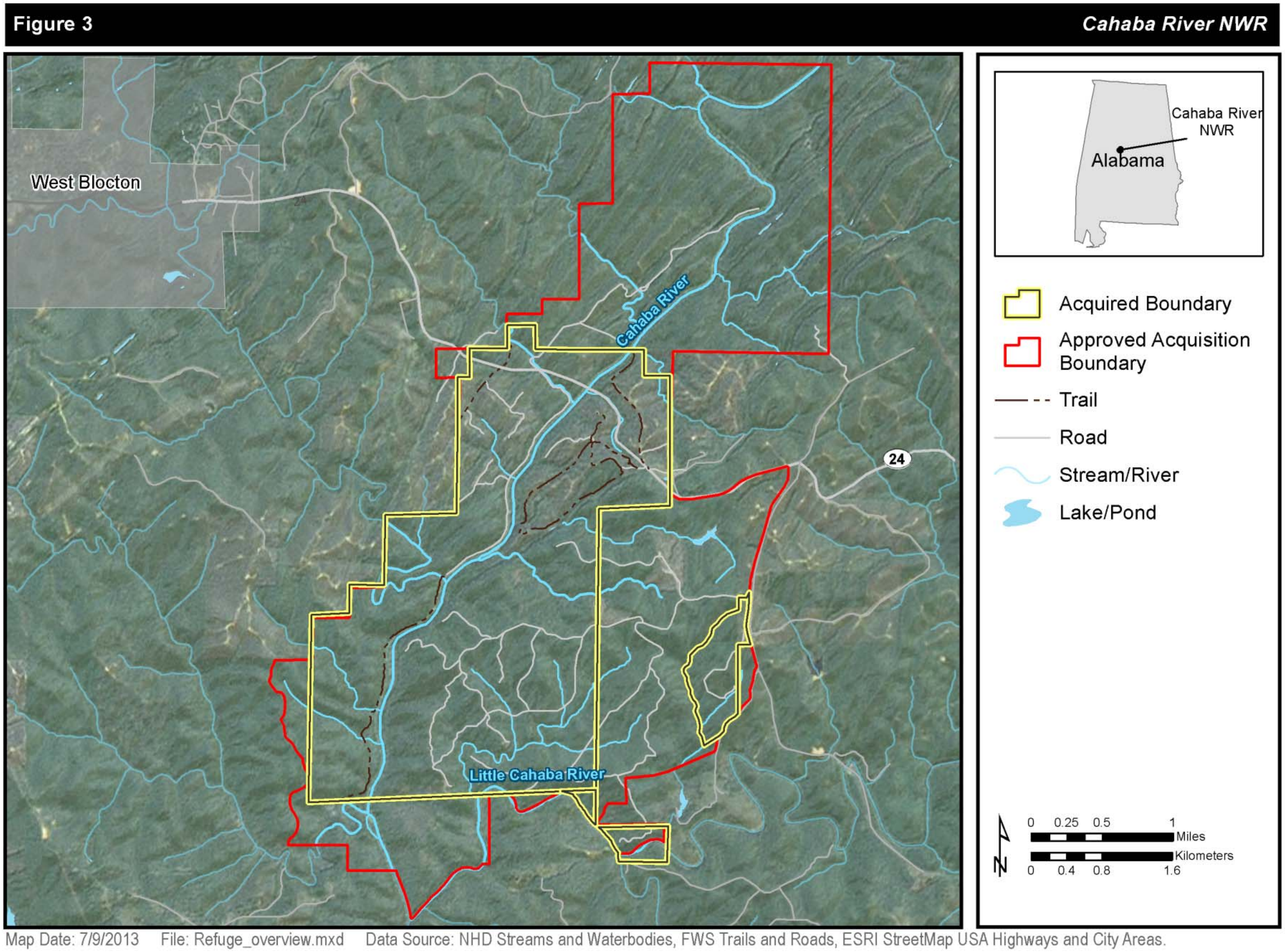


Figure 3. Cahaba River NWR showing the approved acquisition boundary, and the boundary of land acquired as of April 2013.

The Cahaba River supports a wide diversity of endemic plants and animals including more than 65 rare and imperiled species (Benke and Cushing 2005; ALNHP 2012). Recent species occurrence records document 126 native fish species in the Cahaba River basin (NatureServe 2010; Appendix B), as well as 32 Gastropod species and 39 Unionid mussel species (Johnson et al. 2005; Johnson et al. 2011; Appendix B). In addition to the rare and endemic species found in the Cahaba River, 32 federally listed species (including candidate species) are known to occur or have historically occurred in the basin (Appendix B with citations). Biological surveys conducted within refuge boundaries have documented 12 of these species (*Leptoxis ampla* - round rocksnail, *Lepyrium showalteri* - flat pebblesnail, *Lioplax cyclostomaformis* - cylindrical lioplax, *Hamiota altilis* - fine-lined pocketbook, *Ptychobranchus greenii/foremanianus* - triangular kidneyshell, *Hamiota perovalis* - orangenacre mucket, *Notropis cahabae* - Cahaba shiner, *Percina aurolineata* - goldline darter, *Symphyotrichum georgianum* - Georgia aster, *Arabis georgiana* - Georgia rockcress, *Myotis grisescens* - gray bat and *Haliaeetus leucocephalus* - bald eagle) in the refuge (Appendix B with citations). Reintroductions of 2 Federally Endangered mussels (*Epioblasma penita* – southern combshell and *Medionidus parvulus* – Coosa moccasinshell) began in September 2012 in the Cahaba and Little Cahaba River, respectively (Johnson 2012a; Johnson 2012b). Although not federally listed, two species once thought to be extinct (*Clappia cahabensis* - Cahaba pebblesnail, and *Leptoxis compacta* - oblong rocksnail), have been re-discovered in the Cahaba River, and documented to occur within the refuge (Johnson et al. 2005; Johnson et al. 2010; Johnson et al. 2011; Whelan et al. 2012).

The Cahaba River below Mean Low Water (MLW) is owned by the State of Alabama. Therefore, of the 12 federally listed species documented on the refuge, eight are aquatic and actually occur in state waters adjacent to the refuge. The gray bat forages along the river, which is the only known use of the refuge by the bat. Bald eagles have been observed along the river during the spring, and eagle nests have been documented just south of the refuge. The Georgia aster is associated with the upland habitat within the refuge, and Georgia rockcress is primarily associated with the high bluffs along the river (Federal Register 2013). Many aquatic species that occur within the Cahaba River drainage and on refuge lands may be federally listed in the future. For example, numerous mollusk species within the drainage were originally considered for listing in 1991 and 1994 (Federal Register 1991 and 1994). Many of these species are included in a recent petition by the Center for Biological Diversity to list 404 predominantly southeastern aquatic species currently under consideration by USFWS (CBD 2010). More detailed information about the biological assemblages found within the Cahaba River basin is summarized in Section 5.3 of this report.

As of June 2013, the refuge is currently unstaffed and administered through the Mountain Longleaf National Wildlife Refuge headquarters in Anniston, Alabama. Most of the refuge is closed to motorized vehicles and open to foot traffic only. The exception is a small gravel parking area located off County Road 24 (the parking area is approximately 10,000 square feet with 2 paved Americans with Disability Act [ADA] accessible parking spots), and a two mile section of road (River Road) extending from County Road 24 south to the mouth of Caffee Creek. River Road was a gravel road when acquired as part of the original land purchase for the refuge, and was improved (with culverts and additional gravel) in 2004.

A concrete and gravel canoe launch with ADA accessibility was constructed south of County Road 24 along River Trace Road in 2007 (USFWS 2007). Additionally, a 2.0 mile gravel interpretive trail (Piper Trail) with ADA access is maintained that runs east of the river along the former Piper railroad bed, across a footbridge over a small tributary stream to the river (USFWS 2006). The trail provides interpretation of the former mining area and views along the river. Originally 1.3-miles, Piper Trail was expanded in 2012 by adding two scenic overlooks along the river, as well as connecting the Piper Trail to Cahaba Overlook Road (Figure 3; USFWS 2007; Sarah Clardy, personal communication). Ridge Trail is approximately 1.5 miles and provides access from River Trace Road up to the top of a ridge. No bathroom facilities exist at the trailhead, parking area, or along River Trace Road. Portable toilets are provided on a temporary basis for larger-scale special events occurring at the refuge.

The refuge is composed of upland ridges and slopes that support a variety of natural community types (USFWS 2007). The formation of these communities was influenced by elevation, slope, aspect and soils. In addition to geographic and physical factors, the introduction of fire has the ability to structurally change the composition of many of these natural communities. Detailed natural community descriptions for the refuge are provided in the Habitat Management Plan, as well as goals, strategies and objectives for restoring and maintaining these habitats (USFWS 2007). As part of the Habitat Management Plan for Cahaba River NWR, 17 management units were delineated to facilitate and prioritize resource management and prescribed burning programs (USFWS 2007).

Primary refuge concerns related to water resources include increasing urbanization within the watershed, the reduction in surface and groundwater availability, water quality degradation, and effects of historical and current landscape disturbance (e.g., logging, mining, off-refuge agriculture, methane gas extraction, and future energy extraction activities).

4 Natural Setting

4.1 Region of Hydrologic Influence (RHI)

This assessment focuses on water resources within the geographic extent of the refuge acquisition boundary, and more broadly on water resources within a Region of Hydrologic Influence (RHI) containing the refuge. The RHI describes some portion of the watershed – either the entire or partial watershed – upstream of the refuge that affects the condition of water resources on the refuge. This construct anchors the refuge in the greater watershed and thereby provides a reference for discussing the refuge within a watershed context. Because water travels down gradient, it is the activities occurring upstream of the refuge that influence water quantity (e.g., diversions, withdrawals, land cover changes) or water quality (e.g., pollution from agricultural, urban, or industrial land uses) on the refuge. In this riverine system, activities occurring downstream of the refuge are less likely to directly affect water resources on the refuge. Accordingly, the focus of the RHI is limited to areas upstream of the refuge.

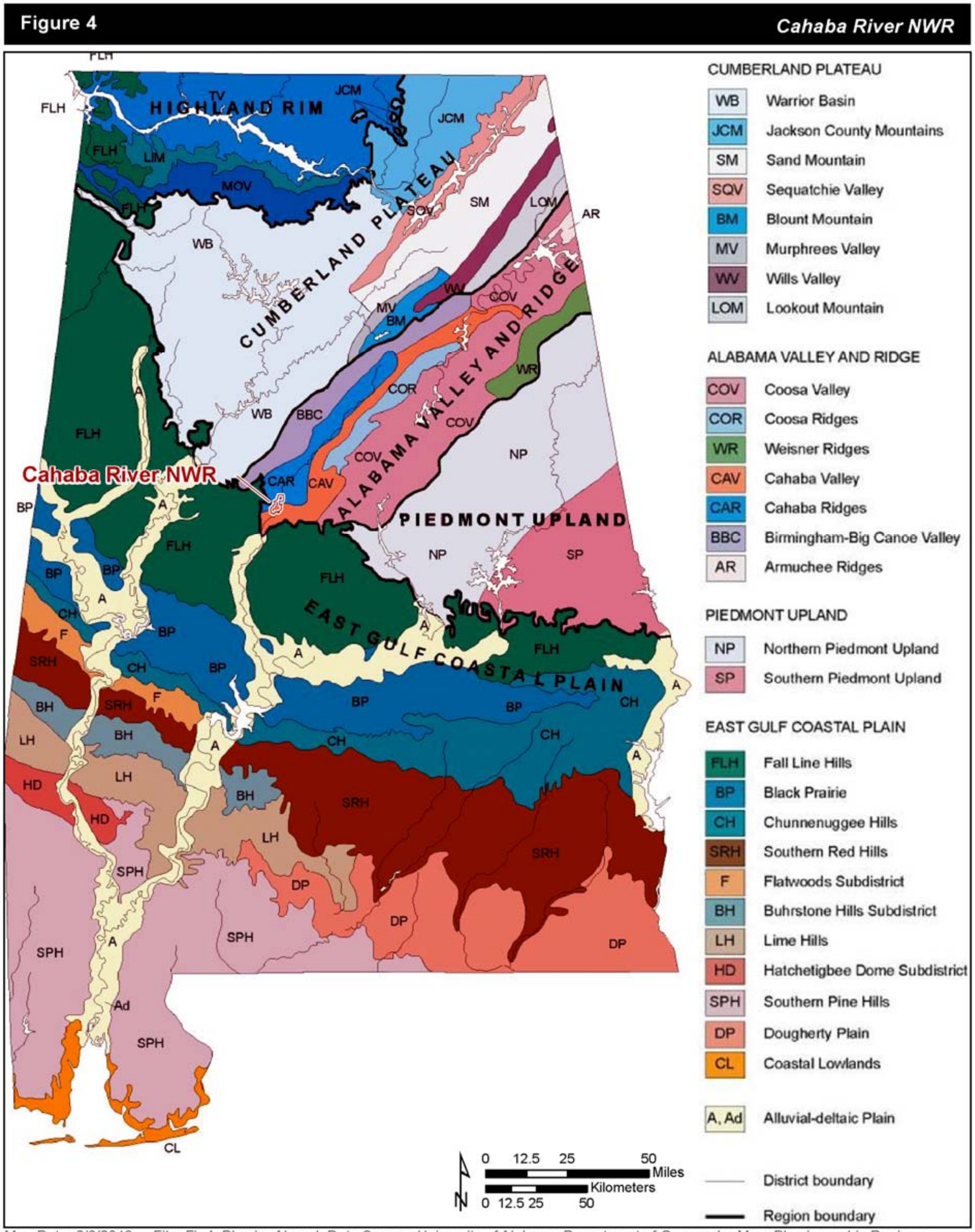
For the purposes of this assessment, the RHI was defined as the upper portion of the Cahaba River subbasin (Figure 2, Figure 13). Specifically, the RHI includes four watersheds (Headwaters Cahaba River [0315020201], Buck Creek-Cahaba River [0315020202], Shades Creek [0315020203], and Little Cahaba River [0315020204]) that comprise the upper half of the Cahaba River subbasin (HUC 03150202). These geographic delineations are based on the National Watershed Boundary Dataset (WBD), a hierarchical framework that divides the landscape into progressively smaller hydrologic units. At the coarsest scale these hydrologic units are called hydrologic regions and assigned unique codes (HUCs). At progressively finer scales, 4-, 6-, 8-, 10-, and 12-digit HUCs translate into subregions, basins, subbasins, watersheds, and subwatersheds, respectively (Laitta et al. 2004).

4.2 Topography and Landforms

The Fall Line between the Gulf Coastal Plain and the Valley and Ridge physiographic provinces divides Alabama into two distinct physical regions (the upland and lowland), and is a significant physical feature in Alabama affecting the distribution of plants and animals (CRBCWP undated; O'Neil and Shepard 2007; Williams et al. 2008). Because of limitations due to life-history, morphological adaptations, or lack of invasion routes, many endemic species are limited to either above or below the Fall Line. More discussion about the influence of underlying land forms and topography on stream ecosystems and diversity can be found in the Aquatic Habitat and Biota section of this document (Section 5.3.1.3), as well as in Ward et al. (1992), and Lydeard and Mayden (1995).

The refuge is located in the Valley and Ridge physiographic province, approximately 10 miles north of the Fall Line, separating it from the Gulf Coastal Plain physiographic province (CRBCWP undated; USFWS 2007; Figure 4). Elevations within the watershed range from 100 to 1,100 feet.

The Valley and Ridge province is characterized by numerous zigzagging ridges separated by deep steep-sided valleys that trend northeast-southwest with elevations ranging from 600 to 2,100 feet (CRBCWP undated).The Cahaba River drains two of the districts in the province: the Cahaba Valley and the Cahaba Ridges (Figure 4). The principal streams draining the Cahaba Valley are the upper Little Cahaba River and Lake Purdy, Cahaba Valley Creek, Buck Creek and the lower Little Cahaba River near Centreville. The ridges in the Cahaba Ridges district rise 200-500 feet above the surrounding valleys. The Cahaba Ridges forms a structural barrier to the flow of the Cahaba River, which has adapted by developing a trellised drainage pattern with the main river channel meandering back and forth through the ridges (CRBCWP undated).



Map Date: 6/6/2013 File: Fig4_Physio_Al.mxd. Data Source: University of Alabama Department of Geography Map: Physiographic Regions.

Figure 4. Cahaba River NWR in relation to Alabama physiographic provinces and districts.

The Gulf Coastal Plain province within Eastern Alabama is characterized by gently rolling hills, sharp ridges, prairies and broad alluvial flood plains (CRBCWP undated). Within the Gulf Coastal Plain province two districts are found in the lower Cahaba River basin: the Fall Line Hills and the Black Belt Prairie (Figure 4). The topography of the Fall Line Hills can be fairly rugged with steep slopes, particularly near streams. Streams draining the Fall Line Hills are well sustained because of extensive sand and gravel aquifers; they include Haysop Creek, Affonee Creek, Oakmulgee Creek, Mill Creek, Goose Creek, Sandy Creek and Rice Creek (CRBCWP undated). The Black Belt Prairie district, a deeply weathered plain located in the extreme southern part of the Cahaba River watershed, has thin soils and impermeable rocks (chalk and marl). The Black Belt Prairie district represents a unique and clearly defined hydrologic region in the state, with high runoff rates and streams noted for flow variability during storm events, as well as variable seasonal flow rates and persistence (CRBCWP undated).

The topography of the Cahaba River NWR includes rolling hills and steep ravines along the river and its tributaries. The river is 220 feet above sea level (asl) with some hilltops reaching 560 feet asl. The topography has been altered due to historic strip-mining for coal along the northern edge of the refuge (USFWS 2007).

Five main rivers flow through the Gulf Coastal Plain in Alabama: The Chattahoochee, Choctawhatchee, Conecuh, Alabama and Tombigbee-Black Warrior. The Alabama has a well-defined alluvial plain composed of material deposited by the river itself (Figure 4). The alluvial plain reaches up to six miles wide in Clarke County, and the river meanders over it for its entire course. Smaller alluvial plains occur along the Cahaba, Black Warrior, Tombigbee, and Chattahoochee rivers (Figure 4). Additional information about hydrology and geomorphology is discussed in Section 4.5.

4.3 Geology

As noted previously, the refuge is located in the Valley and Ridge physiographic province, approximately 10 miles north of the Fall Line separating it from the Gulf Coastal Plain physiographic province (CRBCWP undated; USFWS 2007; Figure 4).

The Valley and Ridge Province consists of chert and sandstone ridges, alternating with valleys composed of limestone and shale. The Cahaba Valley district is developed on weathered, soluble limestones and dolomites, erodible shales and resistant chert beds, and extends for approximately 75 miles across Bibb, Jefferson, Chilton, Shelby, and St. Clair Counties (CRBCWP undated; GSA 2006a). The Cahaba Valley is within the Appalachian foreland fold and thrust belt, and is underlain by Paleozoic sedimentary rocks ranging in age from early Cambrian to Late Mississippian (CRBCWP undated; Hatcher et al. 1990; GSA 2006a). The Cahaba Ridges district is about 65 miles long and five miles wide and is characterized by massive sandstone and conglomerate beds of the Pottsville and Parkwood formations, rising 200-500 feet above the surrounding valleys (Figure 5).

In the vicinity of the refuge, the Pottsville Formation is reported to be more than 8,000 feet thick and divided into three assemblages. The youngest assemblage of the Pottsville Formation, Conglomerate Measures, is 2,500 feet thick and contains the coal beds of the Cahaba Coal Field where significant coal mining took place. This assemblage is composed of chert, granite, basalt, gneiss, schist and volcanics (QORE, Inc. 2004). The Cahaba Coal Field contains medium to high-volatile bituminous coal of present or future commercial value (Culbertson 1964; USGS 1996). Coal mining in the northern part of the refuge occurred in the Thompson Coal Bed, which ranges from 2 to five feet thick (QORE, Inc. 2004; USFWS 2007). A very detailed analysis of the stratigraphy, physical and chemical characteristics, and estimates of coal reserves in the Cahaba Coal Field is provided by Culbertson (1964). Currently, the Geological Survey of Alabama (GSA) is digitizing more than 300 maps of current and historic coal mining activities and underground coal mines within the RHI (Richard Carroll, personal communication). Additional discussion about mining and associated land use alterations can be found in Section 4.6 (Anthropogenic Landscape Changes) and Section 5.3 (Water Monitoring) of this report.

Aquifers in the vicinity of the refuge include Coker, Pottsville and Gordo (GSA undated). The hydrogeology of aquifers in the Valley and Ridge Province is described in Section 5.1.5.

The Gulf Coastal Plain Province, located south of the refuge and outside of the RHI, is underlain by sedimentary deposits consisting of sand, gravel, porous limestone, chalk, marl and clay that dip to the southwest approximately 20 to 40 feet per mile. More resistant strata form distinctive, broad saw-toothed ridges called cuestas that have steep north-facing slopes and gentle south-facing slopes (CRBCWP undated). Detailed geology, physiography and stratigraphy of the area are also found in Kopaska-Merkel et al. (2005).

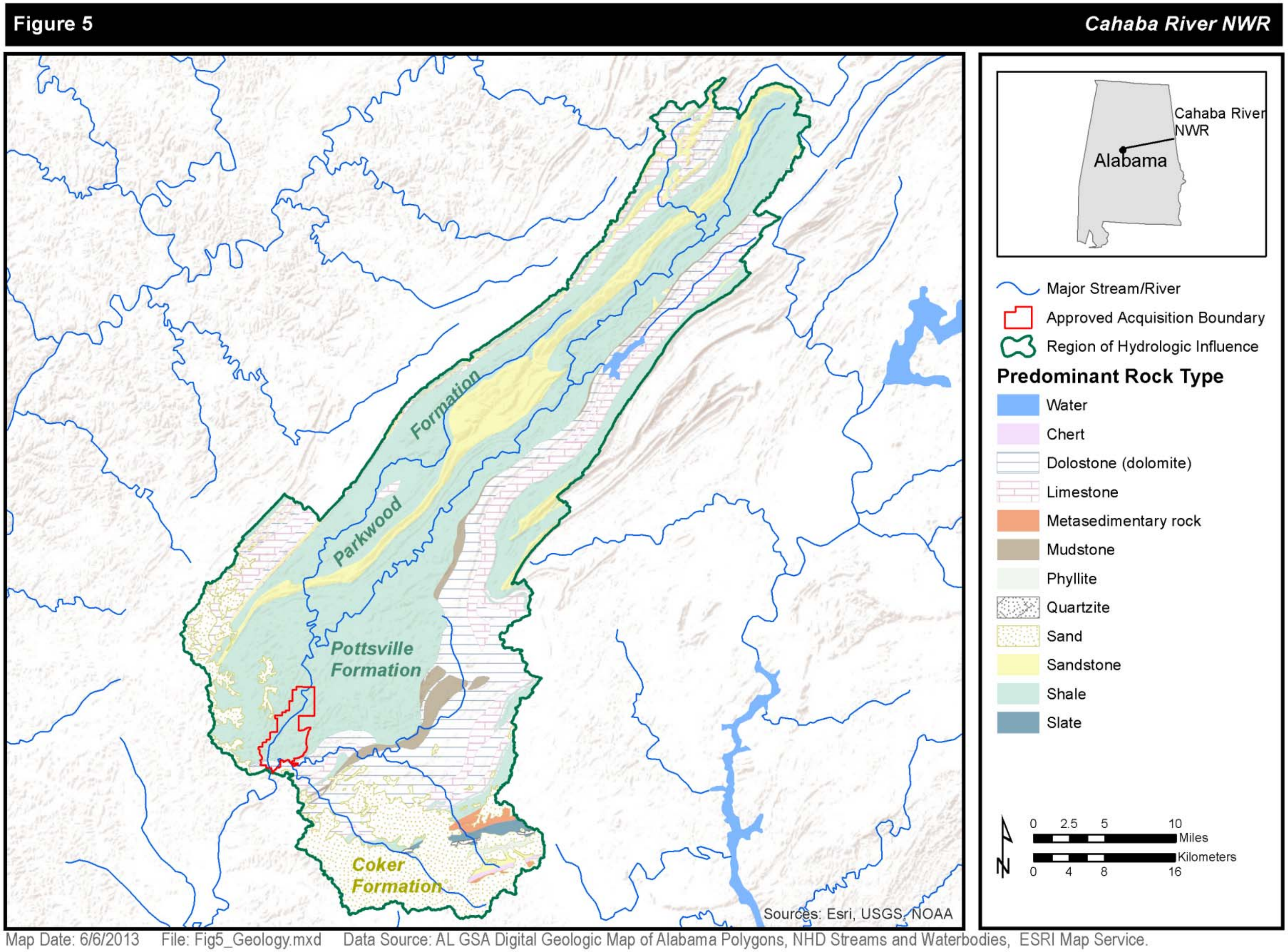


Figure 5. Generalized geology within the RHI based on GSA (2006a) data.

4.4 Soils

The major soils of the Cahaba River system were formed from sedimentary rocks deposited during the Pennsylvanian sub-period (320-286 million years ago) and the Cretaceous Period (145-65 million years ago) (CRBCWP undated). Within the Cahaba basin, five major soil provinces are represented: soils of the limestone valley and uplands, soils of the Appalachian Plateau, soils of the Coastal Plain, soils of the floodplains and terraces, and soils of the Black Belt Prairie (Kaufman and Wise 1978; CRBCWP undated). The following descriptions are taken from Kaufman and Wise (1978):

Limestone Valleys and Uplands: Soils of the limestone valleys and uplands were formed from the weathering of pure and cherty limestone. Soils in valleys formed from pure limestone while soils on the uplands formed from cherty limestone. These soils are typically red clay loams where plants are cultivated on the gentle slopes while steeper slopes are wooded. The Minvale-Bodine-Fullerton association is commonly found in the limestone valleys and uplands.

Appalachian Plateau: Appalachian Plateau soils are dominated by the Montevallo-Townley-Enders association and were formed principally from sandstone and shale and occur most frequently in mountainous regions in the folded valleys and ridges. Sandy loams are found on the sandstone plateaus.

Coastal Plain: Coastal Plain soils were formed from erosion of sediments of the Appalachian Plateau region to the north. The Luverne-Smithdale-Boswell association is representative of soils in the Coastal Plain. These well-drained soils are found in gently rolling to hilly woodlands that support pine mixed with hardwoods and large open areas of crop or pasture.

Floodplains and Terraces: The Cahaba-Chewacla-Myatt soil association is a major component of floodplains and terraces along the main stem of the Cahaba. These soils are typical of bottomland hardwoods, fields, and along streams in the Coastal Plain. Cahaba soils are deep, well drained, and found along terraces of larger streams. The Chewacla and Myatt soils are deep but poorly drained and occupy level flood plains and low terraces.

Black Belt Prairie: The soils in the Black Belt are represented by the Sumter-Oktribbeha-Leeper association, which are moderately deep to deep and well drained. They have neutral and calcareous subsoils with some being highly calcareous in the surface layers. Clayey soils with a high shrink/swell potential are common. The topography of these soils is rolling with some steep hills and level fields and prairies. A large portion of the Black Belt is grassland with pine occurring on more acid soils.

Almost two-thirds of the refuge is composed of partially hydric soils (73 %), with the remainder non-hydric (Table 1). The environmental conditions that create hydric soils (water remaining at or near the soil surface for extended time periods during the growing season) also favor the formation of many types of wetlands. Therefore, hydric soils can be used to identify the presence and boundaries of wetlands. As a result, hydric soils are a very important issue in land management and land planning due to their role in the identification of wetlands and their function in wetland ecology.

The Natural Resources Conservation Service (NRCS) defines a hydric soil as "soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part." The concept of hydric soils includes soils developed under sufficiently wet conditions to support the growth and regeneration of hydrophytic vegetation. Soils that are sufficiently wet because of artificial measures are included in the concept of hydric soils. Also, soils in which the hydrology has been artificially modified are hydric if the soil, in an unaltered state, was hydric. Some soil series designated as hydric have phases that are not hydric depending on water table, flooding, and ponding characteristics. NRCS maintains a national list of hydric soil components (USDA undated). Within the Soil Survey Geographic (SSURGO) Database, "hydric soils" include all map units in which the majority of soil components meet hydric criteria. "Partially hydric soils" may have some hydric components within a larger matrix of non-hydric components (SSURGO undated-b).

The majority of the refuge soils are representative of the well-drained Sipsey-Nauvoo-Sunlight and Sipsey-Nauvoo-Townley complexes (Table 2, Figure 6). The deep, moderately permeable soils Nauvoo Series soils cover refuge hills and ridge-tops, and are agriculturally productive; they are used for growing cotton, corn, soy beans, small grains, hay and pasture. The Nauvoo Series, along with the moderately deep, slowly permeable Townley soils, cover slopes and summits, while the moderately deep Sipsey Series and shallow Sunlight series soils cover slopes (USDA 2008). The Gorgas-Rock Outcrop complex is the third largest soil complex on the refuge (Table 2). Gorgas soils (shallow, well-drained, moderately rapid permeable) are found on steep slopes that have sandstone rock outcrops. The Nauvoo sandy loam (deep, well-drained, moderately permeable) is the fourth largest soil series on the refuge, and is found on the summits, slopes and knolls of narrow ridges. Additional soil descriptions can be found in Table 3, the refuge Habitat Management Plan (USFWS 2007) and in Kopaska-Merkel et al. (2005).

Table 1. Hydric classes of soils within Cahaba River NWR acquisition boundary. [Source: SSURGO undated-a].

Hydric Class	Acres within Acquisition Boundary
Not hydric	2094.9
Partially hydric	5572.5
Total	***7667.4***

Table 2. Soils types within Cahaba River NWR acquisition boundary. [Source: SSURGO undated-a].

Soil Series	Acres within Acquisition Boundary
Bibb-Iuka complex, 0 to 1 percent slopes, frequently flooded	5.1
Bodine very gravelly silt loam, 6 to 15 percent slopes, stony	192.1
Bodine-Minvale complex, 15 to 35 percent slopes, stony	98.4
Bodine-Minvale complex, 35 to 50 percent slopes, stony	10.9
Cahaba sandy loam, 2 to 5 percent slopes, rarely flooded	16.9
Gorgas-Rock outcrop complex, 35 to 60 percent slopes	713.8
Mantachie, Iuka, and Kinston soils, 0 to 1 percent slopes, frequently flooded	4.0
Minvale gravelly silt loam, 2 to 6 percent slopes	1.7
Nauvoo sandy loam 2 to 8 percent slopes	661.8
Palmerdale and Brilliant soils, 6 to 45 percent slopes	383.6
Sipsey-Nauvoo-Sunlight complex, 15 to 35 percent slopes	3009.0
Sipsey-Nauvoo-Townley complex, 6 to 15 percent slopes	2252.6
Smithdale sandy loam, 2 to 8 percent slopes	50.2
Talbott silt loam, 6 to 15 percent slopes, boulder	0.4
Water	266.9
TOTAL ACRES	***7667.4***

Table 3. Descriptions of soil map units within Cahaba River NWR acquisition boundary. [Source: SSURGO undated-a].

Map Unit	Description
Nauvoo-Sipsey-Townley-Sunlight	Dominantly gently sloping to very steep, well drained and somewhat excessively well drained soils that have a loamy surface layer and a loamy or clayey subsoil; formed in materials weathered from sandstone and shale.
Gorgas-Rock outcrop	Shallow, dominantly steep to very steep, well-drained soils with a loamy sand surface layer, sandy loam subsurface layer, and sandy loam subsoil; derived from sandstone
Palmerdale and Brilliant	Deep, dominantly gently sloping to very steep, somewhat excessively drained soils with a very to extremely channery silt loam surface layer and substratum; located on summits, shoulders, and backslopes.
Bodine-Minvale-Fullerton	Very deep, moderately steep to very steep, well drained and somewhat excessively drained soils that have a loamy or clayey subsoil; formed in residuum derived from limestone and cherty limestone.
Smithdale	Very deep, well-drained gently sloping to moderately steep soils with sandy loam to sandy clay loam surface layer and subsoil; located on ridges and hillslopes.
Cahaba	Dominantly level to gently sloping, well drained soils that have a sandy loam to fine sandy loam surface layer and a sandy loam or sandy clay loam subsoil; located on low stream terraces.
Bibb-luka complex	Dominantly level, poorly drained to moderately well drained soils with sandy loam surface and subsurface layers; located along floodplains.
Mantachie-luka-Kinston	Dominantly level, somewhat poorly drained, moderately well drained and poorly drained soils that have a loamy surface layer and subsoil or have a loamy or sandy substratum; located on lower parts of floodplains.
Talbott	Moderately deep, dominantly gently to moderately sloping, well-drained soils with a silt loam to silty clay loam surface layer and silty clay to clay subsoil; derived from limestone.

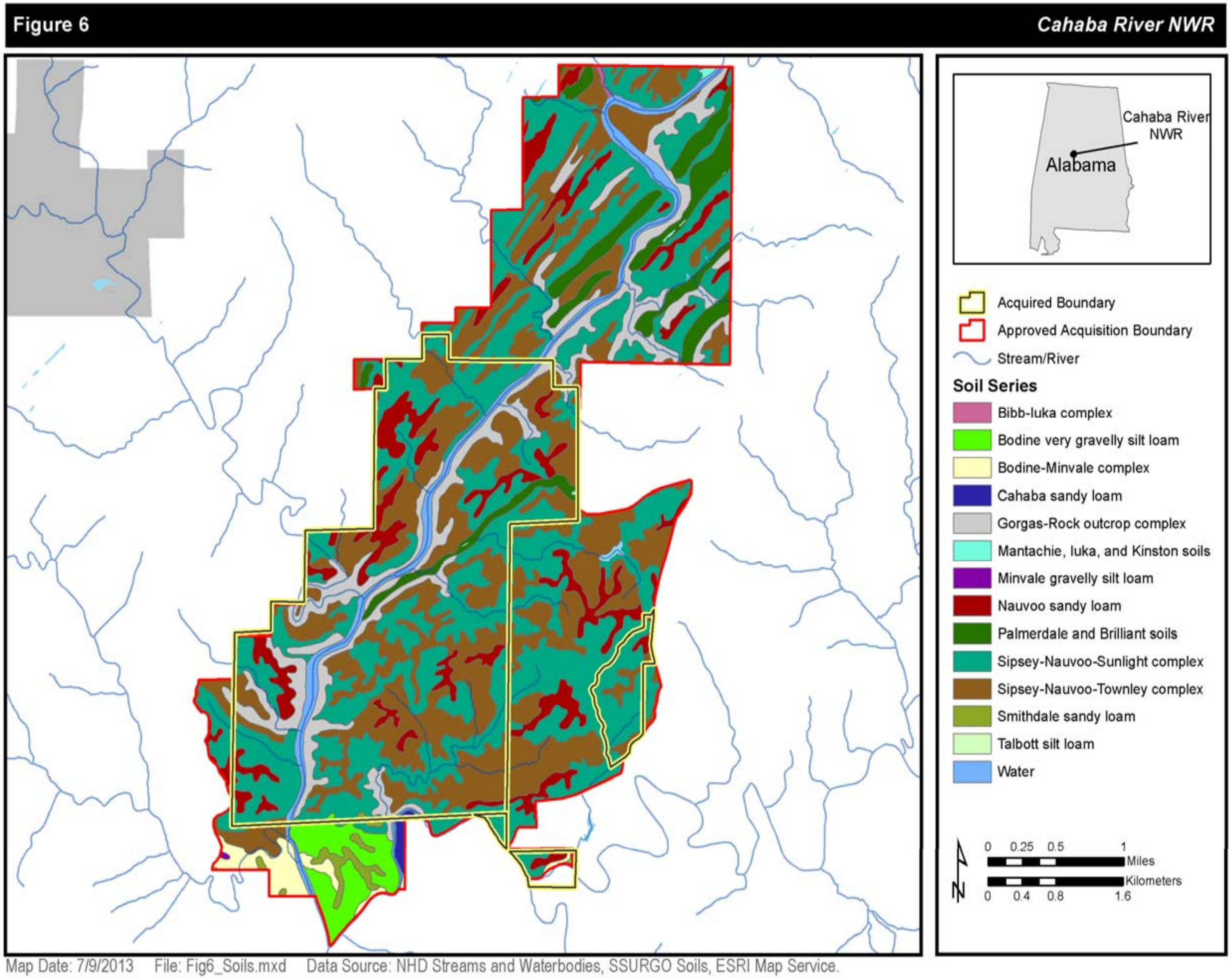


Figure 6. Soil types within Cahaba River NWR acquisition boundary based on SSURGO soils data.

4.5 Hydrology and Geomorphology

Cahaba River NWR is located within the Cahaba (03150202) subbasin (Figure 2) of the Alabama River basin (031502), which consists of adjacent drainages lying within both the Valley and Ridge and East Gulf Coastal Plain physiographic provinces. The Cahaba River is the third largest tributary to the Alabama River in the Mobile Bay - Tombigbee basin (031602).

The Cahaba River originates from springs and seeps on the southern slope of Cahaba Mountain in St. Clair County, and from springs and seeps along the edge of Red Mountain in Jefferson County, northeast of Birmingham (USGS 1959; Benke and Cushing 2005). Flowing approximately 191 miles from its headwaters to its confluence with the Alabama River southwest of Selma, Alabama (USGS 2010; USGS 2013a), the drainage area lies entirely within the state of Alabama and encompasses approximately 1,824 square miles including portions of St. Clair, Jefferson, Shelby, Bibb, Tuscaloosa, Perry, Chilton, and Dallas Counties (ADEM 2012a; CRBCWP undated). Although described as Alabama's longest free-flowing river, the Cahaba River technically contains the longest stretch of free-flowing river in Alabama (an approximately 150 mile stretch of free-flowing water from the Highway 280 diversion dam to the river's confluence with the Alabama River; see Section 5.4.2 - Hydrologic Alteration).

Elevation in the watershed ranges from 1,100 feet in Shelby County to 100 feet at the confluence with the Alabama River (CRBCWP undated). From its headwaters to the Fall Line the river descends approximately 200 meters (m) at a rate of 1.3 meters per kilometer (m/km). Stream channels in the headwaters are narrow and bedrock-boulder dominated and follow a rectangular drainage pattern as a result of faulting. Downstream of the headwaters, the river width increases and large shoals develop, but high sandstone bluffs constrain the channel and allow limited floodplain development. Farther downstream carbonate outcrops are present where the river has eroded through the younger, overlying Pottsville sandstone. As the river passes over the Fall Line into the Coastal Plain is average gradient declines to approximately 0.2 m/km, the bluffs diminish, the channel widens, and discharge increases as the river flows over unconsolidated alluvial sediments. The lower Cahaba River includes oxbow lakes, Black Belt chalk and prairie cliffs. The channel of the lower Cahaba River is wide (50 m or 164 ft) and deep (4 to 6 m or 13 to 20 ft) with shear banks. The upper basin is primarily precipitation fed, while the lower basin in the Coastal Plain receives substantial contributions of groundwater (Benke and Cushing 2005).

4.6 Anthropogenic Landscape Changes

Numerous landscape-level activities and actions have directly and indirectly influenced both water quantity and water quality within the Cahaba River basin and are discussed below. Specific research related to how these landscape changes have altered water quantity and water quality are discussed in Sections 5.4.3 and 5.5.4 of this report. Land cover analysis is discussed in Section 5.5.4.

<u>Cultural Resources</u>: The refuge and surrounding Cahaba River basin contain rugged terrain and the archaeological potential is limited primarily due to slope. In areas where the floodplains of the Cahaba River and its tributaries broaden out, the potential for Native American and historic period occupations increase dramatically. Quarries, lithic workshops, petroglyphs, and ephemeral resource extraction, exploitation, and processing camps represent the most probable types of Native American sites seen in the areas away from the floodplains and valleys. However, the potential for intact pre-Columbian archaeological sites is quite low primarily due to substantial ground disturbance associated with the early – mid 20th century coal mining operations and slope. Industrial sites and features associated with the 19th to 20th century commercial mining operations dominate much of the landscapes. These sites and features include mine shafts, foundations, and/or building ruins for mining-related operations and

quarters for mine workers, abandoned railroad grades, and/or roads. Section 106 of the National Historic Preservation Act of 1966, as amended, requires the Service to evaluate the effects of its actions on cultural resources (e.g., historic, architectural, and archaeological) that are listed or eligible for listing in the National Register of Historic Places (NRHP). Systematic cultural or historic resource surveys have not been conducted on the refuge. In the future, if the Service plans or permits any actions that might affect historic properties, appropriate site identifications, evaluations, and protection measures will be done as specified in the regulations and in Service directives and manuals.

Early Human Settlement: The Cahaba River basin has been important to human populations for thousands of years. The prehistory of the region dates the earliest documented appearance of humans in the area to 9000 B.C. (Walthall 1980). For a detailed summary of prehistoric cultural use of the area spanning the Paleo-Indian, Archaic, Gulf Formational, Woodland, and Mississippian stages, see Walthall (1980), Jenkins and Krause (1986) and Futato (1989).

Located adjacent to the Cahaba River basin, the Moundville Archaeological Site (1000-1450 A.D.) was the second largest community of the Mississippian culture, and the largest in Alabama. At its height, the Moundville community contained a population of about one thousand people, with around ten thousand in the entire valley (Hudson 1976; Walthall 1980; Knight 2013;). The Moundville community included a roughly 300-acre (121 hectares [ha]) residential and political area protected on three sides by a bastioned wooden palisade wall, with the remaining side protected by the river bluff (Dickens 1979; Walthall 1980; Knight 2013). In addition, archaeologists have found evidence of borrow pits, other public buildings, and dozens of small houses constructed of pole and thatch, many of which have yielded burials beneath the floors (Knight 2010). Based on findings during excavations, the residents at Moundville were skilled in agriculture (especially the intensive cultivation of maize), and had considerable imported luxury goods including copper, mica, galena, and marine shell (Hudson 1976; Dickens 1979; Walthall 1980; Knight 2010). As summarized by Knight (2013), neither the rise of Moundville nor its eventual decline is well understood. The immediate area appears to have been thickly populated and heavily used through about A.D. 1200, but by around A.D. 1350, Moundville shifted to more intermittent use for ceremonial and political functions. A decline ensued that included abandonment of some mounds, the loss of religious importance in others, and a decline in the importation of goods. By the 1500s, most of the area was abandoned with only a few portions of the site still occupied. The precise ethnic and linguistic links between Moundville's inhabitants and what became the historic Native American tribes are still not well understood.

The refuge is located within lands formerly part of the Creek Indian Nation, and adjacent to lands formerly part of the Choctaw Indian Nation (USFWS 2007). Prior to 1814, Choctaw lands were located a short distance west of the Cahaba River, whereas permanent Creek settlements existed along the east bank of the Cahaba and within the Coosa and Tallapoosa basins (USFWS 2007). Lands west of the Cahaba River provided a buffer between the two Indian Nations, and were used primarily for hunting (USFWS 2007). Throughout the area, small openings in the woodlands were typically cleared to cultivate crops in and around the village sites (Ellison 1984). In 1814, following battles with U.S. Military Forces led by Andrew Jackson, the Treaty of Fort Jackson forced the cessation of all Creek lands west of the Coosa River and the relocation of Indians inhabiting those areas to lands east of the Coosa River (Ellison 1984; Satz 2002; USFWS 2007). Following the treaty, settlers began moving into the area and first inhabiting the areas previously cleared by the Creeks. Cahaba County (now Bibb County) was established in 1818 and early settlement in the 1820s was concentrated in northern Bibb County along Caffee Creek, the Little Cahaba River and Mahan Creek (USFWS 2007). The Cahaba River ends at the former town of Cahaba, which served as Alabama's first seat of government from 1820 to 1825 (CRS 1998).

Ironworks: Iron was a major industry in the Cahaba River basin, and within Alabama. From 1815 through the Civil War, small stone-jacketed blast furnaces and facilities fueled primarily with charcoal were established across Bibb county, with some of the larger ones (e.g., Brierfield Iron Works and Brighthope) along the Little Cahaba River and Mahan Creek (Bennett 1999; AHIC 2006). The Tannehill Ironworks (originally the Roupes Valley Iron Company) was located on the edge of Bibb and Jefferson counties along Roupes Creek, a tributary to the Cahaba River. Additional stone blast furnaces and facilities within the Cahaba basin included Irondale, and Oxmoor, located in Jefferson County (Bennett 1999; AHIC 2006). Furnaces supplied "pig iron" to various foundries where they were transformed into finished products including ordinance and other Civil War munitions, armaments and supplies, as well as farming machinery, customized castings, railroad products and household goods (Bennett 1999; AHIC 2006; Armes 2011). Many of the smaller furnaces in the area were destroyed during the Civil War, although some (Brierfield) were rebuilt. By the early 1890s, the iron industry had almost disappeared from the county as production moved to Birmingham – the South's leading producer of iron at the turn of the century (Ellison 1984; Bennett 1999; USFWS 2007); the Brierfield Iron Works closed in 1894 (AHIC 2006).

In the decades after the Civil War, Alabama became one of the nation's leading iron and steel producers and the Birmingham District became the largest iron and steel producer in the southern United States (Lewis 1975; White 1981; AHIC 2006). The proximity of essential raw materials (iron ore, coal, limestone and dolomite) to production facilities afforded Birmingham the lowest raw-material assembly costs in the United States (Bergstresser 1993). At the beginning of the 20th century, there was large-scale consolidation within the American iron and steel industry and steel production increased with the rise of merchant foundry iron plants. By the 1920s, Birmingham produced one fourth of the nation's foundry iron (White 1981). In the latter half of the twentieth century, Birmingham's iron and steel industry began a decline that continues today. Air quality requirements, foreign competition, and the rise of ductile iron made from scrap forced the shutdown of foundry iron furnaces and their coal and ore mines in the early 1970s, although Birmingham remains an important steel producer (Lewis 1975; White 1981).

Coal Mining: Coal has been mined commercially in 21 northern Alabama counties for more than 150 years. Ranking 14th in the United States, Alabama routinely produces over 20 million short tons of coal each year. About two-thirds of Alabama's coal is mined in deep underground mines, with the remainder coming from surface mines (GSA 2006b). Currently, the Geological Survey of Alabama (GSA) is digitizing more than 300 maps of current and historic coal mining activities and underground coal mines within the Region of Hydrologic Influence in the Cahaba River basin (Richard Carroll, personal communication). A directory of underground coal mines in Alabama was published in 1986 by GSA (DeJarnette 1986).

The first coal was mined from Alabama in 1827, with coal mining operations in the Cahaba watershed occurring prior to and during the Civil War in the towns and mines later known as Piper and Coleanor (Bennett 1999; USFWS 2012a). One of the earliest mining operations in Alabama mined coal from what came to be known as the Cahaba Coal Field, as did some of the earliest underground mining which occurred in the area around 1856 (DeJarnette 1986; Bennett 1999; USFWS 2012a). Located in the Cahaba watershed, the Cahaba Coal Field covers approximately 360 square miles including parts of Bibb, Jefferson, Shelby, and St. Clair Counties (DeJarnette 1986). A very detailed analysis of the stratigraphy, physical and chemical characteristics, and estimates of coal reserves in the Cahaba Coal Field is provided by Culbertson (1964). The geology of the Cahaba Coal Field was described in an 1890 monograph by Joseph Squire (Squire 1890a; Squire 1890b).

Systematic underground mining techniques, along with the demand for large quantities of coal to supply the Confederate war effort during the Civil War substantially increased coal production in the area (DeJarnette 1986). Coal was mined for the Confederacy within refuge boundaries; this operation eventually developed into the Piper coal mines. Although the demand for coal declined after the Civil

War, the Bibb County coal industry was rekindled by the expansion of the railroad systems in Alabama and the Southeast, and the growing demand for coke by the Birmingham steel industry. By 1876, underground coal mining had dramatically increased (Bennett 1999; DeJarnette 1986). By 1890, there were seven mines and a coke oven in the Blocton area (USFWS 2007; USFWS 2012a). Additionally, significant quantities of local timber were required, estimated at half a cubic foot of timber for every ton of coal (Mohr 1901; Harper 1943; USFWS 2007). The coal mining towns of Piper and Coleanor were established in 1901 along the northeastern edge of the refuge, with portions of these towns and the Piper mines within current refuge boundaries (Walker 1993; USFWS 2007; USFWS 2012a). Three abandoned underground mines (Piper I, II and III), dating from 1900 to 1930, historically existed within the refuge. Attempts were made to mine the coal seam between 1930 and 1960, and again in the 1980s. Remnants of the mining activities on the refuge include portions of the Piper and Coleanor mining towns, a gob pile (pile of accumulated spoil), two ponds, an abandoned tipple (building where mine cars were tipped and emptied of coal), one sediment basin that has been breached (QORE, Inc. 2004; USFWS 2007) and remnant highwalls. A highwall is the working face of a surface mine or quarry, especially of an open-pit coal mine (Neuendorf et al. 2005).

The Abandoned Mine Lands (AML) Program, in coordination with the refuge, is currently conducting a reclamation project for the Piper II mine. The project will be conducted in two phases beginning in 2013. The first phase will reclaim approximately 35 acres by using onsite spoil material to backfill a portion of the highwall (Appendix C). The last remaining sections of highwall (65 acres) will be reclaimed in the second phase. During Phase II, the exposed mine portal will be closed to restore the hydrology of a nearby stream and eliminate leaching of arsenic and strontium (Sarah Clardy, personal communication; Appendix C). In total, the Piper II Reclamation Project will reclaim 100 acres of land. Additionally, the Jesse Creek Mining LLC (formerly Talcoa Minerals LLC) Piper I Mine was in reclamation as of February 2012 (ADEM 2012c). Additional discussion about mining and associated land use alterations can be found in Section 5.3 (Water Monitoring) of this report.

Forestry: The lumber industry was stimulated by the construction of the Alabama and Chattanooga Railroad (later known as the Southern Railway). Several sawmills were in operation in northern Bibb County by the 1870s, and in 1918 four sawmills were operated in the area by W.E. Belcher (Ellison 1984; USFWS 2007). In more recent years, what is now the refuge was owned by industrial timber companies that converted longleaf pine forest into extensive loblolly pine plantations. Today, approximately 60% of the refuge is composed of pine plantations and clear-cuts, 30% is hardwood and hardwood-mixed pine forest, 5% is natural longleaf pine forest and the remaining 5% is riverine (USFWS 2007). These areas are being managed to restore longleaf pine over the long-term with many techniques including prescribed fire (Sarah Clardy, personal communication). Plans are also underway to thin existing loblolly pine stands and to plant longleaf seedlings within these thinned stands. Maintaining habitat integrity while converting loblolly stands to longleaf is a long-term habitat management goal for the refuge, albeit one with the noted difficulty of providing consistently reliable prescribed fire management (Sarah Clardy, personal communication).

Refuge: Cahaba River National Wildlife Refuge was established in 2002. As of June 2013, the refuge is currently unstaffed and administered through the Mountain Longleaf National Wildlife Refuge headquarters in Anniston, Alabama. Most of the refuge is closed to motorized vehicles and open to foot traffic only. The refuge maintains a parking area, a two-mile section of road, canoe launch facilities, and several miles of trails. Portable toilets are provided on a temporary basis for larger-scale special events occurring at the refuge. Aside from recreation, the major land use activities occurring within the refuge include coal mine reclamation activities and forest habitat management as described in the habitat management plan for the refuge (USFWS 2007).

Recent Land Use Change: Multiple iterations of GIS land change analysis for the Cahaba River watershed (both the upper and lower watersheds, and combinations of one or the other) have been completed by multiple agencies for various purposes (see Howard et al. 2002; ADEM 2004; El-Kaddah and Carey 2004; ADEM 2006b; Buell 2011; ADEM 2012a; ADEM 2012b). Overall, the various land use summaries and analyses show and increase in the extent of urban and “disturbed” areas in the central and upper part of the Cahaba River basin, with increased development in general within the basin (“disturbed” land use includes residential, commercial, industrial, transportation, and bare ground).

Specifically, Howard et al. (2002) examined the change in land use classes over an 8-year period (1990 to 1998) for the entire Cahaba River basin, and noted dramatic increases in the “disturbed” land use class. As of 1998, over 38% of the watershed was in classified into the “disturbed’ land use class; up from 8.8% in 1990. Land use analysis of Buck Creek, a major tributary to the Cahaba River, indicated that over 63% of that watershed fell into the “disturbed” land use class. The “disturbed” land use class here includes residential, commercial, industrial, transportation, and bare ground. The “undisturbed” land use class is basically forested lands and grasslands.

The Alabama Department of Environmental Management (ADEM) (2004) summarized land use for the entire Cahaba River basin based on 7 categories (Open Water, Urban, Mines, Forest, Pasture, Row Crops, Other). The analysis was completed at the subwatershed level for 17 subwatersheds. Values were based on Soil and Water Conservation District (SWCD) Conservation Assessment Worksheet land use estimates (ASWCC 1998). Results for the Cahaba River basin showed 65% Forest, 3% Row Crop, 13% Pasture, 1% Mining, 15% Urban, 1% Open Water, and 2% Other.

Buell (2011) conducted land cover change analysis for the Cahaba River basin based on NLCD land cover data from 1992 to 2001, using the Land Cover Change Retrofit product (MRLC). Fifteen separate land cover classes were delineated for both the U.S. Geological Survey (USGS) 10-digit and 12-digit hydrologic units in the Cahaba basin, although land cover change was calculated for 7 classes (Water, Urban, Barren, Forest, Grassland, Agriculture, Wetland). The headwaters, upper, and lower Cahaba River subwatersheds (10-digit HUCs) experienced significant increases in developed land use as well as significant decreases in the percent cover for mixed forest (50% to 90%).

ADEM (2012a) assessed land use change for the Upper Cahaba subwatershed based on 2006 National Land Cover Database (NLCD) land cover data, using 20 land cover classes. Overall trends show developed urban areas are concentrated in the central and upper part of the subwatershed, while the lower part is dominated by rural forested landscapes. Agricultural lands and cultivated crops are not prominent land use types in the Upper Cahaba River Watershed. Urban areas include Birmingham, AL and areas in southern Jefferson County and northern Shelby County are some of the fastest growing areas in the state.

Land use change, especially the increase in impervious and disturbed lands within the watershed, can result in altered hydrologic regimes, increased storm-generated runoff laden with sediments and/or nutrients, and represents potential impacts to water quantity, quality and ecosystem integrity of the river systems (Welch 1992; Waters 1995). The impact on the Cahaba River from changing land use (mainly urbanization) is discussed in Section 5.4 (Water Quantity) and Section 5.5 (Water Quality).

4.7 Climate

4.7.1 Historical Climate

Climatic information presented in this WRIA comes from the U.S. Historical Climatology Network (USHCN) of monitoring sites maintained by the National Weather Service (NWS) (Menne et al. undated), additional NWS weather stations (Weather Warehouse undated), and the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping service, which is the U.S. Department of Agriculture's (USDA) official source of climatological data (PRISM 2010). The period of record for the USHCN data is 1895-2010, while the PRISM data represent 1971-2000 climatological normals. The closest USHCN station is located in Selma, AL, approximately 50 miles south of the refuge. The NWS currently maintains stations located in West Blocton and Brent, AL, approximately 6 miles northwest and 25 miles southwest of the refuge, respectively (Figure 15 – labeled as Atmospheric Monitoring Sites in blue). The NWS maintained a weather station at Centreville from 12/15/1916 to 11/30/1974 that was moved in 1974 to its present location in Brent. The Brent NWS station has been operational from 12/1/1974 through present, and is also known as the Centreville WSMO (Weather Service Meteorological Observatory). Data from Centreville and Brent are presented together in this report. For the PRISM location, a central point within the refuge was selected (32.997434, -79.593201) and used to access the PRISM Data Explorer (http://prismmap.nacse.org/nn/).

Temperature: Mean monthly temperatures for Centreville/Brent range from approximately 45°F (7.2°C) in January to 80°F (26.7°C) in July and August (Figure 7). Mean monthly temperatures exhibit the greatest year-to-year variability in fall through early spring (October through March) and the least variability in the spring and summer (April through August). The PRISM dataset shows average minimum and maximum daily temperatures in the vicinity of the refuge ranging from approximately 32°F (0°C) in January to 91.5°F (33.1°C) in July with a relatively uniform average monthly temperature range (22-27°F) throughout the year (Table 4). Average daily maximum, mean, and minimum temperature by water year (1895 – 2010) at Selma, AL (USHCN Station 017366; Menne et al. undated) show no apparent trends in average daily mean or minimum temperatures over the period of record. However, there appears to have been a relatively abrupt 2-3 °F decrease in average daily maximum temperatures beginning around 1939 (Figure 8).

Precipitation: Precipitation amounts and patterns in Alabama are affected to a large degree by the Gulf of Mexico and the Appalachian Mountains, with annual precipitation of about 55 inches statewide, ranging from about 50 inches in central and west-central Alabama to about 65 inches near the Gulf of Mexico (USGS 1991). Seasonal rainfall patterns result in more than one-half of the average rainfall between December and May except on the Gulf Coast.

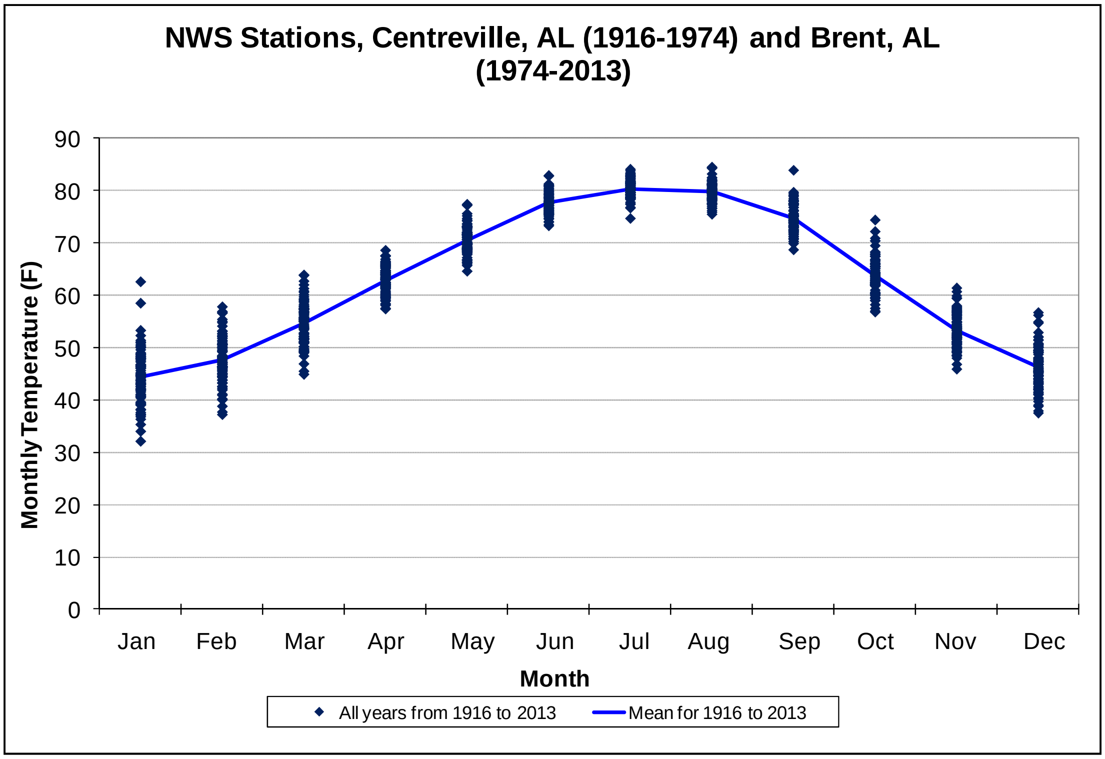


Figure 7. Mean and distribution of monthly temperature for 1916 – 2013 for NWS Stations at Centreville and Brent, AL. [Source: Weather Warehouse undated].

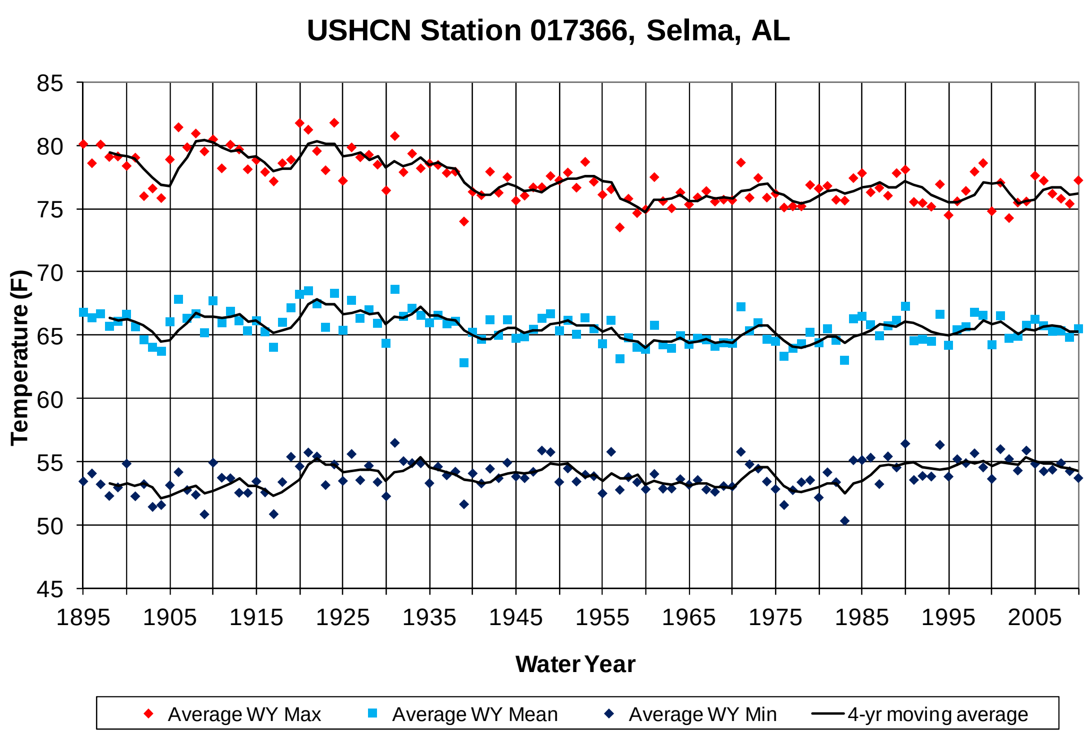


Figure 8. Average daily maximum, mean, and minimum temperature by water year (1895 – 2010) at Selma, AL (USHCN Station 017366). [Source: Menne et al. undated].

Table 4. PRISM Monthly Normals (1971-2000) for precipitation and maximum and minimum temperature at Cahaba NWR. [Source: PRISM 2010].

Month	Precipitation (Inches)	Max Temp (° F)	Min Temp (° F)	Range (Max-Min)
January	6.31	54.16	32.38	21.78
February	5.21	59.56	35.33	24.23
March	6.63	67.78	42.39	25.39
April	4.99	75.25	48.51	26.74
May	4.69	82.04	57.65	24.39
June	4.43	88.66	65.28	23.38
July	5.15	91.54	69.17	22.37
August	3.51	90.79	68.11	22.68
September	4.44	85.82	62.22	23.6
October	3.49	76.23	49.93	26.3
November	4.89	65.93	41.38	24.55
December	5.05	57.24	34.99	22.25
Total Precipitation	**58.79**			
Mean Temperature		**74.59**	**50.61**	

1971-2000 Normals for -79.593201, 32.997434. Downloaded 4/9/2012 from http://prismmap.nacse.org/nn/. Copyright 2010. PRISM Climate Group, Oregon State University.

Precipitation (cont.): Mean monthly precipitation (from PRISM dataset) varies between about 3.5 to 6.6 inches (8.9 to 16.8 cm), with the least rain falling in August and October and the most occurring in January and March (Table 4). Precipitation data from the NWS station at Centreville/Brent shows relatively uniform monthly rainfall totals throughout the year, although the months of May, September, and October generally have slightly lower precipitation amounts and exhibit slightly less year-to-year variability in precipitation that in other months (Figure 9).

Figure 10 shows the total annual precipitation by water year (1895 - 2010) at Selma, AL (USHCN Station 017366; Menne et al. undated). For the period of record, data suggest the late 1910s, mid- to late 1940s, late 1960s to early 1980s and early 2000s were periods of above average precipitation. The late 1920s, mid-1950s and mid-1980s show periods of below average precipitation. For the period of record, no obvious increasing or decreasing trends are seen, based on the total annual precipitation.

Snowfall has been recorded at the West Blocton and Centreville/Brent stations in January through March and December through April, respectively. Snowfall has been recorded in December through April (with the exception of March) at the USHCN station in Selma (SERCC 2013).

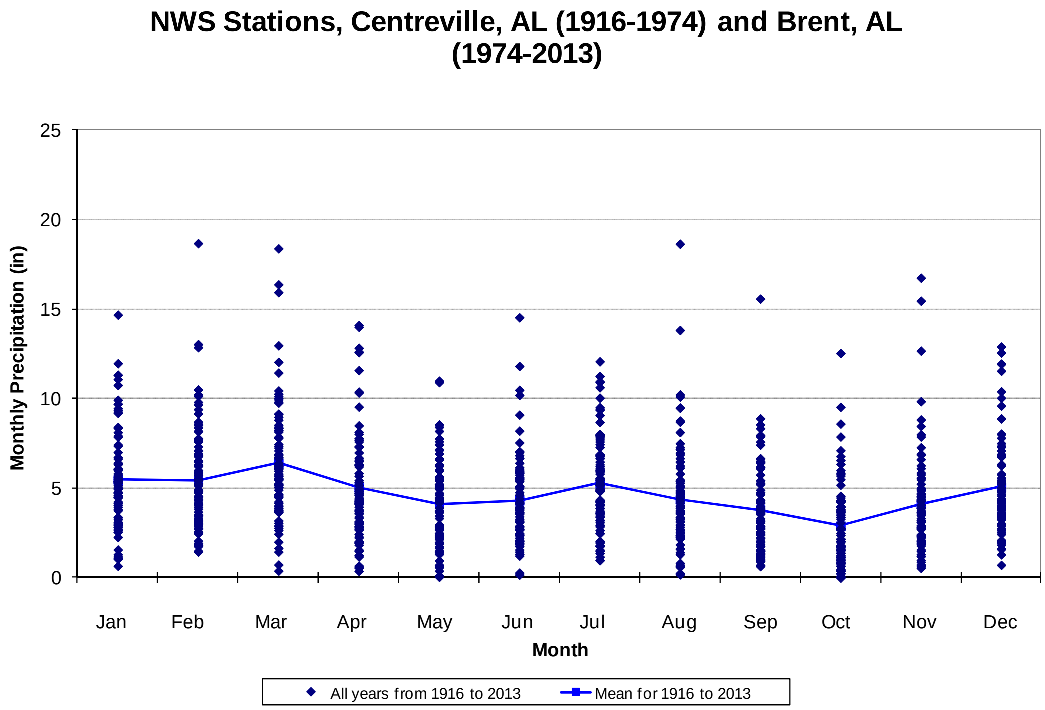


Figure 9. Mean and distribution of monthly precipitation (1916 – 2013) at Centreville and Brent, AL. [Source: Weather Warehouse undated].

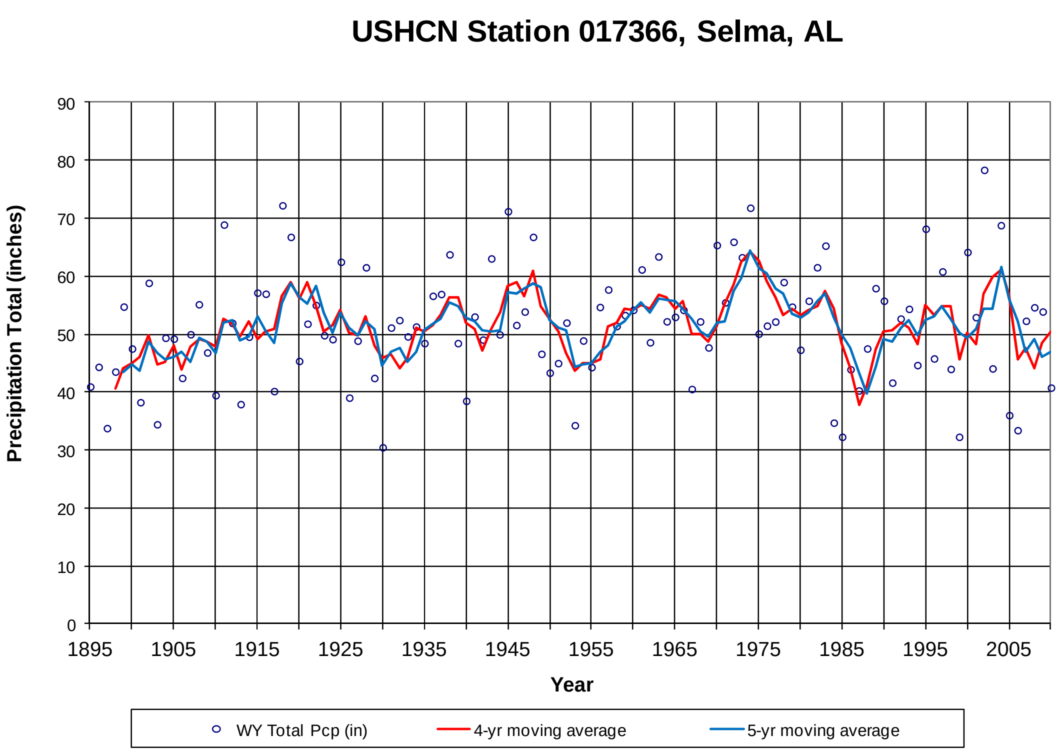


Figure 10. Total annual precipitation by water year (1895 – 2010) at Selma, AL (USHCN Station 017366). [Source: Menne et al. undated].

Streamflow: Within the Cahaba Basin, streamflow is linked to precipitation, as well as upstream surface water flows and groundwater contributions. Information related to water quantity conditions within the Cahaba River is presented in the water quantity section later in this document (Section 5.4). General trends for the Cahaba River, based on the USGS gage at Centreville, AL (02424000) are summarized for the period of record in Figure 11 and

Figure **12**. Average monthly discharge is highest between January and April, with the lowest flow conditions of the year on average occurring in June through November (Figure 11,

Figure **12**). Periods of predominantly above average streamflow occurred in 1936-1949 and 1973-1984 with periods with predominantly below average streamflow include occurring between 1952-1960, 1965-1970, 1985-1988, and 1999-2002 (

Figure **12**). Further analysis of streamflow data and drought by USGS (1991) confirms these trends through the mid-1980s (see below).

Drought Conditions: Persistent drought conditions occur occasionally within the Cahaba Basin, primarily in May and October (CRBCWP undated), with serious impacts (GSA 1986). State-wide, Alabama has had five major droughts since streamflow recordkeeping began: 1929-32, 1938-45, 1950-63, 1980-82, and 1984-88 (USGS 1991). These droughts all lasted more than one year and had substantial adverse effects on agriculture and industry, although the severity and extent of the droughts differed across Alabama (USGS 1991). The streamflow record on the Cahaba River at Centreville, AL (USGS Gage 02424000) shows annual flow dropped below the long-term average during these droughts (USGS 1991; Figure 11**;**

Figure **12**). Depressed streamflow in the Cahaba River at Centreville for 1999-2002 and 2006-2008 reflect more recent drought periods.

Included in the sustained drought of 1950-63 was a severe drought during 1954-55. In terms of extent and severity, 1954 was an extreme drought year. The annual departure graphs presented in USGS (1991) including the gage on the Cahaba River at Centreville, AL show a generally negative departure from 1950 to 1955 (USGS 1991; Figure **11**;

Figure **12**). The drought of 1950-63 had a recurrence interval of 44-60 years for gaging stations in the Mobile River basin (USGS 1991). The drought of 1980-82 affected most of Alabama and had recurrence intervals of 10-25 years. Greater than average rainfall during 1983 resulted in recoveries in streamflow until about mid-1984 when significant negative annual departures were again noted that continued through 1988. The drought of 1984-88 affected the entire state to some degree; maximum rainfall deficiencies in east-central Alabama ranged from 21.1 to 25.3 inches during 1986 (NOAA 1986;

Figure **12**). Similar rainfall deficiencies were reported for 1987. Emergency water measures and restricted reservoir releases were implemented, and crop losses during 1986 were significant (approximately $500 million) (USGS 1991). More recent droughts have occurred between 1999 – 2002, and 2006-2008, showing lower streamflows than those in 1954 (

Figure **12**).

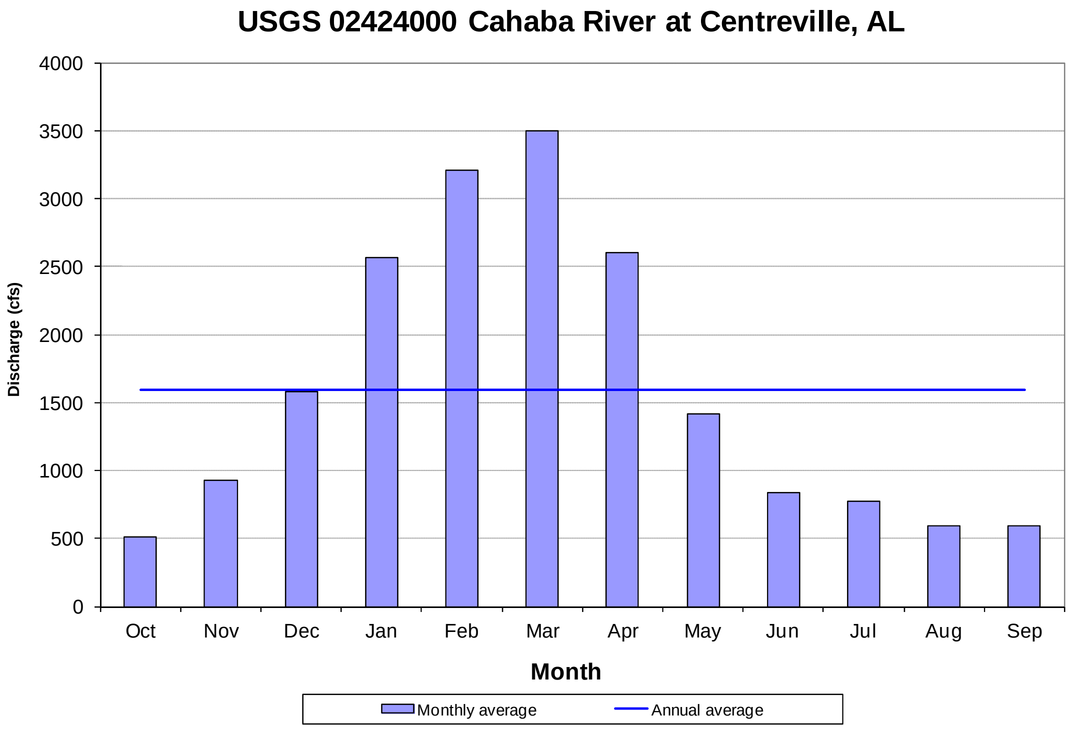


Figure 11. Average monthly discharge from the Cahaba River near Centreville, AL. From data collected between 1901– 2011. [Source: USGS 2013a].

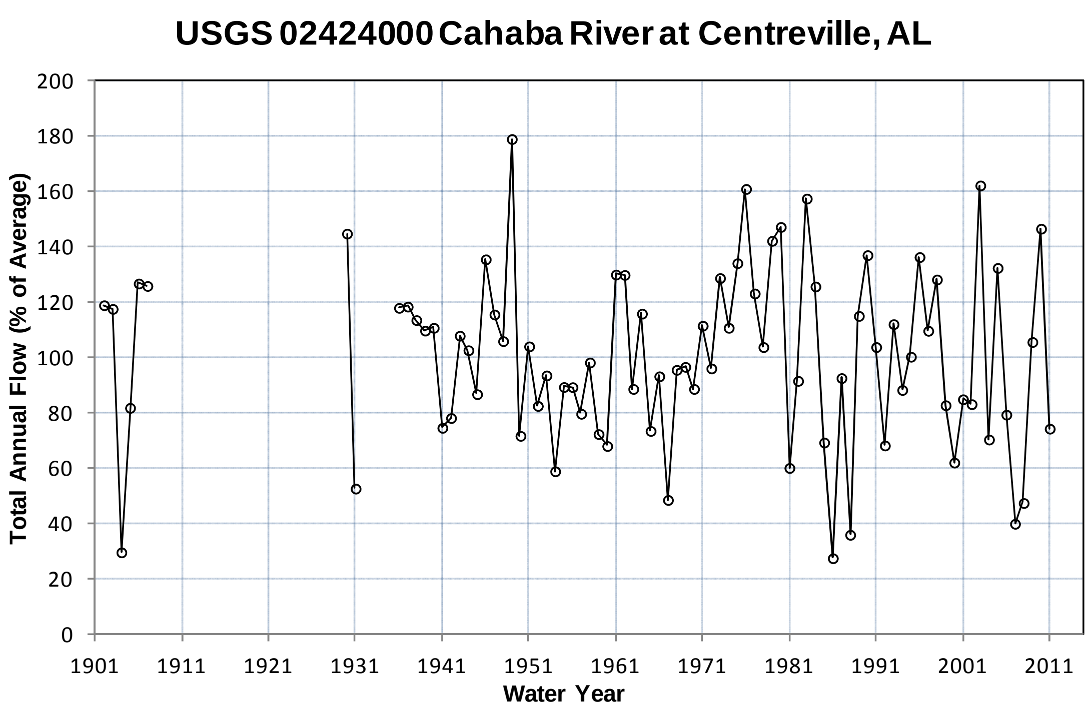


Figure 12. Percent of average annual flow on Cahaba River near Centreville, AL: 1901-2011. Average annual flow from the period of record is 1,594 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013a].

Storm Frequency and Intensity: Flood-producing rains in Alabama are associated with frontal systems (annually in November – April) and tropical storms (July – November) (USGS 1991). Frontal systems usually produce steady rainfall over large areas. Major flooding in Alabama has been produced by rains associated with broad cyclonic storms embedded in frontal systems (USGS 1991). Tropical storms are less frequent but produce torrential rains when movement is inland from the Gulf of Mexico. Flood producing storms within the Cahaba River basin usually occur from frontal systems in the winter and spring months (most often in March). Approximately 30% of significant river floods in the Cahaba basin result from tropical storms (USGS 1991; SERFC 2009; CRBCWP undated). The magnitude and frequency of floods within Alabama (including analysis of floods in the Cahaba basin) are provided in multiple studies since 1954, and were updated using data through September 1991 in Atkins (1996). An overall discussion examining both flood and drought in Alabama is provided in USGS (1991).

Central Alabama is also characterized by occasional tornado activity within the Cahaba River basin, with the greatest number of tornados occurring in spring (March to May) and November (SERCC undated). Tornado strength is rated based on estimated 3-second gust wind speed according to the Enhanced Fujita (EF) scale, ranging from EF-0 (65-85 mph) to EF-5 (>200 mph) (NOAA undated). Strong (EF-2-3) and violent (EF-4-5) tornadoes occur most frequently across Alabama, Mississippi, Arkansas, and Louisiana (SERCC undated). There has been an upward trend in the frequency of weak tornadoes since 1950s, most likely due to improvements in storm detection and population growth (SERCC undated). April 2011 ranked as the most active tornado month on record across six southeastern states including Alabama, and was also the deadliest tornado month on record across Alabama and Georgia (SERCC undated).

4.7.2 Climate Change Projections

The U.S. Global Change Research Program's 2009 report Global Climate Change Impacts in the United States (Karl et al. 2009) synthesized a large body of scientific information and numerous peer-reviewed scientific assessments globally and regionally for various parameters including water resources. Climate models project continued warming in the southeastern United States, and an increase in the rate of warming through 2100. The projected rates of warming are more than double those experienced since 1975, with the greatest temperature increases projected to occur in the summer. By 2080, projected mean temperature increases relative to a 1961-1979 baseline range from about 4.5°F under a low CO_2 emissions scenario to 9°F (10.5°F in summer) under a higher CO_2 emissions scenario.

Although the specific impacts climate change will have on the Cahaba River system are not known, climate change is likely to magnify the influences of other identified threats and challenges (Scott et al. 2008) currently impacting the system. Based upon information contained within the Report by the Climate Change Science Program (CCSP 2008), it is anticipated that temperatures within the southeast will increase and fire severity will increase 10 to 30% within the next 50 years. Based on an interpretation of Wigley (1999), Davenport (2007) projects the northern half of Alabama will experience the most significant warming within the state, and will experience a slightly drier winter and summer, a slightly wetter spring, and a significantly wetter fall. Despite predictions of an overall increase in precipitation, higher temperatures will cause greater evaporation which, combined with the expected increase in severity of storm events, will lead to less water absorbed, retained and available for use for natural systems, businesses and the public. Increases in temperature would also increase water temperatures, placing additional stress on the system. These anticipated climate effects could dramatically alter the aquatic and terrestrial ecosystems of the Cahaba River Basin. Any change that exacerbates the current instream flow or other water quality and water quantity challenges within the Cahaba River system would make recovery and management of federal trust resources, including the multiple federally listed aquatic species within the system, more difficult.

Temperature: The southeast U.S. did not exhibit an overall warming trend in surface temperature over the 20th century (IPCC 2007). As summarized in NOAA (2013), annual and seasonal temperatures across the region exhibited much variability over the first half of the 20th century, although most years were above the long-term average. This was followed by a cooling period in the 1960s and 1970s. Since then, temperatures have steadily increased, with the most recent decade (2001 to 2010) being the warmest on record. The recent increase in temperature is most pronounced during the summer season, particularly along the Gulf and Atlantic coasts, while winter season temperatures have generally cooled over the same areas. The frequency of maximum temperatures exceeding 95°F has been declining across much of the Southeast since the early 20th century; however there has been an upward trend over the last three decades, particularly across the northern Gulf Coast. The frequency of minimum temperatures exceeding 75°F has generally been increasing across most of the Southeast, although DeGaetano and Allen (2002) have attributed this trend to increasing urbanization.

As noted by Karl et al. (2009), CCSP (2008), and NOAA (2013), temperature projections for the Southeast show an average increase in the near-term (present day to 2040) of about 2°F, with a range of 1.3°F and 3.6°F for the high and low emissions scenarios. In the mid-century (2040-2070), the increase in annual mean temperature is projected to be approximately 3.2 to 4.0°F, with a range of 1.6 to 5.4°F based on the high and low emissions scenarios. By the end of the century (2070-2099), annual mean temperature in the Southeast is projected to increase by 4.5 to 7.8°F, with a range of 2.5 to 9.6°F. Projected seasonal mean temperatures are expected to increase, although the mean temperature for the summer months is projected to experience the greatest increase in warming of all the seasons. In addition, the number of extreme heat days (a combination of heat and humidity, typically consecutive days over 95°F) is expected to increase.

Precipitation: Inter-annual variability in precipitation has increased over the last several decades across much of the Southeast, with more exceptionally wet and dry summers observed as compared to the middle part of the 20th century (Groisman and Knight 2008; Wang et al. 2010; NOAA 2013). This precipitation variability is related to the mean positioning of the Bermuda High, a semi-permanent high pressure system typically situated off of the Atlantic Coast (NOAA 2013).

As summarized by Karl et al. (2009), CCSP (2008), and NOAA (2013), changes in annual precipitation for the Southeast do not exhibit any strong trends, although projections for the near-term (present day to 2040) show notable seasonal variations, with a decrease in precipitation during summer months, and an increase in the fall (1-2%). It should be noted that there is considerable disagreement between the various climate models on the magnitude and direction of changes in precipitation, and that none of the CMIP3 (Coupled Model Intercomparison Project phase 3) climate models reproduced the observed 30% increase in decadal mean fall precipitation (relative to a 1901-1960 average) in the Southeast (NOAA 2013: Figure 46; Karl et al. 2009). For future time periods (2021-2050; 2040-2070; 2070-2099) for both low (B1) and high (A2) emissions scenarios simulate both increases and decreases in annual mean precipitation. The inter-model range of changes in precipitation (i.e., the difference between the highest and lowest model values) varies from 14% to 34% (NOAA 2013).

In the mid-century (2040-2070), the greatest seasonal mean change in precipitation is projected to occur in winter months, with the mean ranging from an increase of 1% to a decrease of 2%. By the end of the century (2070-2099), the largest seasonal mean decrease of precipitation is projected to occur during the summer season, with a mean decrease of about 0 to 8% (FHA 2012). Gulf Coast states are also projected to have less rainfall in winter and spring, compared with more northern states in the Southeast (Karl et al. 2009).

Storm Severity: The frequency of extreme precipitation events has been increasing across the Southeast, particularly over the past two decades (NOAA 2013). This trend in more intense precipitation events is also seen in other places around the world (IPCC 2007), and may be tied to a warming atmosphere which has a greater capacity to hold water vapor, therefore producing higher rates of precipitation (NOAA 2013). The increase in extreme precipitation, coupled with increase runoff due to the expansion of impervious surfaces and urbanization, has led to an increased risk of flooding in urban areas of the region (Shepherd et al. 2011; NOAA 2013). Across the Southeast, for all regional climate model simulations and emissions scenarios, the average annual number of days with precipitation exceeding 1 inch increases, with the largest increases across the Appalachian Mountains (NOAA 2013).

Increases in storm severity will exacerbate existing problems caused by run off from developed areas within Birmingham (USFWS 2009b). Increased run off leads to unnaturally high peak flows and velocities, decreasing the stability of the sand and gravel substrates that many species of mussels and fish depend on. Any additional increases in run off from a climate change-based increase in storm severity would cause additional scouring and river bank deterioration, along with impacts from nonpoint source pollution and sedimentation.

5 Inventory Summary and Discussion

5.1 Water Resources

This section briefly summarizes and discusses important aspects of the water resources inventory (both surface water and groundwater) for Cahaba River National Wildlife Refuge, including important physical water resources, water resources related infrastructure and monitoring, water quantity, and water quality conditions. Links to additional information including streamflow and groundwater data and relevant water resource reports for the Cahaba watershed (HUC 03150202) are available at the USGS website: http://water.usgs.gov/lookup/getwatershed?03150202.

5.1.1 Rivers/Streams/Creeks

The Region of Hydrologic Influence (RHI) for the Cahaba River NWR includes a total of 2,089.2 miles of named and unnamed streams (Table 5, Figure 13). Major tributaries within the RHI include the Little Cahaba River in Shelby County, which joins the Cahaba below Lake Purdy in the headwaters of the basin southeast of Birmingham; Shades Creek, which enters the Cahaba from the northwest a few miles north of the refuge acquisition boundary; and Little Cahaba River in Bibb County, which joins the Cahaba near the southern acquisition boundary of the refuge (Figure 13). Within the refuge acquisition boundary, there are eight named creeks and rivers, totaling 17.6 miles, as well as 15 miles of unnamed streams (Table 6; Figure 13). The Cahaba River flows through the refuge acquisition boundary for 8.3 miles, varying from 125 to 250 feet in width and in depth from a few inches (shoals) to almost 10 feet (pools). The Little Cahaba River flows through the southern boundary of the refuge. It drains nearly 265 square miles and has an average width of 50 to 75 feet (USFWS 2007). Caffee Creek, the next largest tributary stream, enters the Cahaba from the west near the middle of existing refuge lands ("acquired boundary" in Figure 13) and averages 25 feet wide and less than a foot in depth.

Table 5. Miles of named and unnamed streams within the Region of Hydrologic Influence for Cahaba River NWR. [Source: USGS 2010].

Category	Miles within RHI
Named Streams	680.3
Unnamed Streams	1408.9
Total	***2089.2***

Table 6. Named creeks and streams with mileage inside the Cahaba River NWR acquisition boundary (see Figure 13 for locations). [Source: USGS 2010].

Stream Name	Miles on Refuge	Miles within Acquisition Boundary
Bear Branch	0.3	0.3
Big Ugly Creek	0.0	1.1
Caffee Creek	1.6	1.6
Cahaba River	5.0	8.3
Little Cahaba River	1.2	2.9
Little Ugly Creek	0.9	0.9
Pine Island Creek	1.1	1.6
Pratt Creek	0.0	0.9
Unnamed Streams	9.7	15.0
Total	***19.8***	***32.6***

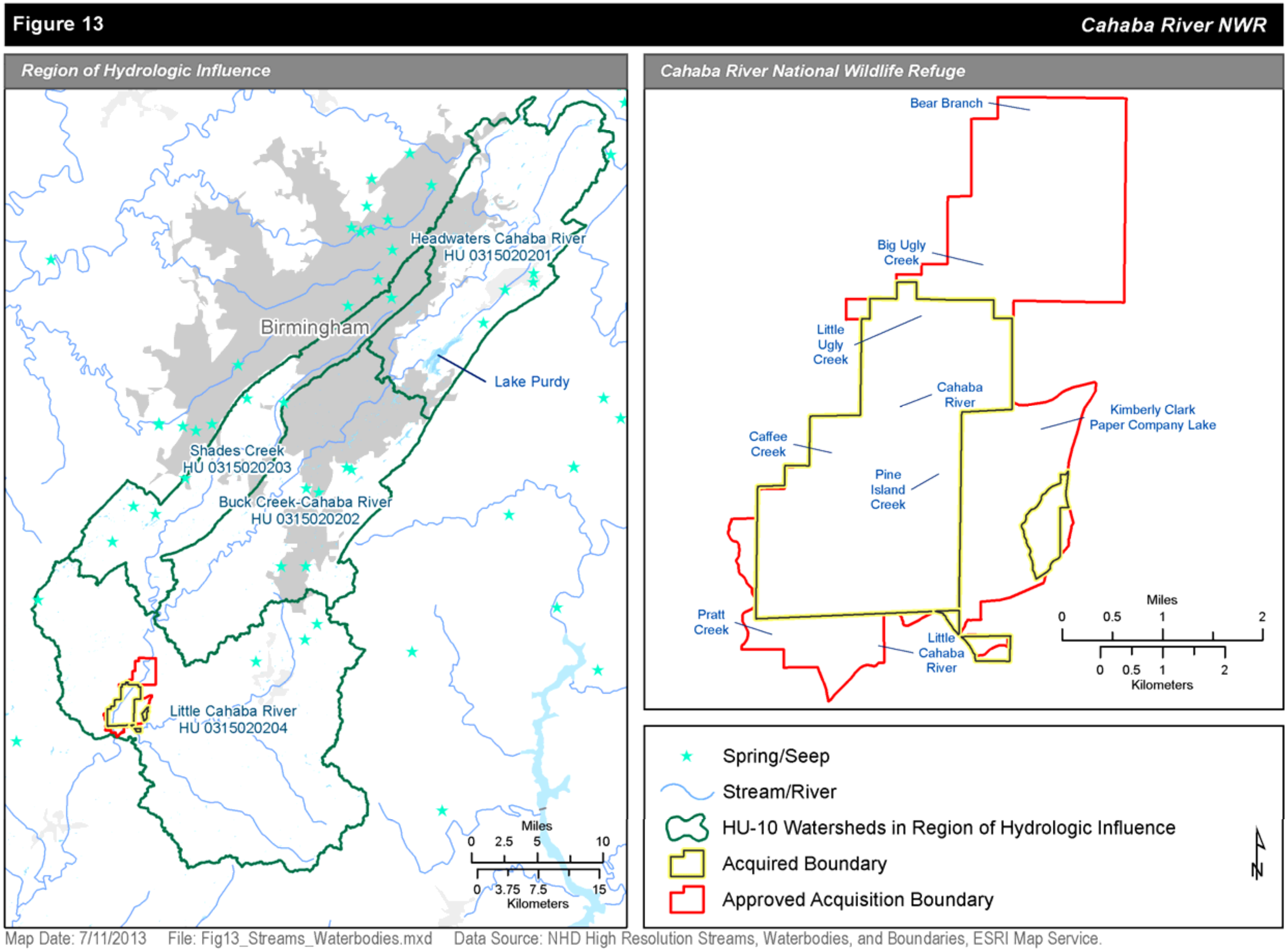


Figure 13. Region of Hydrologic Influence and named creeks and streams within the Cahaba River NWR acquisition boundaries.

5.1.2 Lakes/Ponds

Within the RHI there are 92 named lakes and ponds (2,609 acres) and 140 unnamed lakes and ponds (183 acres). There are 0.9 acres of lakes and ponds within the acquired lands boundary of the refuge (dated April 2013), and 8.9 acres within the acquisition boundary, including the Kimberly Clark Paper Company Lake.

Lake Purdy reservoir, located on the Little Cahaba River upstream from the refuge, was created in 1911 by the Lake Purdy Dam (Mooty and Kidd 1997; see Section 5.4.2). The reservoir's primary function is to supplement the City of Birmingham's water supply during periods of low flow on the Cahaba River. It has a storage capacity of 17,500 acre-feet.

5.1.3 Springs and Seeps

A spring is defined as a place where groundwater flows naturally from a rock or the soil into the land surface or into a body of surface water (Neuendorf et al. 2005). Low-volume springs with little ponded water or surface flow are often referred to as seeps. The occurrence of springs and seeps depends upon the nature and relationship of permeable and impermeable rock strata, on the position of the land surface in relation to the water table, and the topography of the area (Chandler and Moore 1987; Neuendorf et al. 2005). The Cahaba River originates from springs and seeps on the southern slope of Cahaba Mountain in St. Clair County, and springs and seeps along the edge of Red Mountain in Jefferson County, northeast of Birmingham (USGS 1959; Benke and Cushing 2005).

There are no known springs on the refuge, but there are 21 documented springs or seeps within the RHI (Figure 13). Additionally, the "Springs of Alabama" report lists 11 springs in Bibb County (Chandler and Moore 1987), eight of which have inactive USGS monitoring sites. The Lightsey Pond Spring near Centreville had a monitoring station for streamflow that was active from 1970-1982 (Chandler and Moore 1987).

Two seeps were identified and mapped within the refuge, as a result of the initial planning and assessment related to reclamation of the Piper II mine (QORE, Inc. 2004). One was associated with drainage entering the highwall from the east, and the second was immediately downstream of "Pond 1," a small pond that is significantly silted in with no overlow structures. A total of three ponds were found at the site: one believed to be a breached sediment detention pond and two that may also have been associated with surface mining activities, but this was not definitively determined. Additional information about these ponds and seeps including locations is provided in Appendix C.

5.1.4 Wetlands

The National Wetland Inventory (NWI) is a program of the U.S. Fish and Wildlife Service established in 1974 to provide information on the extent of the nation's wetlands (Tiner 1984). NWI produces maps of wetland habitat as well as reports on the status and trends of the nation's wetlands. Using the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979), wetlands have been inventoried and classified for approximately 90% of the conterminous United States and approximately 34% of Alaska. Cowardin's classification places all wetlands and deepwater habitats into five "systems:" marine, estuarine, riverine, lacustrine, and palustrine. The different systems can be broken down into subsystems, classes, and hydrologic regimes based on the wetland's position in the landscape, dominant vegetation type, and hydrology. Most of the wetlands in the United States are either estuarine or palustrine (Tiner 1984). The two predominant wetland systems at Cahaba River NWR are defined in Cowardin et al. (1979) as either Riverine or Palustrine:

Riverine: The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5 ‰. A channel is "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960:5).

Palustrine: The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5% (e.g., inland marshes, bogs, fens, and swamps).

For Cahaba River NWR, less than 5% of the land within the refuge acquired boundary and less than 4% of the acquisition boundary is classified as wetlands according to the NWI (Table 7, Figure 14). The wetlands are primarily riverine, with small areas of freshwater forested/shrub wetland and freshwater pond (Table 7). Two of the wetland areas identified from the NWI are associated with current restoration work (Appendix C; USFWS 2012a): a settling pond associated with the gobpile, and a second wetland located east of and adjacent to the highwall that coincides with the abandoned and collapsed mine portal. Currently, storm flow enters the mine portal during all but extreme storm events. During these events, water flows southwest along the base of the highwall (Appendix C; USFWS 2012a).

Table 7. Wetland habitat delineated by the National Wetland Inventory inside the Cahaba River NWR acquisition boundary. [Source: USFWS undated-a].

Habitat Type	System	Acres on Refuge	Percent of Total	Acres within Acquisition Boundary	Percent of Total
Freshwater Forested/Shrub Wetland	Palustrine	32	0.9	49	0.6
Freshwater Pond	Palustrine	4	0.1	16	0.2
Riverine (Perennial)	Riverine	115	3.4	227	3.0
Upland/Unclassified		3210	95.5	7376	96.2
Total		***3361***	***100.0***	***7668***	***100.0***

One goal of the Cahaba River NWR Habitat Management Plan (HMP) is to protect, restore and enhance the Cahaba River aquatic environment adjacent to the refuge. This goal includes a primary objective to restore, where feasible, the pre-settlement hydrologic environment through the use of weirs or other structures to trap river sediments and re-establish areas of unconsolidated streambed sediment for organisms that rely on this habitat (USFWS 2007). Another goal is to manage wetlands, streamside, and hardwood forests as a component of the mountain longleaf pine ecosystem. Historically, canebrakes were a widespread component of floodplain forests, existing within forest openings, as an understory component of floodplain forests, and as broad thickets without forest cover. The historic distribution of canebrakes on the refuge is unknown, but the presence of fire-dependent longleaf pine forests on adjacent uplands suggests cane was once more widespread. Without fire and with the spread of invasive species (e.g. Chinese privet), canebrakes have diminished. The refuge plans to encourage the spread and reintroduction of cane through controlled burning and experimental plantings (USFWS 2007).

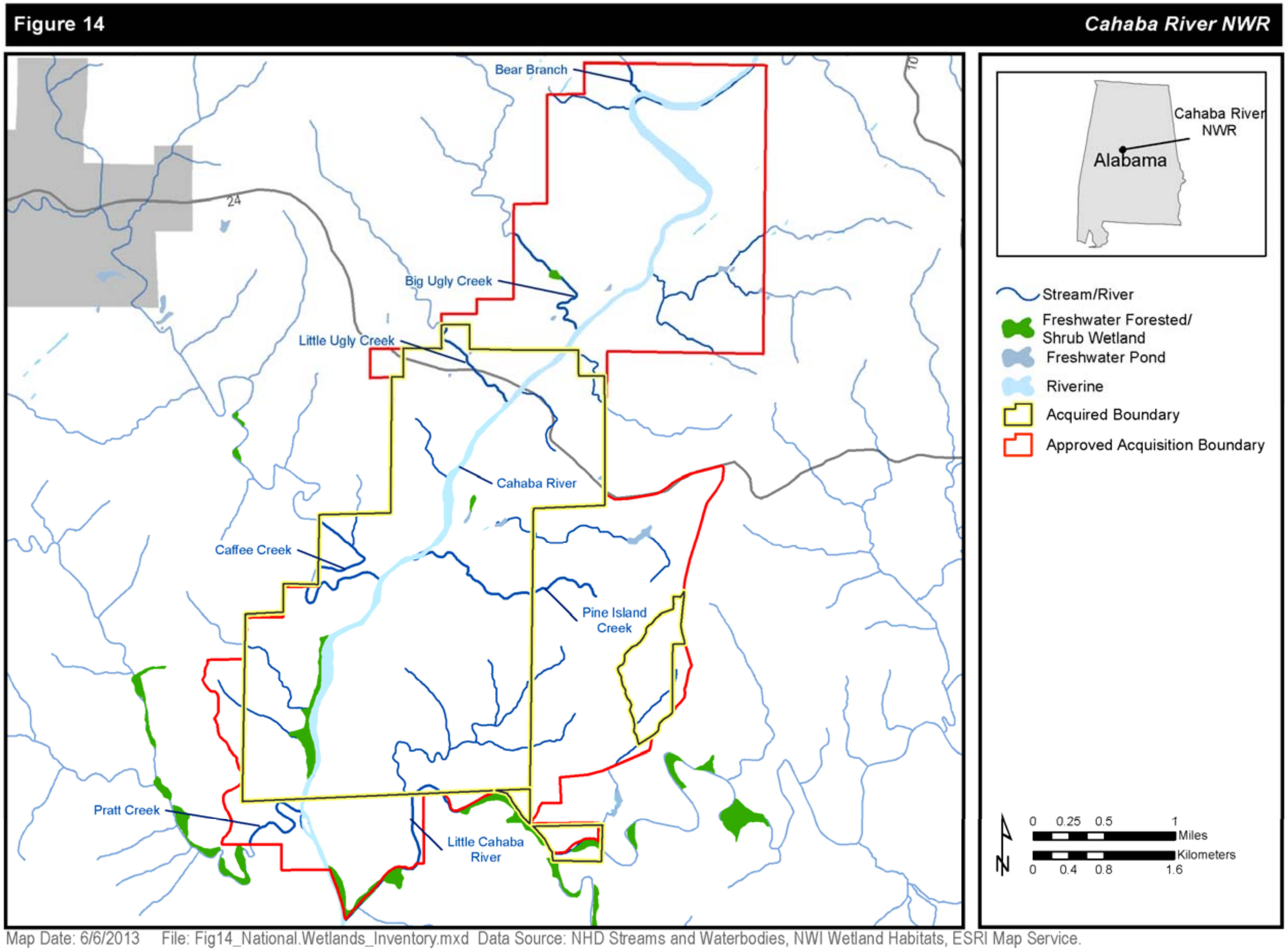


Figure 14. National Wetlands Inventory (NWI) land cover within or in the vicinity of the Cahaba River NWR acquisition boundary.

5.1.5 Groundwater

The refuge is located near both the Valley and Ridge and Coastal Plain provinces (Mooty and Kidd 1997). There are three general types of aquifers present in the vicinity of the refuge: porous-media, solution-conduit and fracture-conduit. Porous-media aquifers occur in unconsolidated or poorly consolidated sediments in the Valley and Ridge and Coastal Plain provinces. Mooty and Kidd (1997) found that porous-media aquifers have low well yields (i.e., 10 gallons per minute [gpm]) in the Valley and Ridge province and are therefore not major sources of groundwater in the vicinity of the refuge. However, well yields for porous-media aquifers within the Coastal Plain have higher yields (100-200 gpm) and are used for limited public water supply. By contrast, wells constructed in solution-conduit aquifers, which occur in well-cemented carbonate rocks of the Valley and Ridge province, may supply anywhere from 10 gallons to several thousand gpm. Finally, wells in fracture-conduit aquifers, occurring in shale, siltstone, and sandstone of the Valley and Ridge Province, may supply 10 to 200 gallons of water per minute (Mooty and Kidd 1997). Aquifers in the vicinity of the refuge include Coker, Pottsville, and Gordo (GSA undated), within the larger Valley and Ridge aquifer system and the Pottsville aquifer system. The Coker aquifer has limited areal extent and thickness (0-30 ft.) and is not tapped by any public water supply well in the area. The Pottsville aquifer has variable quality due to high iron (>0.3 mg/L) (Kopaska-Merkel et al. 2005). The hydrogeology of these aquifers is described in detail in Kopaska-Merkel et al. (2005).

According to Mooty and Kidd (1997), groundwater resources are underutilized in the vicinity of the refuge, although long-term water level data at wells in the region are generally lacking. Groundwater is not utilized by the refuge for habitat management or drinking water supply. Mooty and Kidd (1997) estimate that baseflow from groundwater discharge supplies approximately 48% of the mean annual discharge of the Cahaba River at Centreville. However, during periods of prolonged drought, stream discharges at multiple sites on the Cahaba River were sustained entirely from groundwater baseflow.

Relevant groundwater related resources including data and reports for the Cahaba watershed (HUC 03150202), are available from USGS: http://water.usgs.gov/lookup/getwatershed?03150202.

Groundwater quantity and quality information is discussed in Sections 5.3.2 and 5.5.3 of this document.

5.2 Infrastructure

The refuge maintains a gravel parking area, a two mile gravel road, canoe launch facilities, and several miles of trails along the east of the river (USFWS 2006). Trails provide interpretation of the former mining area and views along the river and ridge overlook. No bathroom facilities exist in the area, although portable toilets are sometimes provided for larger-scale special events at the refuge. The refuge has no water management infrastructure. However, historic mining activity resulted in roads, berms, impoundments, tailing piles, and both surface mining structures and underground tunnels that affect overland flow of precipitation and runoff (QORE, Inc. 2004).

5.2.1 Water Supply Wells

There are no buildings within the refuge acquisition boundary and therefore no drinking water supply wells related to either surface water or groundwater. The presence and location of historic water supply wells are unknown. A significant number of oil and gas wells are located within refuge boundaries and within the RHI, discussed in Section 5.5.4 and listed in Appendix J.

5.2.2 Water Control Structures and Impoundments

There are four known impoundments on the refuge, comprising approximately 10 acres. Two are a direct result of coal mining activities; one is from an underground mine and the second is from a strip mine. These impoundments have associated earthen dams but are not actively managed. There is one underground mine opening that receives surface water inputs (USFWS 2009a; USFWS 2012a; Appendix C). These mining remnants will be addressed as part of the mining reclamation work to restore natural hydrology. Reclamation activities (expected October 2013 through 2014) are detailed and outlined in Appendix C, and were described briefly in Section 4.6 of this document. Although not on the refuge, there are numerous barriers to fish passage, primarily at road crossings within the Cahaba drainage. They are further discussed in Section 5.4.2 (Hydrologic Alterations).

5.2.3 Other Water Resources Infrastructure

From 1975 to 1984 a USGS monitoring station was located within the acquired boundary of the refuge at the Piper Bridge near West Blocton (County Road 24) (USGS Gage 02423647) (Figure 15, Section 5.4.1, Appendix D). The refuge is investigating the possibility of reopening the station (USFWS 2007), although maintaining the currently active USGS gage located in Centreville, AL (USGS Gage 02424000) approximately 10 miles downstream of the refuge is a higher priority. A list of various water monitoring infrastructure (both surface water and groundwater quality and quantity) is provided in Appendix D and Appendix E, and locations are shown in Figure 15,Figure **17**Figure 16, and Figure 17. Additional discussion about water quality and quantity monitoring is provided below in Sections 5.3 and 5.4.

5.3 Water Monitoring

5.3.1 Surface Water

5.3.1.1 Hydrography

There are 57 USGS surface water quantity monitoring sites (stream gages and sites that were periodically measured for water levels) within the RHI (Figure 15, Appendix D). Currently, there are 11 active USGS surface water quantity monitoring sites and one well in operation (**Table 8**). The closest active USGS monitoring station to the refuge is located in Centreville, AL (USGS Gage 02424000), approximately 10 miles downstream of the refuge boundary. The Centreville gage measures hourly discharge and stage on the Cahaba River (Figure 11,
Figure **12**, Figure 15). An additional five discontinued sites that operated for more than 10 years are listed in Table 1Table 8.

Table 8. Regional USGS and GSA long-term surface and groundwater quantity monitoring sites within or in the vicinity of the Cahaba River NWR acquisition boundary (see Figure 16). Additional information is summarized in Appendix D. [Sources: GSA 2010; USGS 2013a].

# Figure 16	Site Number	Site Name	Latitude	Longitude	Begin Date	End Date	Site Type
1	L-5	JEFFERSON CO. PERIODIC – FORT PAYNE CHERT	33.63278	-86.595	6/21/1968	present	Well
2	02423130	CAHABA RIVER AT TRUSSVILLE, AL.	33.62232	-86.5994	3/4/1989	present	Stream
3	02423397	LITTLE CAHABA RIVER BELOW LEEDS, AL.	33.53454	-86.5625	1/26/1996	present	Stream
4	02423398	LITTLE CAHABA RIVER NEAR LEEDS AL	33.52427	-86.5755	2/10/1981	11/15/2007	Stream
5	02423400	LITTLE CAHABA RIVER NR JEFFERSON PARK, AL.	33.49982	-86.6142	1/19/1987	present	Stream
6	2934086353801	BIRMINGHAM WATER WORKS BOARD WELL NEAR LEEDS, AL	33.49277	-86.5937	10/10/2010	present	Well
7	02423380	CAHABA RIVER NEAR MOUNTAIN BROOK AL	33.48177	-86.7128	4/13/1979	present	Stream
8	02423414	LITTLE CAHABA RIVER AT CAH BEA RD NR CAHABA HTS AL	33.43982	-86.6989	8/6/2004	present	Stream
9	JEF-1	JEFFERSON CO. REALTIME – BANGOR LIMESTONE AQUIFER	33.43567	-86.8752	1975	present	Well
10	02423425	CAHABA RIVER NEAR CAHABA HEIGHTS AL	33.41566	-86.7397	3/16/1976	present	Stream
11	02423515	PATTON CREEK NR BLUFF PARK BL PATTON CHAPEL, ALA	33.38899	-86.8272	6/21/1956	8/30/2010	Stream
12	02423620	LITTLE SHADES C AT STATE HWY 150 NR BESSEMER AL	33.38066	-86.9292	7/11/1980	5/7/2001	Stream
13	02423500	CAHABA RIVER NEAR ACTON AL	33.36344	-86.813	2/28/1939	present	Stream
14	02423496	CAHABA RIVER NEAR HOOVER, AL	33.36927	-86.7842	3/5/1989	present	Stream
15	02423630	SHADES CREEK NEAR GREENWOOD AL	33.32622	-86.9497	2/12/1965	present	Stream
16	242354750	CAHABA VALLEY CREEK AT CROSS CR RD AT PELHAM, AL.	33.31344	-86.8064	1/31/1999	present	Stream
17	02423550	BUCK CREEK AT HELENA AL	33.29705	-86.843	9/19/1991	9/2/2010	Stream
18	02423555	CAHABA RIVER NEAR HELENA AL	33.28455	-86.8825	2/22/1961	present	Stream
19	C-1	BIBB CO. PERIODIC – CHEPULTEPEC DOLOMITE	33.16889	-87.1533	4/29/1985	present	Well
20	L-4	BIBB CO. PERIODIC – COKER FORMATION SAND	33.03806	-87.2631	11/7/1967	present	Well
21	02423800	LITTLE CAHABA RIVER NEAR BRIERFIELD AL	33.05762	-86.9528	2/6/1958	3/20/1970	Stream
22	02424000	CAHABA RIVER AT CENTREVILLE AL	36.87833	-87.1392	8/1/1901	present	Stream
23	O-5	BIBB CO. PERIODIC – COPPER RIDGE DOLOMITE	32.93944	-87.1319	9/30/1983	present	Well
24	W-3	BIBB CO. PERIODIC – COKER FORMATION SAND	32.89833	-87.2511	11/15/1983	present	Well
25	T-6	BIBB CO. PERIODIC – COKER FORMATION SAND	32.85472	-86.9639	11/28/1967	present	Well

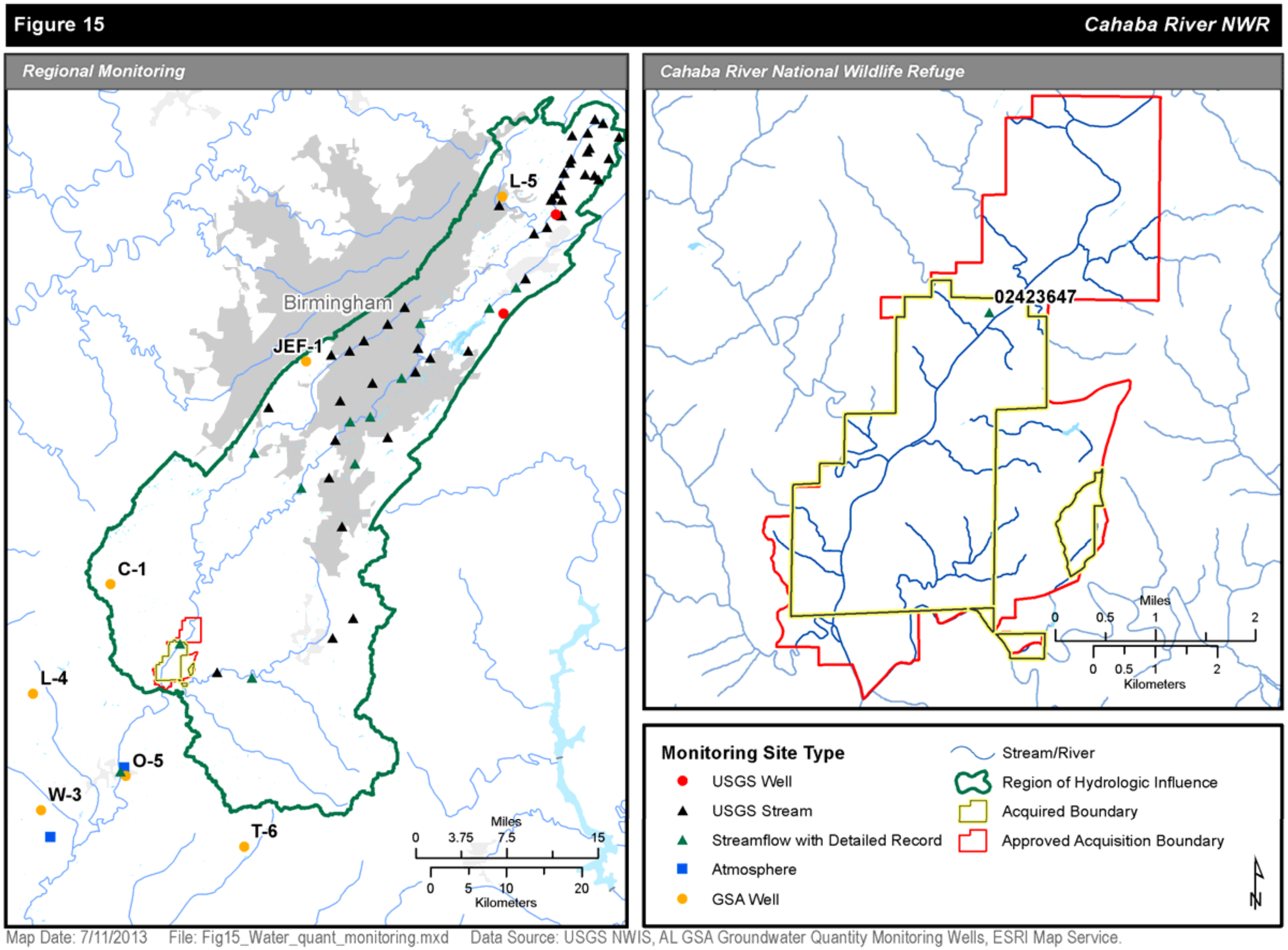


Figure 15. Regional USGS and GSA water quantity monitoring within the Region of Hydrologic Influence and in the vicinity of the Cahaba River NWR. (specific data for these sites including geographic coordinates and period of record are summarized in Appendix D).

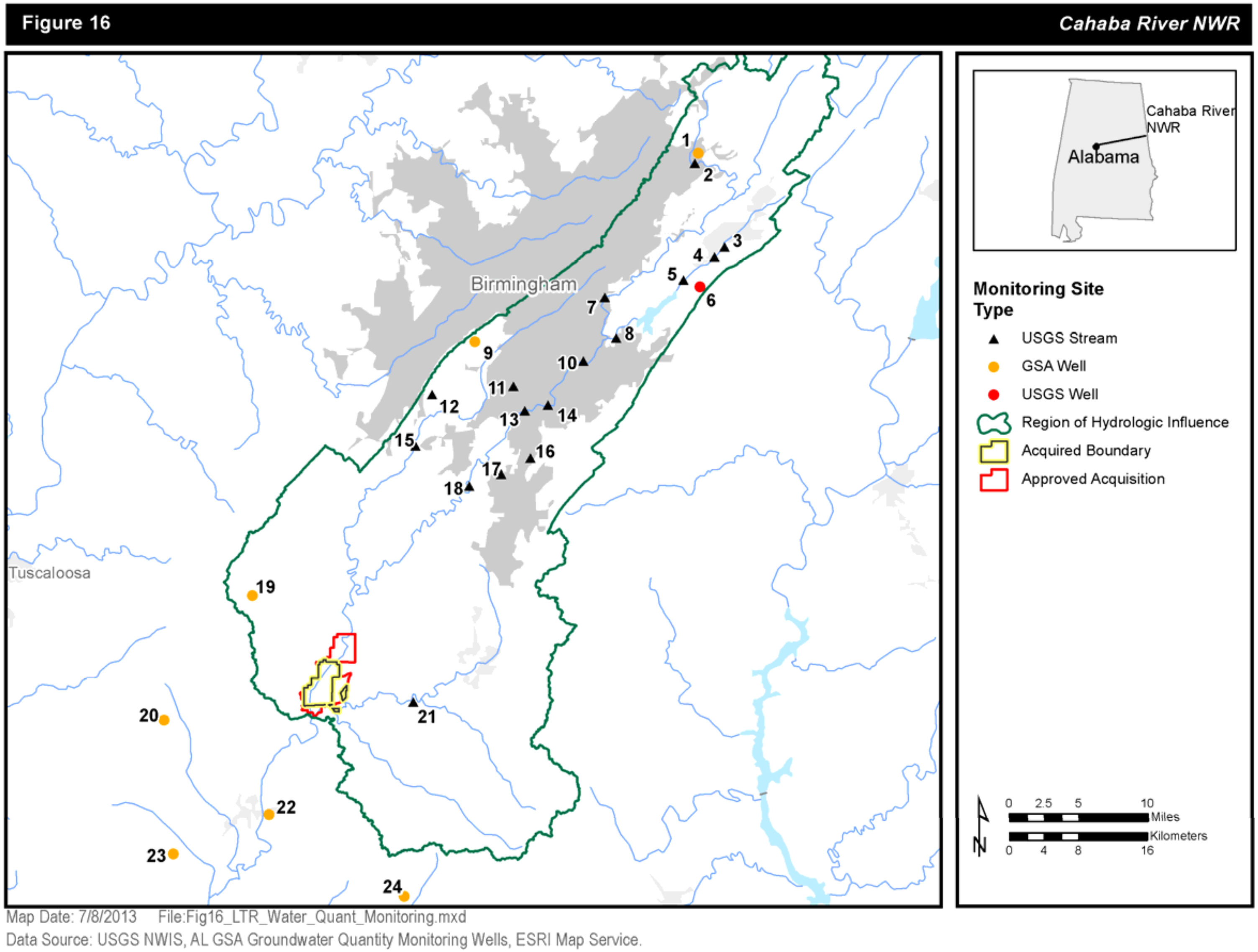


Figure 16. Long-term USGS and GSA surface and groundwater quantity monitoring sites within and near the Region of Hydrologic Influence. Numbered sites are listed in Table 8.

5.3.1.2 Water Quality Monitoring

Multiple agencies conduct water quality monitoring within the Cahaba River. Based on data from the USGS National Water Information System (NWIS) (http://waterdata.usgs.gov/nwis), USGS has conducted surface water quality monitoring at 116 sites within the RHI, including streams, lakes and springs (Figure 17, Appendix E). Within or in the vicinity of the Cahaba River NWR acquisition boundary, there are six surface water quality sites (Figure 17; Table 9). One-time samples associated with refuge establishment were collected in 2009 at five of the six sites (Table 9). The USGS Cahaba River near West Blocton site (Map ID #4) was monitored for water quality January 1976 to August 1983, during which 69 samples were collected and measured for metals, nutrients and other parameters. Measurements of pH, conductivity, and dissolved oxygen (DO) from this site are presented in Appendix F.

As part of U.S. EPA Clean Water Act reporting, ADEM implements a Wadeable Rivers and Streams Monitoring Program that provides data to estimate overall water quality, categorize the status of waters, and develop criteria to assess rivers and streams statewide. Under this program there are four types of monitoring sites: probabilistic (random), targeted (provide data for listing/delisting decisions), long-term ecoregional reference reaches, and ambient trend sites (provide data for total maximum daily loads [TMDLs] and criteria standards). There are two ambient trend monitoring sites near the refuge: (CABB-1) on the Cahaba River in Centreville, AL and (C3) located upstream of the refuge near Helena, AL. Ambient sites are monitored three times per year in May, August and October. Additionally, there is an ecoregional reference reach (MAYB-1) located on Mayberry Creek, a tributary to the Little Cahaba River, in Bibb County (ADEM 2007a; Appendix E). Water samples are assessed for a suite of physical, biological, and chemical parameters and compared to established criteria (ADEM 2010). These water monitoring sites are displayed in Figure 17 with additional information provided in Appendix E.

In 2001 and 2002, the U.S. Environmental Protection Agency (U.S. EPA) conducted water quality studies on the Cahaba River and selected tributaries in order to establish appropriate targets for Total Maximum Daily Loads (TMDLs) for stream segments on the §303(d) list. The 2002 study involved rapid bioassessments of the benthic macroinvertebrate community, surveys of periphyton percent coverage, stream geomorphology surveys, and water quality sampling for nutrients, chlorophyll-*a* and algal growth potential. One of the stations (CR-9) was located within the acquired boundary of the refuge at the County Road 24 Bridge. Biological sampling was not conducted at that station, but the results indicated elevated nitrogen and phosphorus concentrations, elevated chlorophyll-*a*, and elevated pH levels. Overall, the study found excessive sedimentation and nutrient enrichment to be the major water quality problems on the Cahaba River (EPA 2002). Additional discussion of this work is provided in Section 5.5.

A Contaminant Assessment Process (CAP) was initiated in April 2013 through the USFWS Contaminants Program, and completed in October 2013. In 2012, soil and water samples were collected and analyzed for contaminants including heavy metals (e.g., mercury, arsenic, cadmium, lead, nickel and strontium) as part of the Piper II Reclamation Project (see Appendix C). Soil samples were collected at three locations and water samples were collected at six locations; other sampling is planned as the mining reclamation work proceeds (USFWS 2012b, Sarah Clardy, personal communication). Also part of the Piper II Reclamation Project, the USFWS Alabama Ecological Services Field Office developed an Environmental Contaminants Monitoring and Quality Assurance Project Plan that outlines proposed monitoring required before, during, and after highwall reclamation (see Appendix C; USFWS undated-b). Seven sites will be monitored for turbidity, specific conductance, pH, dissolved oxygen, and metal/trace elements (USFWS undated-b). In addition, monitoring is required as part of the National Pollutant Discharge Elimination System (NPDES) stormwater permit issued for this reclamation work (Section 5.5.2).

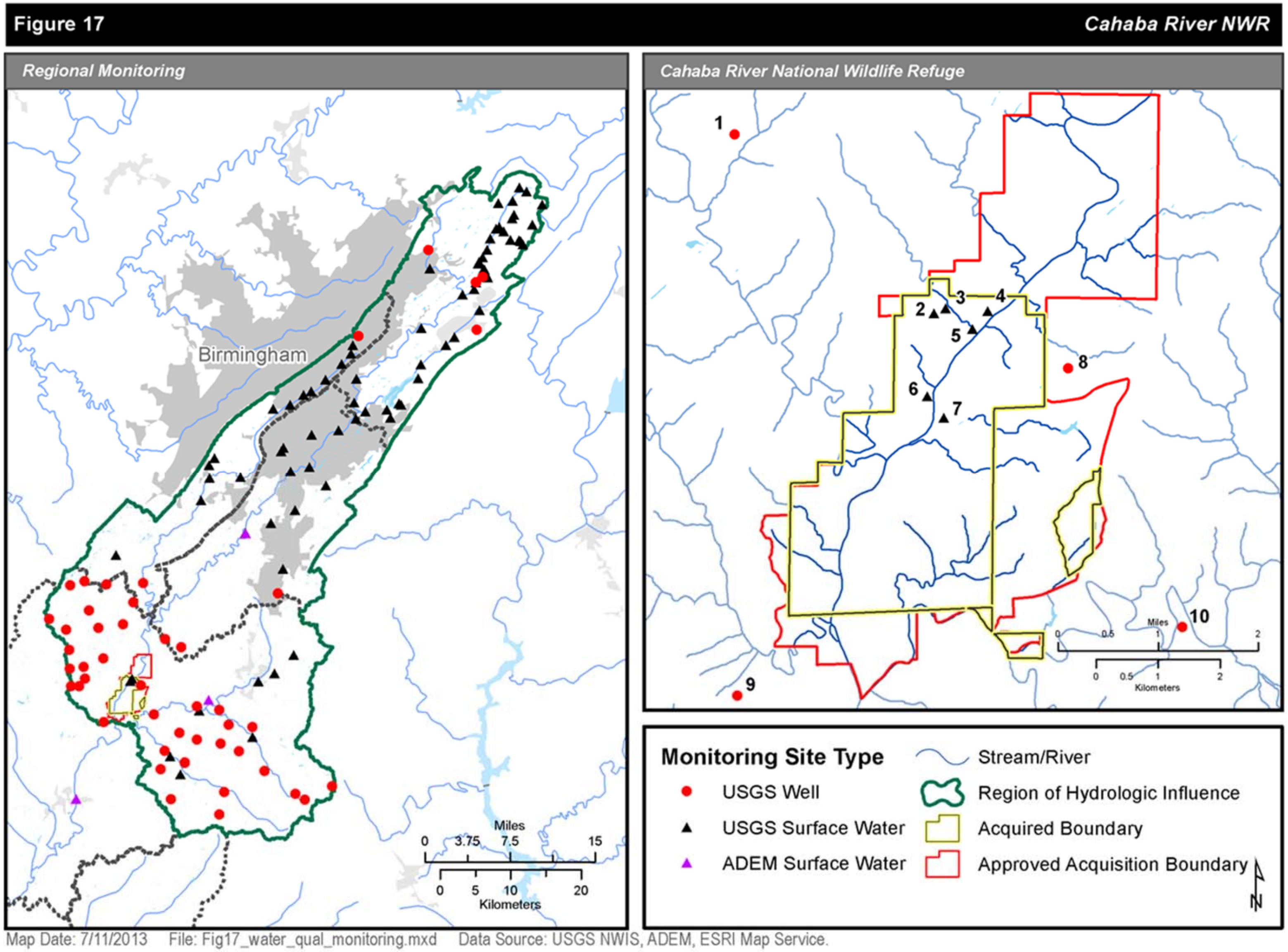


Figure 17. Regional USGS and ADEM surface and groundwater quality monitoring sites within the Region of Hydrologic Influence and in the vicinity of the Cahaba River NWR acquisition boundary.

Table 9. Regional USGS surface and groundwater quality monitoring sites within or in the vicinity of the Cahaba River NWR acquisition boundary (see Figure 17). [Source: USGS 2013a; EPA 2013].

ID # (Figure 17)	Site Number	Site Name	Type	Date of Sample	pH	SpCond	DO	DO%
1	330725087055201	F 2-USGS 330725087055201	Well	12/27/1967	6.6	177		
2	330552087035001	JIM'S POND (CAHABA R NWR) NR W BLOCTON, AL	SW	4/30/2009	6.7	132	2.8	30
3	330554087034301	LITTLE UGLY CR PIT (CAHABA R NWR) NR W BLOCTON, AL	SW	4/29/2009	6.1	74	2.1	22
4	02423647	CAHABA RIVER NEAR WEST BLOCTON AL	SW	*multiple - see Appendix F				
5	330544087032601	LITTLE UGLY CR (CAHABA R NWR) NR W BLOCTON, AL	SW	4/30/2009	8.1	694	7.9	90
6	330508087035401	RIVER ROAD POOL (CAHABA R NWR) NR W BLOCTON, AL	SW	5/1/2009	6	91	1.3	15
7	330457087034401	COAL PILE POND (CAHABA R NWR) NR W BLOCTON, AL	SW	4/30/2009	6.9	125	7.8	91
8	330538087021801	J 1-USGS 330538087021801	Well	1/5/1968	7.1	291		
9	330242087060001	J 2-USGS 330242087060001	Well	11/9/1967	8.4	317		
10	330320087010801	J 3-USGS 330320087010801	Well	11/13/1967	8.4	305		

pH: pH, unfiltered field measurement, standard units;
SpCond: Specific conductance, unfiltered, uS/cm @ 25 °C
DO: Dissolved oxygen, mg/L
DO%: Dissolved oxygen, percent of saturation

5.3.1.3 Aquatic Habitat and Biota Inventories and Monitoring

The aquatic biodiversity within Alabama and especially within the Mobile River basin (including the Cahaba River) is exceptional. Alabama is a hotspot of biodiversity for aquatic ecosystems in North America, containing 43% of all known gill-breathing snails, 52% of known freshwater aquatic or semi-aquatic turtles, 60% of known Unionid mussels (Williams et al. 1998), and 38% of known freshwater fishes (Lydeard and Mayden 1995). Specifically, the Mobile Basin ranks third in the nation in variety of fishes (>160-180 species) (Swift et al. 1986; Buckner et al. 2002), and is among the top ten river basins in the world in diversity of freshwater mussels (>75 species) (USFWS 2000). The Mobile Basin also provides habitat for the richest aquatic snail fauna in the world (>120 species) (Bogan et al. 1995).

The rich biodiversity of Alabama waterways directly relates to the history of the drainages in which they are found (Ward et al. 1992). In Alabama, river systems traverse an extremely diverse array of physiographic regions, ecosystems, geologic systems, and geomorphologic features (including the Appalachian Plateau, Valley and Ridge, and Piedmont) from their headwaters in the Appalachian Mountains to their mouths in the coastal plain (Lydeard and Mayden 1995). High levels of speciation resulted from ancient geologic events including: the fluctuation of sea level over millions of years, the resulting erosion and deposition within river systems, and the fact that aquatic and terrestrial ecosystems of Alabama avoided direct impacts of Pleistocene glaciation (USFWS 2000).

Unfortunately, 50% of all documented U.S. species extinctions since European settlement have occurred during this century in the Mobile River basin (USFWS 2000). The fauna and their habitats have been extensively affected by impoundment, channelization, mining, dredging, and pollution from point (specific) and nonpoint (diffuse) sources. Alabama, through which this vast river system courses, has the unfortunate distinction of being the most extinction-prone state in the continental United States, with 98 species extinct (USFWS 2000; Stein 2002). Most of Alabama's many rivers have been impounded for hydropower or dredged for barge transport, resulting in the disappearance of many riverine habitats and species. Within this landscape of species loss, the Cahaba River maintains the state's longest free-flowing section of river (approximately 150 miles), and one of its most biologically rich (Lydeard and Mayden 1995; Master et al. 1998). The Nature Conservancy highlighted the Cahaba River as one of the top areas for conservation due to its distinction as a hotspot for aquatic diversity, recognizing the river as one of 87 watersheds in the continental United States harboring 10 or more imperiled fish and mussel species (Master et al. 1998).

Biological Inventories: Numerous inventories of the aquatic fauna in the Cahaba River and the Mobile basin have been conducted, with some dating back to the early 1800s: Timothy Abbott Conrad (1830s), Alexander Agassiz (1850s), and Isaac Lea (1800s) (USFWS 2000). Herbert H. Smith made extensive collections of the snails and mussels throughout the Mobile and adjacent drainages in the early 1900s (van der Schalie 1938; USFWS 2000), now housed in the Alabama State Museum in Tuscaloosa. Jim Williams and the other authors of The Mussels of Alabama conducted field surveys and extensive examinations of museum collections in order to complete this statewide assessment (Williams et al. 1998). Other books documenting the aquatic fauna in Alabama include the Fishes of Alabama (Boschung and Mayden 2004), the Fishes of Alabama and the Mobile Basin (Mettee et al. 1996), and Alabama Wildlife: Imperiled Aquatic Mollusks and Fishes (Mirarchi et al. 2004). Crayfish diversity within Alabama is also unparalleled. With 85 known species, Alabama has the highest diversity of crayfish in North America (Smith et al. 2011). From 2008-2010, the GSA and partners conducted a statewide crayfish assessment for the Alabama Department of Conservation and Natural Resources (Smith et al. 2011; GSA 2013). From 767 collections, 64 of the 85 species known to occur in the state were documented, including one invasive species and three new species (Smith et al. 2011). The Illinois Natural History Survey examined literature and museum records for crayfish across Alabama, generated a species list, and included proposed conservation statuses in 2004 (Schuster & Taylor 2004).

The Cahaba River is also incredibly icthyologically diverse; no other river of its size or larger in North America has more species of fish per mile than the Cahaba River (Pierson et al. 1989; Boschung and Mayden 2004). Based on various sources, 131 species of fishes have been documented in the Cahaba River system, with 18 species being found nowhere else outside of the Mobile Basin (Pierson et al. 1989; Master et al. 1998; NatureServe 2010; Appendix B), and new species are still being described. For example, a recent examination of variation in morphology and mitochondrial DNA on the Redeye Bass, *Micropterus coosae*, highlighted additional species-level variation resulting in descriptions of a total of four new species, including *Micropterus cahabae*, a new species restricted to the Cahaba River system (Baker et al. 2013).

Besides fish diversity, the Cahaba River also supports extremely high mussel and snail diversity, with 48 species of mussels and 39 species of snails historically occurring (Johnson et al. 2011). Several snail and mussel surveys in the Cahaba River have been completed on the refuge or nearby (Fobian et al. 2011). In 2004 the USFWS surveyed freshwater mussel and snail populations along a 3-mile stretch of the Cahaba River within the refuge, providing baseline information for the area including presence/absence data for several threatened or endangered species (Hartfield 2004). A comprehensive inventory of freshwater mollusks (snails and mussels) in the Cahaba River basin was initiated by the Alabama Biodiversity Center in 2004 (Johnson et al. 2005). As part of this project, qualitative and quantitative mollusk surveys have been conducted throughout the Cahaba basin by Johnson et al. (2004-2012), documenting 32 Gastropod species and 39 Unionid mussel species (Johnson et al. 2005; Johnson et al. 2011; Appendix B). A detailed analysis of mollusk species occurrence and distribution since the 1880s was also conducted based on examination of museum collections as part of this work (Johnson et al. 2005). Much of this information informed the recent Gastropod conservation status report published in *Fisheries* (Johnson et al. 2013).

In addition, 146 species of caddisflies (Trichoptera) have been documented from the Cahaba River (Harris et al. 1984).

<u>Biological Monitoring</u>: Large-scale water quality monitoring paired with biomonitoring on the upper and lower portions of the Cahaba River over multiple years (1989-1994) was conducted by the Geological Survey of Alabama. This bioassessment work is summarized in two separate reports published through GSA: the Upper Cahaba River Drainage (Shepard et al. 1994), and the Lower Cahaba River Watershed (O'Neil & Shepard 2000).

In 2001 and 2002, the U.S. EPA conducted water quality studies on the Cahaba River and selected tributaries in support of establishing TMDLs for stream segments on the §303(d) list. Work included multiple rapid bioassessments of the benthic macroinvertebrate community, snail density surveys, surveys of periphyton percent coverage, stream geomorphology surveys, and water quality sampling for nutrients, chlorophyll-*a* and algal growth potential. The findings were published (Howard et al. 2002; EPA 2006). Bioassessments identified impairment of the benthic community at three tributaries to the Cahaba: an unnamed tributary (UT-1), the Little Cahaba River (LCR-2), and Buck Creek (BC-2). Benthic macroinvertebrate impairment was also identified at five sites in the Cahaba mainstem. Low water levels in July 2002 prevented summer bioassessment samples from being collected. Also noted in this study was the change in an ecoregional reference site for the Ridge and Valley ecoregion. Previously, station CR-1 was used as a reference site, but due to evidence of scouring, the control site was shifted to site CR-AT (detailed site information is presented in Howard et al. 2002).

The GSA conducted monitoring of snail and mussel populations at stations along the Cahaba River in 2004 and 2005 (McGregor & Garner 2004; McGregor & Garner 2005). In 2004, a total of 1,592 individuals representing 25 species were collected live in about 54.8 hours of sampling, for a cumulative catch per unit effort (CPUE) of 29.1 mussels per hour. In 2005, a total of 1,031 individuals representing 25 species were collected live in about 84.5 hours of sampling for a CPUE of 12.2 mussels per hour. Both years of survey work documented live individuals of three federally listed species: Finelined Pocketbook (*Hamiota altilis)*, Ovate Clubshell (*Pleurobema perovatum*), and Triangular Kidneyshell (*Ptychobranchus greenii*). Both surveys noted a decline in mollusk abundance and diversity and poor Index of Biotic Integrity (IBI) scores downstream of Shades Creek, which has been listed as impaired for siltation, habitat alteration, turbidity and pathogens since 1996, and based on physical, chemical, and benthic macroinvertebrate sampling, is considered to be in very poor condition (ADEM 2007b). Declines of mollusk abundance and diversity values were also noted in the vicinity of small dams on the Cahaba River.

Extensive fish IBI work has been conducted in Alabama, with the intent to use fish IBI as a statewide bioassessment tool (O'Neil & Shepard 2007). This work involved the delineation and calibration of five Ichthyoregions in Alabama in addition to the compilation of a comprehensive, georeferenced statewide database of 855 fish community samples pooled from multiple institutional sources:

- Delineation of Ichthyoregions in Alabama – OFR 0711 (O'Neil & Shepard 2007)
- Calibration: TN Valley Ichthyoregion – OFR 1004 (O'Neil & Shepard 2010)

- Calibration: Ridge and Valley Piedmont Ichthyoregion – OFR 1109 (O'Neil & Shepard 2011a)
- Calibration: Plateau Ichthyoregion – OFR 1111 (O'Neil & Shepard 2011b)
- Calibration: Hills and Coastal Terraces Ichthyoregion – OFR 1116 (O'Neil & Shepard 2011c)
- Calibration: Southern Plains Ichthyoregion - OFR 0908; OFR 1210 (O'Neil & Shepard 2009, 2012)

A map delineating the Ichthyoregions, based on O'Neil and Shepard (2007) was also produced (O'Neil et al. undated). ADEM, Alabama Department of Conservation and Natural Resources (ADCNR)/Wildlife and Freshwater Fisheries Division, and GSA use standard sampling protocols for all IBI fish assessments (O'Neil et al. 2006; O'Neil & Shepard 2007). Reports conducted through the Ecosystems Investigations Program of the GSA are available from http://www.gsa.state.al.us/gsa/eco/ofrs.htm.

The Alabama Department of Environmental Management (ADEM) collects extensive chemical, physical, and biological data related to surface water (both lentic – lakes/reservoirs; and lotic – perennial and intermittent rivers) and groundwater quality annually across the state using standardized sampling protocols. In addition, ADEM annually samples 133 Active Ambient Monitoring Trend Stations in order to identify long-term trends in water quality statewide and to provide data for the development of TMDLs and water quality standards. Sampling occurs three times a year (June, August, and October) statewide annually, with select sites sampled more frequently. Sampling frequency and parameters collected at these sites vary from other station types used to assess the water quality condition for individual stream reaches related to designated use standards. Section 5.3.1.2 provides more information on water quality monitoring and Section 5.5 summarizes designated use standards.

Site-specific biomonitoring has also been conducted at restoration projects and fish barrier sites in the watershed by multiple state, federal, and non-governmental agencies. For example, biomonitoring of mussels and snails was conducted at the site of the Marvel Slab Dam on the Cahaba River from 2004-2010 (TNC and USACE 2009; Freeman 2011). Prior to removal of the dam, average mussel densities at the dam's centerline and 10-40 meters downstream were 0.0 mussels/square meter; 10-40 meters upstream of the dam the average density was 0.6. Since dam removal beginning October 21, 2004, mussel densities have steadily increased at the upstream locations (average of 3.3 by 2008) and slowly increased at the centerline and downstream locations (2008 densities of 1.1 and 0.2, respectively). Additionally, snail densities have significantly increased between 2005 and 2007 at all locations, with percent increases ranging from 1293% to 16,016%. More information is presented in Section 565.4.2.

Jefferson County also conducts annual biomonitoring (invertebrate sampling) and water quality monitoring along the upper half of the Cahaba River, although no reports or documents could be obtained to summarize these data.

Threatened and Endangered Species: The Cahaba River supports a wide diversity of endemic species, including more than 65 rare and imperiled plants and animals (Benke and Cushing 2005; ALNHP 2012). In addition to the rare and endemic species found in the Cahaba River, 32 federally listed species (including candidate species) are known to occur or have historically occurred in the basin (Appendix B with citations). Biological surveys conducted within refuge boundaries have documented 12 of these species (round rocksnail, flat pebblesnail, cylindrical lioplax, fine-lined pocketbook, triangular kidneyshell, orangenacre mucket, Cahaba shiner, goldline darter, Georgia aster, Georgia rockcress, gray bat and bald eagle) in the refuge (Appendix B with citations). Although not federally listed, two species once thought to be an extinct (*Clappia cahabensis* - Cahaba pebblesnail, and *Leptoxis compacta* - oblong rocksnail), have been re-discovered in the Cahaba River, and documented to occur within the refuge (Johnson et al. 2005; Johnson et al. 2010; Johnson et al. 2011; Whelan et al. 2012).

Many aquatic species that occur within the Cahaba River basin and on refuge lands may be federally listed in the future. Numerous mollusk species within the basin were originally considered for listing in 1991 and 1994 (Federal Register 1991, 1994). A recent petition to list 404 predominantly southeastern aquatic species by the Center for Biological Diversity, currently under consideration by the USFWS, included many of these species (CBD 2010). A list of the petitioned species potentially occurring in the Cahaba basin is included in Appendix B.

Recovery Efforts: Efforts to restore mollusk populations in Alabama are currently underway at the Alabama Aquatic Biodiversity Center (AABC) in Marion, Alabama, in partnership with several state, federal and non-governmental partners. The Center is a complex of four buildings that sits on 36 acres of property near the Cahaba River and is the largest state non-game recovery program of its kind in the United States. The mission of AABC is to promote the conservation and restoration of rare freshwater species in Alabama waters and in turn, restore cleaner water in Alabama's waterways. Recovery efforts are currently targeting the Mobile River Basin species due to their high level of imperilment. Within the Cahaba River, reintroductions of 2 Federally Endangered mussels extirpated from the Cahaba River in the 1970s (*Epioblasma penita* – southern combshell and *Medionidus parvulus* – Coosa moccasinshell) began in September 2012 in the Cahaba and Little Cahaba Rivers respectively (Johnson 2012a; Johnson 2012b). If successful, these and other planned reintroductions could greatly enhance conservation efforts for imperiled aquatic species, in addition to increasing the number of federally listed species occurring within the refuge.

5.3.1.4 Other Relevant Monitoring

The Habitat Management Plan (HMP) for Cahaba River NWR (USFWS 2007) describes several biological monitoring surveys conducted on or near the refuge within the past eight years. The Alabama Natural Heritage Program completed a Natural Community and Rare Plant Survey in 2007 that documented twelve critically imperiled, imperiled, or vulnerable species on the refuge (Schotz 2007). This survey represents a baseline that can be used to assist in protecting plant species of concern on the refuge (USFWS 2007). In the vicinity of the refuge, the Alabama Breeding Bird Atlas Project monitored breeding birds in the USGS West Blocton East Topographic Quadrangle between 2000 and 2006 (USFWS 2007). Since publication of the 2007 HMP, additional surveys and monitoring have been completed on refuge lands. In 2010, an inventory of reptiles and amphibians documented 50 species (11 frogs and toads, 10 salamanders, 6 lizards, 15 snakes and 8 turtles) of the 95 species documented in Bibb County and expected to occur on refuge lands (Godwin 2010). Acoustic surveys for bats conducted in 2009 and 2010 documented the presence of 8 bat species (of 14 species potentially occurring in the area) at both Cahaba River NWR and Mountain Longleaf NWR (Kristofik 2012). A dissertation was completed examining macroinvertebrate production of shoal habitats within the refuge (Wynn 2012), and a multi-scale genetic analysis of the shoal lily (*Hymenocallis coronaria*) was completed in 2007 (Markwith and Scanlon 2007).

5.3.2 Groundwater

5.3.2.1 Groundwater Level Monitoring

Groundwater levels within Alabama fluctuate almost continuously in response to discharge and recharge of aquifers through natural and artificial processes such as pumping from wells, natural groundwater discharge, recharge from precipitation, and evapotranspiration (DeJarnette et al. 2002). Observation wells are used to monitor fluctuations in the water table (potentiometric surface), either from natural factors or as a result of human uses and other anthropogenic influences. For example, examination of groundwater levels from 1997-2001 shows dramatic effect of summer droughts on water levels in October of 1999 and 2000 (DeJarnette et al. 2002).

The Geological Survey of Alabama (GSA), through the Groundwater Assessment Program, has been monitoring groundwater levels in Alabama since 1940. GSA monitors 20 wells across the state as part of the Real-Time Groundwater-Level Monitoring System, and measures ambient groundwater levels once a year at 372 wells and discharges for 37 springs located throughout Alabama (ADEM 2010; GSA 2010). Data from each well are published each year by GSA in Circular 112, "Ground-Water Levels in Alabama" (Kopaska-Merkel & Moore 2000).

While there are several wells within the Cahaba River basin, one Real-Time well (JEF-1), and two ambient groundwater monitoring wells are located within the RHI (C-1 and L-5), with the majority of the other monitoring sites located in the lower portion of the watershed (**Table 8**, Figure 15, Figure 16). Within the RHI, the closest ambient well to the refuge is C-1, which has been monitored since April 1985. Hydrographs from both of the GSA ambient wells (C-1 and L-5) in the RHI are available on-line from the GSA website (http://www.gsa.state.al.us/gsa/water/periodic_wells.html), and in Appendix G of this report. GSA ambient well site C-1 in Bibb County shows responsive groundwater levels that fluctuate between 405 and 436 feet AMSL (above mean sea level) with two drops in groundwater levels around January 1989 and November 2008 for the period of record (4/1985 to 10/2012). GSA ambient well site L-5 in Jefferson County shows moderate groundwater fluctuations between 665 and 708 feet AMSL for the period of record (6/1968 to 10/2006) with one large drop to 642 feet AMSL in October 2000.

There are two USGS groundwater level monitoring wells within the RHI, located in the Headwaters Cahaba Hydrologic Unit (**Table 8**, Figure 15, Figure 16, Appendix D).

Links to groundwater monitoring data and other resources for the Cahaba watershed (HUC 03150202), are available from (http://water.usgs.gov/lookup/getwatershed?03150202). Additional information related to groundwater quantity can also found in the following reports cited in this document:

- Groundwater Depletion in the United States: 1900-2008 (Konikow 2013)
- Estimated Use of Water in Alabama in 2005 (Hutson et al. 2009)
- Ground-water Levels in Alabama: 1997-2001 Water Years (DeJarnette et al. 2002)
- Water Down Under: Alabama's Groundwater Resources (ADEM 2001)
- Water in Alabama (including basic water data) (Kopaska-Merkel and Moore 2000)
- Ground-water Resources of the Cahaba River Basin in Alabama – Subarea 7 of the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River Basins (Mooty and Kidd 1997)
- National Water Summary 1988-1989: Hydrologic Events and Floods and Droughts (USGS 1991)
- Ground-water Availability in Jefferson County, Alabama (Hunter and Moser 1990)
- Water Data for Metropolitan Areas: Data Summary from 222 Areas in the US (Schneider 1968)

5.3.2.2 Groundwater Quality Monitoring

The USGS NWIS shows 49 well monitoring sites within the RHI, four of which are in the vicinity of the Cahaba NWR acquisition boundary (Figure 17, Table 9, Appendix H). The four well sites near the refuge were each sampled once for water quality parameters (i.e., specific conductance, hydrogen ion, pH, carbon dioxide, acid neutralizing capacity, bicarbonate, carbonate, hardness, noncarbonate hardness and chloride) between 1967 and 1968. These samples were collected as part of a 1975 USGS study on water availability in Bibb County (Causey et al. 1978; Appendix I).

In each of their biennial Integrated Reports, ADEM chooses a different physiographic region and reports on its groundwater quality. In their 2006 report, data from the Valley and Ridge province were evaluated for contamination sources. A total of 727 sites in the region had confirmed groundwater contamination (primarily sites associated with the Underground Storage Tank (UST) Program); the majority of those sites had stabilized and/or initiated corrective action (ADEM 2006a). Locations of these sites were not included in the 2006 report.

The GSA is preparing reports on aquifer hydrogeology and vulnerability to contamination for each of the 13 physiographic regions of the state. The report on Area 7, which encompasses the refuge, is still in development (Amye Hinson, GSA, personal communication May 2, 2013). The Area 4 report was completed in 2005 (Kopaska-Merkel et al. 2005), which includes areas upstream from the refuge: the headwaters of the Cahaba basin, Birmingham, and the majority of Jefferson County – all within the RHI for this assessment. This report used all municipal and rural public water supply wells, and water level data were used to generalize potentiometric surface maps for the major aquifers.

5.4 Water Quantity and Timing

5.4.1 Historical Streamflows

The Hydro-Climatic Data Network (HCDN) is a network of USGS stream gaging stations that are used to evaluate trends in stream flow conditions (Slack et al. 1992). Sites included in the network have periods of record that exceed 20 years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams.

The closest USGS gage to Cahaba River NWR is located on the Cahaba River at Centreville, AL (USGS Gage 02424000). The station has a period of record from 1901 to present. It is the only station in the 8-digit HUC listed in the HCDN network; however, the listing notes that there are no acceptable HCDN data for this station. The HCDN list also states that the headwaters of the Cahaba River are in a large metropolitan area (Birmingham, AL) and that streamflow diversions and losses can be significant (see http://pubs.usgs.gov/wri/wri934076/stations/02424000.html). In addition, the annual water use report for this site states that an average of 82 cfs is diverted upstream from the station by the Birmingham Water Works Board (BWWB), with flow partly regulated by Purdy Lake (capacity, 15,300 acre-feet) on Little Cahaba River and several waste-water treatment plants (USGS 2012). With this information in mind, the monthly and annual discharge data are presented in Figure 11,

Figure **12** and Table 10.

General trends for the Cahaba River, based on the USGS gage at Centreville, AL (02424000), are summarized for the period of record (1901-2011) in Figure 11 and

Figure **12**. Average monthly discharge is highest between January and April, with the lowest flow conditions of the year on average occurring in August through October (Figure 11); average annual flow for the period of record is approximately 1600 cfs. General trends for the Cahaba River, based on the USGS gage at West Blocton, AL (02423647) are summarized for the period of record (1976-1984) in Figure 18 and Figure 19. Average monthly discharge is highest between March and April, with the lowest flow conditions of the year on average occurring in July, August and September (Figure 18, Figure 19); average annual flow for the period of record is approximately 1200 cfs.

For the Centreville, AL gage, mean daily flows for the Cahaba River show considerable seasonal variation (ranging from 401 cfs to 4,800 cfs), primarily resulting from lower precipitation rates and higher evapotranspiration rates at various times of the year (Table 10). Additional gages maintained by the

USGS in the vicinity of the refuge with water quantity data are listed in **Table 8** and are displayed in Figure 15 earlier in this document.

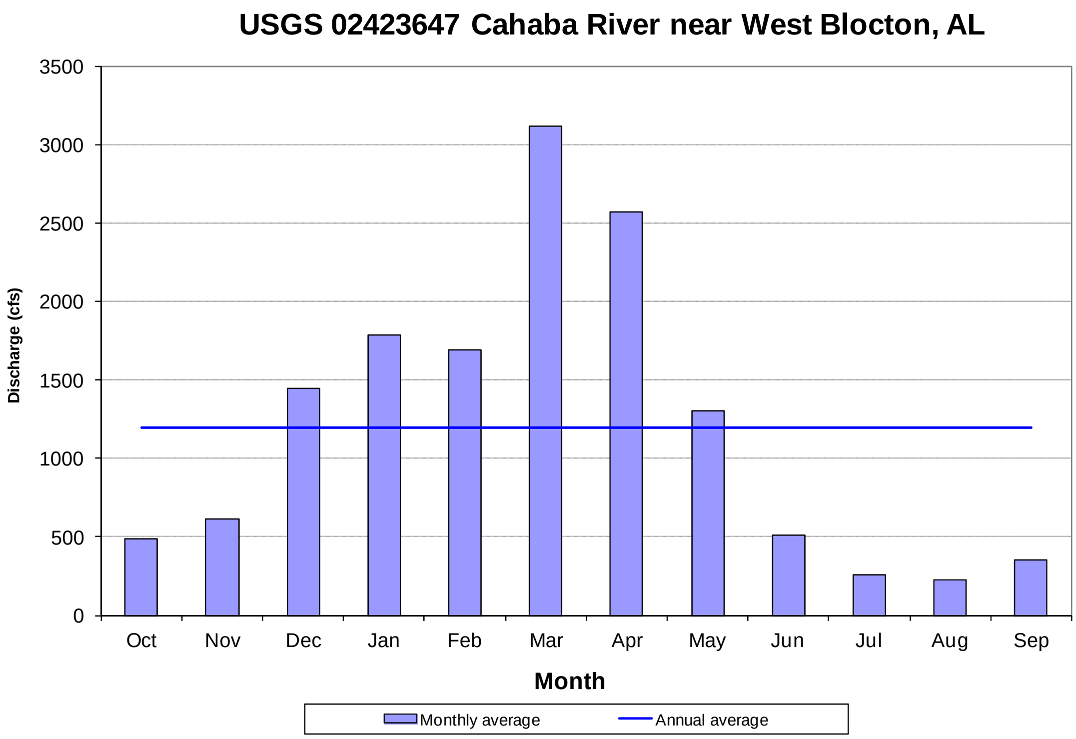


Figure 18. Monthly average discharge at Cahaba River near West Blocton, AL (1975 – 1984). [Source: USGS 2013a]. Annual average flow is approximately 1200 cfs.

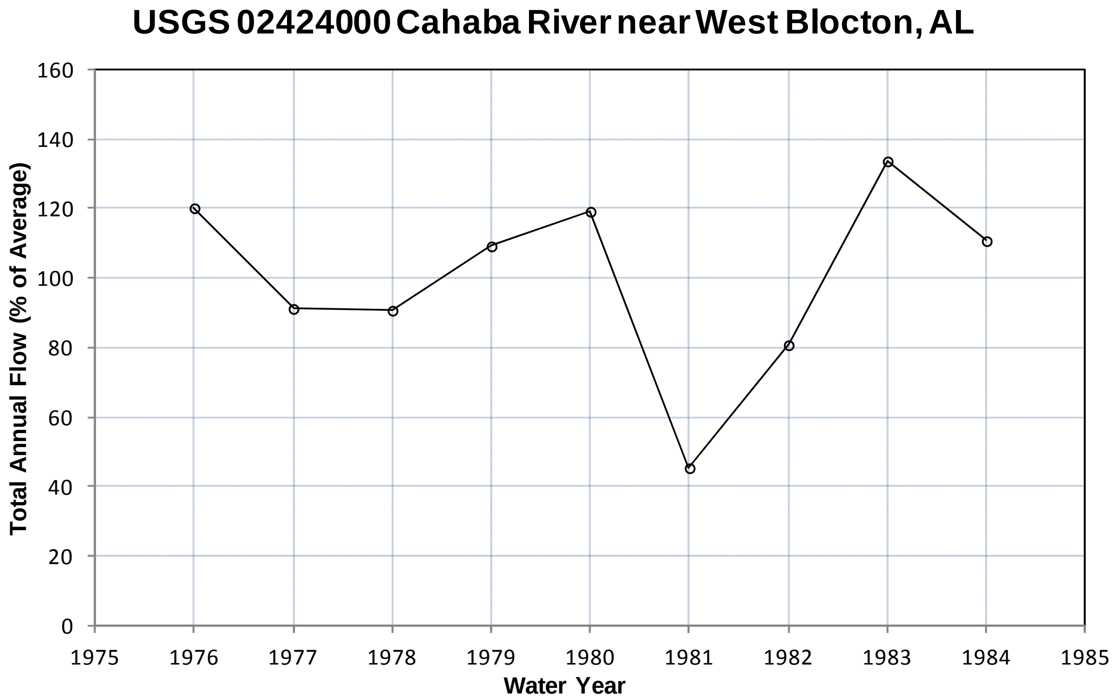


Figure 19. Total annual flow as a percentage of the average for Cahaba River near West Blocton, AL (1976 – 1984). [Source: USGS 2013a].

Table 10. Mean of mean daily discharge values (cfs) for each day for 85 - 88 years of record (1900-2012) at Centreville, AL (USGS 0242000). [Source: USGS 2013a].

Day of month	Mean daily discharge values (cfs) at Centreville, AL (USGS Gage 02424000) (Period of Record: 1900 to 09-30-2012)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	2,280	2,520	3,350	3,730	1,900	1,030	820	794	434	713	428	1,230
2	2,010	2,950	3,160	3,200	1,880	1,010	992	718	462	629	487	1,200
3	2,060	3,100	3,440	3,000	1,750	947	905	673	549	562	542	1,320
4	2,240	3,740	3,720	3,290	1,780	865	845	614	710	558	620	1,420
5	2,410	3,720	3,360	3,840	1,560	834	778	582	688	697	697	1,280
6	2,850	3,740	3,710	3,670	1,460	730	760	573	628	719	615	1,200
7	3,030	3,650	4,070	3,430	1,450	706	805	659	564	559	529	1,250
8	3,240	3,380	3,830	3,650	1,630	889	749	606	480	534	602	1,130
9	2,890	2,990	3,310	3,080	1,760	836	713	560	424	539	527	1,050
10	2,800	3,280	3,080	2,520	1,460	717	718	557	422	532	639	1,170
11	2,700	3,410	2,910	2,340	1,290	642	909	553	427	502	1,000	1,400
12	2,640	2,870	2,820	2,780	1,340	874	844	570	415	466	1,440	1,710
13	2,360	2,760	3,330	3,480	1,630	1,080	813	580	416	475	1,150	1,590
14	2,110	2,560	3,200	3,570	1,410	766	878	609	424	460	1,150	1,520

15	1,950	2,550	3,210	2,850	1,730	791	937	757	401	443	1,200	1,570
16	1,990	3,620	3,930	2,470	1,690	826	902	1,010	426	466	1,090	1,550
17	1,850	3,770	3,720	1,910	1,340	858	962	890	688	421	957	1,470
18	2,140	3,100	3,000	1,780	1,510	893	812	765	703	470	795	1,670
19	2,870	2,800	3,370	2,100	1,740	899	708	629	726	447	769	1,660
20	3,390	3,030	3,980	2,280	1,810	853	635	603	585	423	806	1,570
21	3,120	3,350	4,400	1,940	1,450	710	574	569	780	426	794	1,650
22	2,650	4,230	3,830	1,800	1,290	761	609	531	702	483	934	1,720
23	2,670	3,850	3,180	1,810	1,180	908	681	475	731	498	1,120	1,720
24	2,720	3,220	2,790	1,630	1,150	887	672	446	707	452	1,200	1,700
25	3,220	2,810	2,620	1,770	1,010	709	704	550	591	456	1,130	1,740
26	3,030	2,550	2,560	1,800	924	859	605	517	554	561	1,060	1,710
27	2,760	2,640	3,010	2,060	945	817	652	562	564	493	1,040	1,620
28	2,520	3,600	3,960	1,870	940	718	734	483	725	471	1,640	2,380
29	2,190	1,810	4,350	1,800	967	743	715	454	1,160	433	1,570	2,400
30	2,390		4,280	1,940	908	783	646	407	822	409	1,320	2,080
31	2,640		4,800		910		755	404		411		2,280

5.4.2 Hydrologic Alterations

<u>Dams</u>: Although described as Alabama's longest free-flowing river, the Cahaba River technically contains the longest stretch of free-flowing river in Alabama (an approximately 150 mile stretch of free-flowing water from the Highway 280 diversion dam to the river's confluence with the Alabama River).

The diversion dam south of the U.S. Highway 280 bridge over the Cahaba River in Birmingham, AL was built in 1891 (Figure 20). It was constructed to stabilize the pool for drinking water withdrawals and is still being maintained to manage water levels in the river. It is 15 feet high, backs up water for approximately 3.5 miles upstream, and has a non-functioning fish ladder. It is the only significant structure remaining on the main branch of the Cahaba River (Paul Freeman, personal communication, August 14, 2012). There is only one reservoir within the Cahaba River basin: Lake Purdy on the Little Cahaba River in Jefferson and Shelby counties. The masonry dam forming Lake Purdy reservoir was constructed in 1911 and was originally 40 feet high and 250 feet long. In 1929, the dam was raised an additional 20 feet which increased the storage capacity of the lake to 5.7 billion gallons (17,500 acre-feet of storage (Stricklin 1994; Mooty and Kidd 1997). Lake Purdy is used as a supplemental water supply for Birmingham and surrounding communities.

Historically there were mill dams and small dams on the mainstem of the Cahaba River, but most have been removed or breached. For example, the Marvel Slab low-head dam, which was located north of the refuge on the Cahaba River, was removed over several days beginning October 21, 2004 (Figure 20). Originally built in 1965, this concrete dam was 6 feet high and 210 feet wide, with 46 culverts. It allowed logging and mining trucks and equipment to cross the Cahaba River, but was abandoned in the 1980s. The dam blocked access to habitat for aquatic species and was a safety concern for water recreation.

Prior to removal, mussel and snail species, including many threatened and endangered specimens, were relocated to avoid impacts. Post-deconstruction monitoring (2004 – 2010) indicates increasing snail and mussel densities both upstream and downstream of the former dam site (TNC & USACE 2009; Freeman 2011) (Section 5.3.1.3).

Downstream of the refuge (but outside of the Cahaba River basin) there are two navigation locks and dams located on the Alabama River: the Millers Ferry Lock and Dam (Alabama River Mile [ARM] 133) and the Claiborne Lock and Dam (ARM 73). (The Cahaba River enters the Alabama River near ARM 189.) These two dams were both constructed in the 1960s and significantly impact the ability of many fish species to migrate upstream and downstream from the Alabama River to the Cahaba River, although multiple agencies including USFWS are working with the U.S. Army Corps of Engineers (USACE) to provide fish passage around these dams with varied degrees of success (USFWS 2000; Simcox 2012; TNC 2012). The Robert F. Henry Lock and Dam is a major dam located on the Tallapoosa River (ARM 236).

Surface Water Withdrawals: The surface water intake for the city of Birmingham, AL is maintained by the Birmingham Water Works Board (BWWB), and is located on the Cahaba River upstream of the refuge (Figure 20). The annual water use report for the USGS gage at Centreville, AL (USGS Gage 02424000) states that an average of 82 cfs is diverted upstream from the station by the BWWB (Howard et al. 2002; USGS 2012). The amount diverted and its effect on water resources is highly seasonal. During periods of low flow, virtually all of the discharge of the river is removed at this point, with a portion returned to the river as treated wastewater near U.S. Highway 31 (Howard et al. 2002). The flow on the Cahaba River, based on gage data from Centreville, AL, shows flow is partly regulated by Lake Purdy reservoir on the Little Cahaba River, and by several waste-water treatment plants (USGS 2012).

Within the Cahaba River basin, the total surface water usage in 2005 was 56.64 million gallons per day (mgd), representing 67% of all freshwater use. The BWWB was the largest user at 93% (52.9 mgd), followed by irrigation (3.49 mgd) and livestock (0.25 mgd). BWWB is the only public supplier of surface water; all other public suppliers in the Cahaba River basin rely on groundwater (Hutson et al. 2009). The BWWBs current capacity is 184 mgd and demand is expected to grow to 222 mgd by 2075 as result of population growth in the Birmingham area (Benke and Cushing 2005; Bryant 2010). Since expected demand is beyond BWWBs current capacity, additional drinking water sources are being sought, including water from the Black Warrior basin through inter-basin water transfers.

Groundwater Withdrawals: Besides natural groundwater discharged to streams through seeps and springs, pumpage from wells accounts for any other measurable discharge from the aquifer system. Groundwater withdrawals within the Cahaba River basin, based on 2005 data, totaled approximately 5% of total groundwater withdrawals from state waters; 27.3 mgd of groundwater were withdrawn, 96% of which was for public suppliers. Other categories of groundwater use included irrigation (0.42 mgd), industry (0.40 mgd) and livestock (0.17 mgd) (Hutson et al. 2009). Mooty and Kidd (1997) estimated groundwater use in 1990 to be about 2% of the estimated mean-annual baseflow, and 9.7% of the average drought baseflow near the end of the droughts of 1941, 1954, and 1986. Mooty and Kidd (1997) state that because groundwater use represents a relatively minor percentage of groundwater recharge, even a large increase in groundwater use for the study area (Subarea 7) would likely have little effect on groundwater and surface-water occurrence in Alabama.

Indications of long-term groundwater level declines were not observed; however, long-term groundwater-level measurements at observation wells in Subarea 7 are insufficient to draw conclusions (Mooty and Kidd 1997). Long-term withdrawals of water from the aquifers may result in the formation of depressions on the potentiometric surface of the aquifers, the extent of which depends on the water-bearing characteristics of the surrounding sediments (Kopaska-Merkel et al. 2005).

Treated Wastewater Discharges: Municipal wastewater treatment plants (WWTPs) have historically contributed the majority of nutrient loading to the Cahaba River (ADEM 2006b). Major NPDES-permitted WWTPs in the Cahaba basin discharge to the mainstem of the river, at Trussville and in the Hoover vicinity, Buck Creek and tributaries, and the Little Cahaba River (above Lake Purdy) (ADEM 2006b). There are 12 major (>1.0 million gallons per day [mgd]) and 19 minor(<1.0 mgd) permitted wastewater discharge points, over 100 industrial discharge permits, and over 40,000 septic systems within the watershed (ADEM 2006b). There are varying estimates of the amount of treated wastewater being released into the Cahaba basin. Based on ADEM (2006b), 27 mgd (50 cfs) of treated wastewater are released into the watershed daily with additional permitted capacity to allow over 43 mgd (80 cfs). Other estimates (Randall Haddock, personal communication) show permitted WWTPs within the Cahaba system have a total discharge design volume of 51 mgd (95 cfs), but some plants regularly discharge at rates well over their design, and WWTP discharges are heavily influenced by rain events. An examination of a Permit Compliance System (PCS) retrieval file of the major discharges (>1 mgd) to the Cahaba River and associated tributaries revealed many incidences of NPDES permit violations, for nutrient or nutrient related parameters, over a five year period (November 1996 – November 2001) (Howard et al. 2002).

Road/Stream Crossings: Stream connectivity and habitat diversity are critical components of healthy rivers; the free passage of fish and aquatic species within rivers, streams and estuarine environments is a vital aspect of aquatic ecology. Road crossings can act as barriers by creating a physical blockage, a hydrological barrier, or by forming artificial conditions that act as behavioral barriers to aquatic fauna. The impact of road crossings on stream connectivity and aquatic communities varies depending on the design of the structure, the nature of flow, debris and sediment movement in the waterway, and the mobility of aquatic fauna. Recognizing the imperilment of aquatic species in the Cahaba River, a stream/road crossing analysis was completed for Bibb County, AL from 2008 to 2009. An initial GIS analysis identified 242 sites for road/stream crossing classification. Using methodology adopted from USDA Forest Service National Inventory Assessment Procedure (2005), USFWS staff (refuge staff and staff from the Warm Springs Fish Technology Center) evaluated these 242 sites. Road/stream crossings were placed into three groups (passable, indeterminate, and perched) by visual inspection. Crossing locations that could not be reached because of inaccessibility such as closed roads, private property issues, or locked gates were documented, but not surveyed. Site visits were conducted at 176 of the 242 identified sites. The remaining 66 sites were documented as inaccessible (n=48), on U.S. Forest Service property (n=6), or left as incomplete (n=12). The majority of sites were considered passable (n=92), some were perched (n=54), some were indeterminate based on hydrological conditions (n=19), and the remainder had no flow (n=7) or were not a crossing (n=4). These data were compiled by the refuge with various electronic files, GIS layers, and documents. Conducting this work in other counties such as Shelby County was recommended. Separate from this refuge-based assessment, the Geospatial Fisheries Information Network of the USFWS (GeoFIN – http://ecos.fws.gov/geofin) includes 87 barriers to fish passage in the Cahaba basin (HUC 03150202).

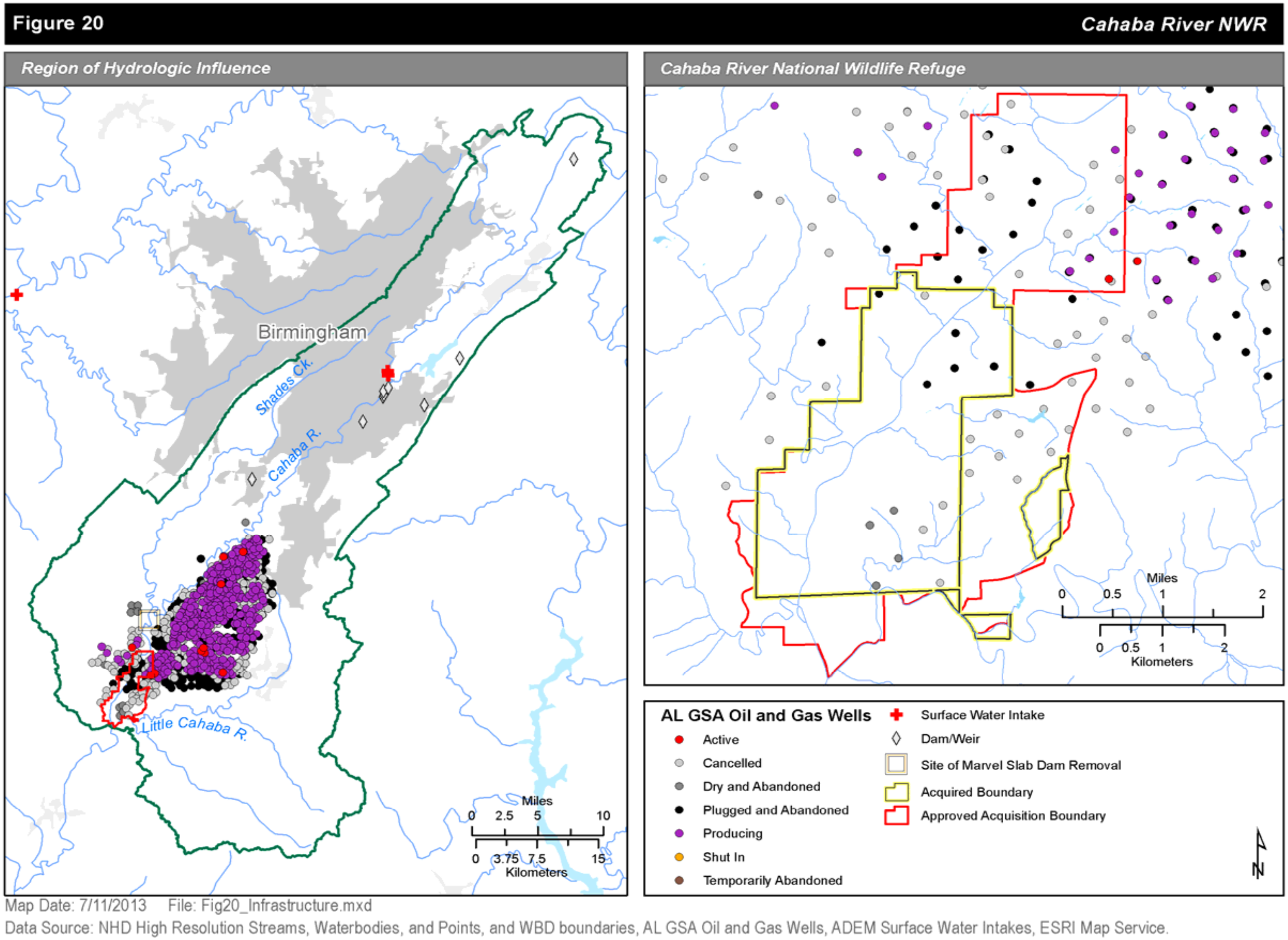


Figure 20. Oil and gas wells, flow diversions, and dams/weirs within the Region of Hydrologic Influence and proximal to the Cahaba River NWR.

5.4.3 Land Use Activities Affecting Water Quantity and Timing

Historical use of refuge lands ranges from intensive strip-mining to intensive silviculture, resulting in altered topography (USFWS 2007). Past land use activities continue to affect landscape dynamics including runoff, soil infiltration capacity, and evapotranspiration rates due to shifts in the forest community structure.

Energy Development: Both surface mining and underground mining for coal are actively taking place within the Cahaba basin (Johnson et al. 2002). In addition to coal, oil and gas are also being extracted from the watershed. The GSA issues permits for oil and gas wells, including coalbed methane wells. Figure 20 shows a high concentration of oil and gas wells within the RHI (>1200 wells) including sites within and upstream of the refuge acquisition boundary. Most of the wells within the refuge acquisition boundary were cancelled, dry and abandoned or plugged and abandoned. However, there are active and producing wells (>380 wells) located northeast of the refuge acquisition boundary (Appendix J). Coalbed methane wells produce relatively high quantities of water compared to conventional oil and gas wells. Wells in the area typically produce an average of 1827 gallons of water per well per day. Water volumes pumped from wells decrease over time as gas production increases following well dewatering. Water disposal is regulated by state and federal agencies and the disposal option (e.g., supplement to water supplies, subsurface injection, surface discharge) depends on the composition of the water. The primary disposal method in the basin is surface discharge (USGS 2000).

Urbanization: The degree of urbanization in a watershed is often measured in terms of impervious area. Impervious areas include roads, driveways, parking lots, and rooftops. As urban environments expand, so too does the impervious area resulting in various hydrologic impacts to water resources. Increased impervious surface alters the timing, duration, frequency, and magnitude of surface water flows, resulting in direct and indirect impacts to receiving streams, such as flooding, channel incision, erosion, and streambed alteration.

As impervious surface increases, surface runoff also increases. The added erosive force of amplified peak flows scours banks and in-stream habitats, produces localized flooding, increases sediment loads, and can drastically alter stream geomorphology. Steam temperatures can also increase as a result of urban runoff (Schueler 1987). The impacts of added impervious area linger even after the storm events pass. The converse to increased runoff is a reduction in soil infiltration, recharge of aquifers, and shallow groundwater storage, which thereby limits the amount available water to sustain baseflow in dry conditions. Increased urbanization includes the increased road density, and potentially more road/stream crossings that can impair stream flow, inhibit migration and movement of aquatic organisms, and drastically change stream hydrology.

GIS land change analysis for the Cahaba River watershed (both the upper and lower watersheds, and combinations of one or the other) have been completed by multiple agencies for various purposes. Overall, the various land use summaries and analyses show the extent of urban and "disturbed" areas are increasing in the central and upper part of the Cahaba River watershed, and increased urbanization in general within the watershed, as discussed in Section 4.6 (Anthropogenic Landscape Changes).

Increased urbanization also increases pollution of waterways (e.g., chemicals, excess nutrients, and sediments from roads, residential areas, sewers, and construction sites). Additional discussion related to urbanization and water quality is found in Section 5.5.4.

5.5 Water Quality Conditions

More than 10 studies (spanning multiple years) have been conducted since 1994 on the Cahaba River basin relating biological communities to water quality conditions (see ADEM 2006a,b; Table 2-2). Some of these data contributed to the listing of water segments in the Cahaba basin as impaired under §303(d) of the Clean Water Act. These data indicate that the health of the system within the listed segments ranges from fair to poor based on species diversity, benthic community structure, and biological condition. The causes are attributed primarily to two mechanisms: siltation from urbanized land areas, and eutrophication (attached filamentous algae growth, also known as periphyton) due to nutrient loading from municipal wastewater sources and nonpoint sources (O'Neil 2002; EPA 2002). Based on available data and information, historical wastewater impacts may have been a contributing reason for the reduction in range of the threatened and endangered species in the basin as well (ADEM 2006b; USFWS 2009b). The river experienced dissolved oxygen (DO) sags in the 1970s and early 1980s due to wastewater discharges from the Patton Creek Wastewater Treatment Plant, which was inactivated in the late 1980s (ADEM 2006b). Water quality in the Cahaba River has improved since this time due to improvements in wastewater treatment (Blancher et al. 1999, 2002). The current biological status/trends of the river may partially be due to a slow recovery from these impacts.

In order to characterize the present biology and water quality for the Cahaba River, the U.S. EPA Region 4, Water Management Division (WMD) requested staff of the Science and Ecosystem Support Division (SESD) to conduct studies of the Cahaba River and associated tributaries during the spring and summer of 2002. Studies were conducted in March /April, July and September of 2002 and focused on the causes of impairment in the Cahaba River. The objective of these studies was and is to provide supporting information for the development of a Total Maximum Daily Load (TMDL) for §303(d) listed segments of the Cahaba River. The study included multiple rapid bioassessments of the benthic macroinvertebrate community, snail density surveys, surveys of periphyton, stream geomorphology surveys, and water quality sampling for nutrients, chlorophyll-*a* and algal growth potential. Work was published in a 2002 report with an addendum in 2006 (Howard et al. 2002; EPA 2006). Results showed elevated nitrogen, phosphorus, and excess sedimentation impacting aquatic habitat and biological communities. Overall, the study found excessive sedimentation and nutrient enrichment to be the major water quality problems on the Cahaba River (Howard et al. 2002; EPA 2006).

During 2002, and again in 2012, the Aquatic Assessment Unit (AAU) of the Field Operations Division (ADEM) completed basinwide screening assessments of the Black Warrior and Cahaba River basins (ADEM 2004). Reviews of land use, ADEM regulatory databases, listing documents, and monitoring data collected by multiple agencies were completed to identify data gaps and to prioritize subwatersheds with the greatest potential for point and nonpoint source impairment. Selected sites were monitored using ADEM's screening-level assessment techniques. Based on analysis of recent bioassessment and intensive water quality monitoring data, 41 impaired subwatersheds were identified, 14 of which contain §303(d) stream or reservoir segments (ADEM 2004). Data for 2012 are not yet reported.

As noted previously, hydrologic conditions affect surface water quality, including high variability in streamflow, characterized by extremely low flows in the late summer-early autumn seasons, magnified peak flows due to high impervious land cover in urbanized areas, decreased groundwater infiltration and retention, and the occasional dewatering effects of the major municipal water supply withdrawal above U.S. Highway 280. Summer and autumn low-flow periods result in reduced stream velocities, increased retention time, and reduced dilution of point source effluents, conditions which are particularly conducive to excessive algal growth when nutrients are in abundance (ADEM 2006b).

According to the Cahaba River Basin Management Plan, rapid urbanization and commercial development in the area south and southeast of Birmingham (Jefferson, Shelby and St. Clair counties) is the primary force directly shaping water quality conditions and biological communities in the upper Cahaba River drainage, and indirectly in the lower Cahaba River drainage through material and pollutant transport (CRBCWP undated). The lower Cahaba River basin is primarily rural, with Centreville, AL and Marion, AL being the largest urban areas (CRBCWP undated). The Cahaba Basin Management Plan also notes the potential for acid mine drainage within the basin, but lists it as the lowest priority in terms of toxic substance sources. Several wood treatment facilities that utilize creosote and other chemicals are located within the middle Cahaba River basin and episodic discharges of these toxins have been known to occur in the past (CRBCWP undated).

Water quality concerns on the refuge include upstream impacts from legacy and current coal mining and energy extraction operations, legacy and current timber operations, urban development (e.g., water withdrawals, run-off, altered flows, etc.) and wastewater discharge from treatment plants (USFWS 2007; USFWS 2009b). In addition, there are suspected groundwater quality impacts due to underground coal mining; however, baseline data have not been collected. Coal in the vicinity of the refuge is known to have above average arsenic, nickel, and strontium levels (USFWS 2009a).

5.5.1 State Water Quality Regulations

ADEM administers the State's water quality standards for surface water quality, both the designated uses and the criteria intended to protect those uses.

Designated Uses: Designated uses are listed in ADEM Administrative Codes for Water Quality (335-6-11), and the water quality criteria are found in Alabama Administrative Code 335-6-10: (http://www.adem.state.al.us/alEnviroRegLaws/files/Division6Vol1.pdf, March 2013). In Alabama, waters can be assigned one or more of seven designated uses pursuant to ADEM Administrative Code 335-6-11 (http://adem.alabama.gov/programs/water/wquality/2012WAM.pdf). These uses include: 1) Outstanding Alabama Water (OAW), 2) Public Water Supply (PWS), 3) Shellfish Harvesting (SH), 4) Swimming and Other Whole Body Water-Contact Sports (S), 5) Fish and Wildlife (F&W), 6) Limited Warmwater Fishery (LWF), and 7) Agricultural and Industrial Water Supply (A&I).

Designated uses 1 through 5 in the list above are considered by U.S. EPA to be consistent with the "fishable/swimmable" goal and, therefore, provide for protection of aquatic life and human health. The State also has two special designations – Outstanding National Resource Water (ONRW) and Treasured Alabama Lake (TAL). These high quality waters require a thorough evaluation of discharges from new or expanded point sources of pollutants and may be assigned to any one of the first five designated uses in the list above.

ADEM recognizes sections of the Cahaba River (including portions that flow through the refuge) as Outstanding Alabama Waters: from the Alabama River upstream to Shelby County Road 52, from the dam near U.S. Highway 280 to Grant's Mill Road, and from U.S. Highway 11 upstream to the source of the Cahaba River (ADEM 2012b). The Little Cahaba River in Bibb County is also designated an Outstanding Alabama Water from its source downstream 16.54 miles to the confluence of the Cahaba (ADEM 2012b). These sections are also designated for Fish and Wildlife uses, and a stretch of the river above the Highway 280 dam is classified as a public water supply (ADEM 2010; ADEM 2012b). A number of Cahaba River tributaries are classified for swimming uses, in addition to the fish and wildlife classification (Pitt 2000). The U.S. EPA lists the Cahaba River basin as a priority watershed for the Southeast Region (EPA 2013).

Water Quality Standards: In Alabama, the Alabama Water Improvement Commission (AWIC) first adopted water quality standards in 1967. In 1982, the Alabama Department of Environmental

Management (ADEM) was formed by merging AWIC with elements of the Alabama Department of Public Health (ADPH). Since first being adopted in 1967, Alabama's water quality standards have been amended on numerous occasions (ADEM 2010). The Alabama Environmental Management Commission (AEMC) has the authority to adopt revisions to the ADEM Administrative Code. The Designated Uses (Chapter 335-6-11 of the Administrative Code) and the Water Quality Criteria (Chapter 335-6-10 of the Administrative Code) are reviewed once every three years pursuant to U.S. EPA regulations at 40 CFR Part 131.20. Known as the triennial review, this process gives the public the opportunity to comment on Alabama's water quality standards. Any changes that ADEM may propose because of the review process are subject to further public comment before consideration by the AEMC.

Under §303(d) of the Clean Water Act, states are required to compile a list of impaired waters and submit that list to the U.S. EPA for approval. Impaired waters are those which do not meet applicable state water quality standards (i.e., waters that do not support their designated use). Listed waters are then scheduled for development of a TMDL, which provides a plan to restore the designated use of the water. Federal regulations require that states consider all existing and readily available information when compiling a §303(d) list. U.S. EPA considers the formal listing process under the Endangered Species Act to be readily available information, and the loss of use of a water segment by a listed aquatic species due to degradation of water quality and/or aquatic habitat to be evidence of impairment. Consequently, such waters must be included on state §303(d) lists and addressed by TMDLs designed to restore conditions suitable for the endangered species. States have responsibility for the development of TMDLs, which are subject to U.S. EPA approval. The applicable water quality criteria in this case are narrative, ADEM Administrative Code, Rule 335-6-10-.06(c) under Minimum Conditions Applicable to All State Waters. Therefore, the process of developing a target for this TMDL will require a numeric translation of narrative water quality criteria to reflect a level of nutrients that would protect the aquatic habitat for the species of concern.

ADEM is responsible for water quality regulation and Clean Water Act reporting. Annually, ADEM collects extensive chemical, physical, and biological data related to surface water groundwater quality across the state, using standardized sampling protocols. River basins are sampled on a 5-year rotating basis. Water quality assessments are reported annually for ambient monitoring, and water quality reports are submitted biennially to Congress and to the U.S. EPA (305(b) Reports) as required by the Clean Water Act. These reports provide a summary of activities related to surface water quality and an assessment of surface water quality conditions in Alabama. Impaired waters lists, §303(d) lists, are also generated using these data (http://www.adem.state.al.us/programs/water/waterquality.cnt). The Cahaba Basin was sampled in detail in 2002 (ADEM 2004) and in 2012 (not yet reported).

Antidegradation Rule: On June 25, 2002, the Alabama Environmental Management Commission adopted Rule 335-6-10-.12, Implementation of the Antidegradation Policy. This rule codifies procedures for implementing ADEM's Antidegradation policy contained in Rule 335-6-10-.04, last amended in 1991 and approved by U.S. EPA Region 4 in 1991. The final implementation procedures rule became effective on August 1, 2002. ADEM's antidegradation policy serves to conserve and protect the waters of Alabama by preventing the deterioration of a waterbody, even when its water quality surpasses the level necessary to meet the fishable and swimmable goals of the Clean Water Act (ADEM 2012b). This antidegradation implementation policy addresses Tier 3, Tier 2, and Tier 1 waters and beneficial uses, and codifies the procedures for reviewing applications for new or expanded discharges to waters designated as Tier 2 waters (that the proposed discharge is necessary for important economic or social development in an area and an evaluation by the applicant of alternatives other than the proposed discharge). Additional guidance and discussion of previous litigation surrounding this Rule can be found in ADEM (2012b). The state's antidegradation policy provides for the protection of high quality waters that constitute an outstanding national resource (Tier 3), waters whose quality exceeds the levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water (Tier 2), and existing instream water uses and the level of water quality necessary to protect the existing uses (Tier 1). In Tier 3 waters, ADEM Administrative Code 335-6-10-.10 prohibits new or expanded point source discharges. In Tier 2 waters, ADEM Administrative Code 335-6-10-.04 provides for new or expanded discharge of pollutants only after intergovernmental coordination, public participation, and a demonstration that the new or expanded discharge is necessary for important economic or social development. Alabama's water quality standards regulations (ADEM Administrative Code 335-6-10 and 335-6-11) may be found at the Department's web page: http://www.adem.state.al.us/alEnviroRegLaws/files/Division6Vol1.pdf

Groundwater Regulations: Groundwater is protected by laws at both the federal and state levels. The U.S. EPA is responsible for groundwater protection through the Safe Drinking Water Act, which requires maximum contaminant level standards for drinking water. The Safe Drinking Water Act established The Underground Injection Control, Wellhead Protection, and Source Water Protection Programs, which in Alabama are administered by ADEM. The Resource Conservation and Recovery Act (RCRA) regulates disposal of solid and hazardous wastes and established a national program for the regulation of underground storage tanks. The Comprehensive Environmental Resource Compensation and Liability Act (CERCLA) set up a Superfund and authorized the federal government to clean up chemical spills or hazardous substance sites that threaten the environment. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), allows U.S. EPA to control the availability of potentially harmful pesticides. The Toxic Substances Control Act (TSCA) authorizes U.S. EPA to control toxic chemicals that could pose a threat to the public and contaminate ground water. The Surface Mining Control and Reclamation Act (SMCRA), regulates mining activities, some of which can negatively impact groundwater.

Specific laws passed by the Alabama Legislature that address protection of groundwater include the Alabama Water Pollution Control Act, the Hazardous Waste Management and Minimization Act, the Alabama Underground Storage Tank and Wellhead Protection Act, and an act which established the Hazardous Substances Cleanup Fund. With the authority provided by these state laws, U.S. EPA allows the State of Alabama to administer the national environmental programs metioned above. ADEM administers all of these programs except for those under FIFRA, which are carried out by the Alabama Department of Agriculture and Industries (ADEM 2001).

In 1993 Alabama developed a Comprehensive State Groundwater Protection Program for statewide groundwater protection. The goal of Alabama's Groundwater Protection Program is the protection of groundwater for drinking water and other beneficial uses. This goal is found in the Alabama Water Pollution Control Act.

5.5.2 Impaired Waters, TMDLs and NPDES Permits

Within the Cahaba River watershed there are 185 miles of streams that do not support, or only partially support, their designated uses (ADCNR 2005). U.S. EPA designated §303(d) waters include 106 miles of the Cahaba River. Major Cahaba River tributaries such as Shades Creek (55 miles impaired), Little Shades Creek, Patton Creek, and Buck Creek are also impaired. Causes of impairment are due to nutrient over-enrichment, compounded by concurrent effects of excess sedimentation and extremes in prevailing hydrologic patterns, as well as elevated levels of pathogens, turbidity, and siltation (ADEM 2006b).

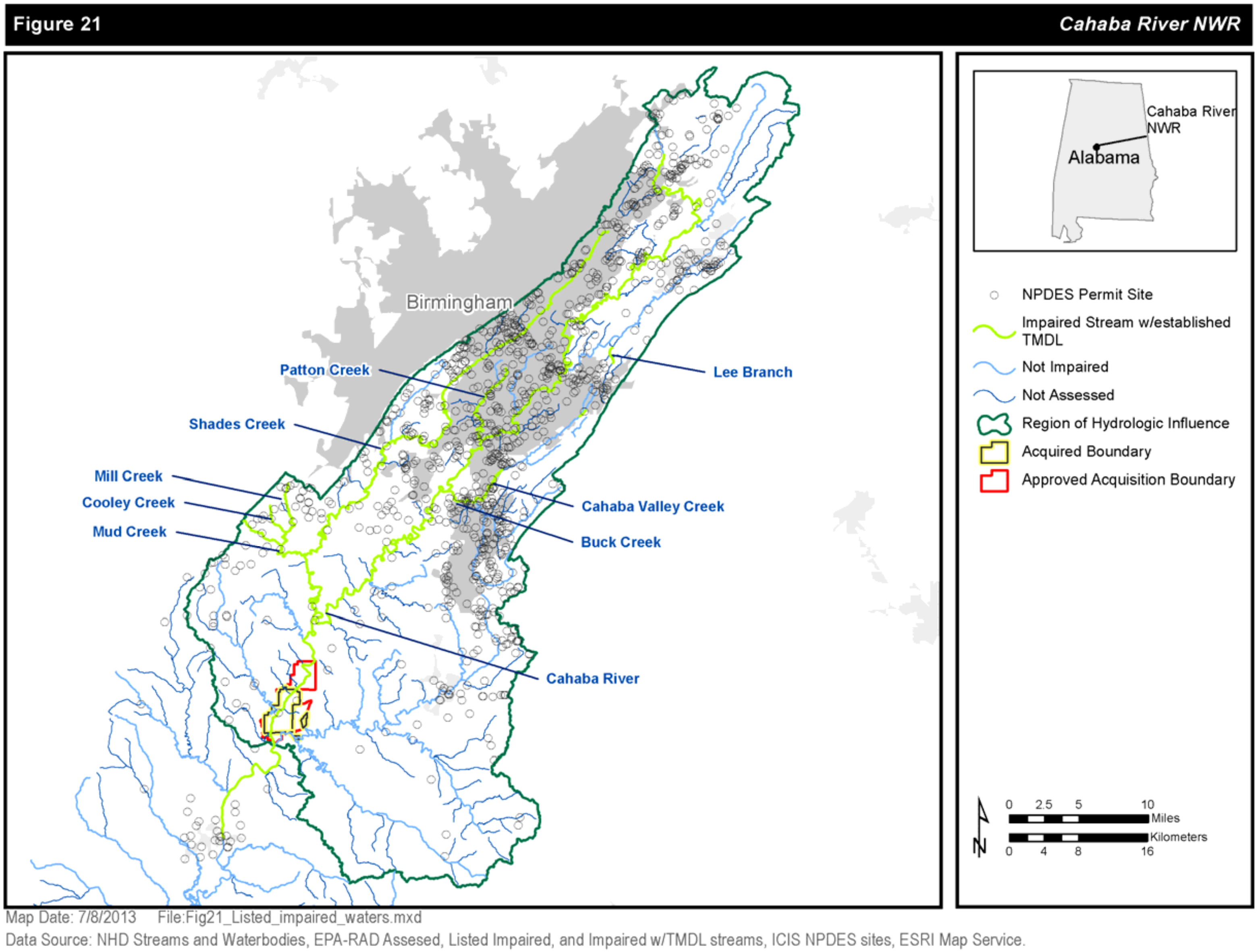


Figure 21. Impaired and assessed streams and NPDES permits within the Region of Hydrologic Influence for the Cahaba River NWR.

Table 11. Existing Total Maximum Daily Loads (TMDLs) for impaired streams within the Region of Hydrologic Influence. [Source: EPA 2010].

Waterbody Name	TMDL ID	TMDL Date	Impairment
Shades Creek	11070	11/1/2004	Other Habitat Alteration(s), Turbidity, Siltation
Shades Creek Watershed (Including Shades Creek, Mud Creek, Mill Creek, And Cooley Creek)	10764	10/29/2003	Pathogens
Patton Creek	11548	1/31/2006	Organic Enrichment/ Low Dissolved Oxygen
Cahaba River	30895	10/26/2006	Nutrients
Lee Branch	40853	9/29/2011	Pathogens
Buck Creek	36541	9/23/2009	Pathogens
Cahaba Valley Creek	36556	9/23/2009	Pathogens

There are several existing TMDLs for impaired streams in the RHI (Table 11, Figure 21). The Cahaba River itself, including the entire extent within the refuge acquisition boundary, was listed as impaired due to phosphorus and sedimentation/siltation (ADEM 2010; EPA 2010). In addition, the Cahaba River between the U.S. Highway 280 diversion dam and Buck Creek is listed as impaired due to pathogens (ADEM 2012d). A nutrient TMDL was approved for the Cahaba River watershed in 2006 (ADEM 2006b) and a draft TMDL for siltation and habitation alteration in the Upper Cahaba River watershed has been prepared and is under revision (ADEM 2012a). Additionally, portions of the Little Cahaba River (0.7 miles) and Caffee Creek (1.6 miles) within the refuge acquisition boundary were assessed in 2008 and found to be unimpaired.

There are 1,138 National Pollutant Discharge Elimination System (NPDES) permittees within the RHI (Figure 21, Appendix K). ADEM issues NPDES permits for point source discharges from facilities such as wastewater treatment plants, mines, and other commercial and industrial activities. For example, there are at least 103 industrial discharge permits in the Cahaba Basin, releasing a variety of toxic metals, chemicals and other substances (USFWS 2007). Permits require the implementation of best management practices (BMPs) to reduce pollution as well as periodic monitoring. In the majority of the mainstem Cahaba River upstream of Centreville, during normal or low flow conditions, effluent discharges from NPDES-permitted point sources dominate and control ambient instream nutrient concentrations (ADEM 2006b). Data analysis of the years 1999-2001 indicates that major NPDES-permitted point sources accounted for nearly 70% of the total phosphorus loading to the Cahaba River, according to an analysis conducted by ADEM (2006). An examination of a Permit Compliance System (PCS) retrieval file of the major discharges (>1 mgd) to the Cahaba River and associated tributaries revealed many incidences of NPDES permit violations for nutrient or nutrient related parameters during a five year period (1996-2001) (Howard et al. 2002).

Within the refuge acquisition boundary, there are two facilities with NPDES stormwater permits. The Piper I mine, operated by Jesse Creek Mining LLC (formerly Talcoa Minerals LLC), was issued a NPDES permit in 2009 for a new source coal mine located near the southern end of the refuge in proximity to Caffee Creek (Table 12). The facility's permit allows discharge of iron, manganese, and solids (suspended and settleable) from 46 outfalls to the Cahaba River and unnamed tributaries (ADEM 2009). As part of its permit, the facility is required to monitor each point source discharge twice monthly for iron, total suspend solids (TSS), pH and manganese and submit quarterly Discharge Monitoring Reports (DMR) to ADEM. Recent DMRs available on ADEM's website show six sampling sites, only one of which (Outfall 40) consistently has any discharge.

The Piper II Mine Reclamation Project was granted coverage under a general NPDES stormwater permit in 2011 for discharges associated with land disturbance from reclamation activities (Table 12). Drainage from the project site will continue to discharge into an exposed mine portal located at the base of the highwall. If drainage overflows the mine portal, as currently happens during extreme storm events, it discharges into the Cahaba River (ADEM 2011; USFWS 2012a; Appendix C).

Table 12. NPDES permittees within the Cahaba River NWR acquisition boundary. [Source: EPA undated].

NPDES ID	Facility Name	Address	Latitude	Longitude	Permit Issued	Permit Expiration
AL0079511	TALCOA MINERALS LLC PIPER MINE (currently Jesse Creek Mining LLC)	SEYMOUR CR 10	33.075278	-87.071389	FEB-09-2009	FEB-08-2014
ALR107849	PIPER II	S SIDE OF HWY 24, 0.73 MILES FROM THE CAHABA RIVER	33.088056	-87.048333	AUG-16-2011	MAR-31-2016

5.5.3 Groundwater Quality

Surface Contamination of Groundwater: The GSA, in cooperation with the ADEM, is revising and expanding a series of hydrogeologic reports that delineates the major aquifers in Alabama and characterizes their vulnerability to contamination. The original reports were prepared by the USGS, in cooperation with ADEM. The state was divided into 13 areas based on physiographic regions; each area is addressed in separate reports. The report on Area 7, which encompasses the refuge, is still in development (Amye Hinson, GSA, personal communication May 2, 2013). The Area 4 report (Kopaska-Merkel et al. 2005), includes areas upstream from the refuge in the headwaters of the Cahaba River basin and within the RHI for this assessment. This report includes assessment of the Coker and Pottsville aquifers within the larger Valley and Ridge and Pottsville aquifer systems, all of which influence the refuge. The report states that the recharge areas of the Valley and Ridge aquifer system are highly vulnerable, and the Pottsville aquifer system is moderately vulnerable to contamination from the land surface in the recharge area, noting that pumping of public water supply wells and irrigation wells can increase the potential for aquifer contamination through altered flow gradients.

Numerous surface sources of potential contamination include point sources such as gasoline tanks, underground storage tanks, septic tanks, landfills, chemical spills, pipeline and sewer leaks, treatment lagoons, and industrial sites. Potential nonpoint sources of pollution include chemicals applied to agricultural fields, confined animal feeding operations, onsite sewage system discharges, chemicals applied to lawns and gardens, and urban runoff (ADEM 2001; Kopaska-Merkel et al. 2005).

Groundwater Withdrawals: No aquifer is immune to contamination from poorly constructed wells and bad management practices. Pumping of large quantities of groundwater by public supply wells, industrial supply wells, or irrigation wells creates cones of depression, increases flow gradients, and draws groundwater and any associated contamination, where present, toward the pumping wells. Further, some contaminants can enter an aquifer in the recharge area or in the vicinity of a poorly constructed well, or enter confined portions of the aquifer typically not vulnerable to direct surface contamination.

5.5.4 Land Use Activities Affecting Water Quality

Historical Coal Mining: Past coal mining and remnants of those activities on the refuge pose the potential for water quality impacts to the Cahaba River and its tributaries. There is an abandoned coal mining portal associated with the Piper II mine on the refuge, which periodically fills with water and is leaching arsenic and strontium (Section 4.6). This portal has the potential to introduce contaminants to both surface and groundwater. The area's coal is high in arsenic, nickel and strontium. A preliminary study associated with the Piper II reclamation found that Thompson Coal, the type thought to be present in the gob pile, is relatively low in pyritic sulfur which is the major contributing factor determining the potential for acid mine drainage generation (QORE, Inc. 2004).

Urbanization: The Cahaba River basin includes the Birmingham, AL metropolitan area, the largest residential and commercial area in the state. Effects of the urban expansion of Birmingham on stream ecosystems in the Mobile Basin were specifically addressed by Coles et al. (2012), in addition to providing an in-depth review of the effects of urban development on stream ecosystems. 2010 census data shows that the City of Hoover in south Jefferson County and adjacent communities in north Shelby County are some of the fastest growing areas in the state. ADEM (2012a) assessed land use change for the Upper Cahaba subwatershed based on 2006 NLCD land cover data, showing that the developed urban areas are concentrated in the central and upper part of the subwatershed, while the lower part is dominated by rural forested landscapes. With the heavy development of the Cahaba River watershed in the last two decades, nutrient enrichment originating from both point and nonpoint sources is a valid concern. This enrichment, along with periphytic growth and excessive sedimentation has contributed to a decline in the overall ecological health of the Cahaba system. For example, the increased volume of stormwater runoff associated with increased imperviousness in urban areas is the largest source of sediment loading to Shades Creek and the Cahaba River (ADEM 2007b; ADEM 2012a). Current threats to refuge surface water quality include sedimentation from upstream sources (e.g., urban and suburban development, commercial timber activities), nutrient inputs from point source discharges (e.g., wastewater treatment plants, septic system failures) and contamination from active mining operations and creosote and wood treatment plants. Excess periphytic growth from excess nutrients and excessive sedimentation as a result of urban growth in the Birmingham area translates into impacts to aquatic fauna (fish and benthic invertebrates) of the Cahaba River (Howard et al. 2002). GIS analysis reveals a significant increase in "disturbed" lands after 1990. For example, the percentage of "disturbed" land in the Cahaba watershed increased from 8.8% in 1990 to 38.7% in 1998. Wang et al. (1996) found that when urbanization exceeds 10%, the Index of Biotic Integrity scores were consistently very low. In addition, in-stream habitat was also adversely affected.

Energy Development: The GSA issues permits for oil and gas wells, including coalbed methane wells. Figure 20 shows a high concentration (>1200 wells) of oil and gas wells in the southern end of the RHI, within and upstream of the refuge acquisition boundary. Most of the wells within the refuge acquisition boundary were cancelled, dry and abandoned or plugged and abandoned, but there are active and producing wells (>380 wells) located northeast of the refuge acquisition boundary (Appendix J). The water produced by coal degasification is generally of higher quality than that of conventional oil and gas wells; however, depending on several factors including the depth of the coal bed, this water can be high in total dissolved solids and in some cases can be saline. Water disposal is regulated by state and federal agencies and the disposal option (i.e., supplement to water supplies, subsurface injection, surface discharge) depends on the composition of the water. The primary disposal method in the basin is surface discharge (USGS 2000). In 1990, the Cahaba River was listed as one of the 10 most endangered Rivers by American Rivers due to proposed methane gas wells (American Rivers 1990). As new technologies become available for coal and other resource extraction, energy development in the watershed will continue to be a concern.

5.6 Water Law/Water Rights

5.6.1 State Water Law Overview

Almost all American states treat surface water (the water in lakes, streams, and creeks) separately from groundwater despite the hydrogeologic interconnection of most of these resources. To regulate surface waters, Alabama adopted and modified the “riparian” common-law doctrine of England (Sax et al. 2006; Elliott 2012). To regulate groundwater, Alabama abandoned the English law governing groundwater and adopted the “American Reasonable Use Rule,” (Sax et al. 2006; Elliott 2012). Alabama has never adopted a modern statute to regulate water use comprehensively.

Water is regulated under the Alabama Water Resources Act (AWRA), Ala. Code § 9-10B-1 *et seq.*

Riparian Water Rights: Alabama follows traditional common-law riparian doctrine to determine legal rights in surface waters. That common law derives originally from England in the 1700s, although it has evolved in the United States to address changes wrought by the Industrial Revolution and subsequent developments (Elliott 2012). Common-law riparian doctrine associates the right to use water with the ownership of land abutting the water. Technically, “riparian” refers to rivers and streams, while “littoral” refers to lakes, but the term “riparian rights” includes lakes, streams, and rivers. Thus, the only way to obtain riparian rights is to purchase riparian property.

As summarized by Elliott (2012) and Sax at al. (2006): A riparian landowner has the right to use a portion of available water (stream or lake) for domestic use and irrigation. Water for irrigation and other commercial purposes must be "reasonable” with respect to the requirements of all other riparian owners. This doctrine can also be applied to groundwater. Riparian rights are generally followed in Eastern states, and were influenced by British Common Law. Needs of other riparian owners must be taken into account. "Reasonable" is defined on a case-by-case basis through litigation. In times of drought, theoretically riparian owners suffer equally. Originally, the riparian doctrine did not allow riparian owners to sell water to non-riparian landowners. As populations have increased, however, variations have been adopted to overcome these and other obstacles.

*Water Withdrawals***:** Alabama has a registration and reporting system in place for surface and groundwater withdrawals. This system involves the Alabama Office of Water Resources (OWR) and a division of the Alabama Department of Economic and Community Affairs with oversight by the Alabama Water Resources Commission. The OWR is responsible for the planning, coordination, development and management of Alabama's ground and surface water resources (NCSL 2013).

The Alabama Water Use Reporting Program, administered by the Alabama Department of Economic and Community Affairs’ OWR, requires that all public water systems and all individuals and organizations with the capacity to withdraw 100,000 gallons per day or more to register with OWR and obtain a Certificate of Use (ADECA undated). This requirement is applicable for both surface and/or groundwater withdrawals.

The OWR and the Water Resources Commission have the responsibility to develop plans and strategies for the management of water use in the state. Use of water for human consumption is considered the highest priority use, and no limitation on human consumption shall be imposed except in an emergency. Any water that is put to a beneficial use shall not be curtailed unless the user is in a “capacity stress area” (Ala. Code § 9-10B-2). “Beneficial use” is defined as the “diversion, withdrawal, or consumption of the waters of the state in such quantity as is necessary for economic and efficient utilization consistent with the interests of this state" (Ala. Code § 9-10B-3(2). "Capacity stress area" is defined as an area of the state where the Water Resources Commission determines that the use of water requires coordination, management, and regulation (Ala. Code § 9-10B-3(3)). One must give a declaration of beneficial use in order to receive a certificate of use by the OWR. Anyone who has the potential to divert, withdraw, or consume 100,000 gallons of water a day or more, and is determined by the Commission as necessary to further the purposes of the Act, is required to file a declaration of beneficial use (Ala. Code § 9-10B-20(c)). However, no declaration of beneficial use shall be required and no certificate of use shall be issued for 1) In-stream uses of water, including, but not limited to, recreation, navigation, water oxygenation system, and hydropower generation, or 2) Impoundments covering not more than 100 acres in surface area confined and retained completely upon the property of the person ("person" includes USFWS) and used solely for recreational purpose, including sport fishing. Any certificate of use must contain the following statement: "The Issuance of this Certificate of Use Shall Not Confer or Modify Any Permanent Interests or Rights in the Holder Thereof to the Continued Use of the Waters of the State of Alabama" (Ala. Code § 9-10B-20(e)). When the Commission determines that a capacity stress area needs limitations on water use, it must immediately undergo rulemaking to impose conditions on holders of certificates of use. In other words, all certificate holders equally bear the burden of shortage, which is typical of Eastern water law. Furthermore, no certificate holder has a priority to water use over other holders or those without a certificate.

Navigable Waters: The Rivers and Harbors Act of 1899 defined navigable waters as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use, to transport interstate or foreign commerce" (ADEM undated). The Cahaba River is classified as navigable waters by the State Lands Division as determined by the Commissioner of the Alabama Department of Conservation and Natural Resources (ADCNR 2003). As such, the waterbottom (below mean-low water), is owned by the State of Alabama. Non-tidally influenced streams (like the Cahaba River) that are declared "navigable," entitle state ownership of the streambed only to the mean low water mark. Therefore, even when a freshwater stream is navigable, the state doesn't own the streambed from bank to bank; the sand bars and stream banks above mean low water are privately-owned property.

Navigable Servitude: Streams which have been declared to be navigable are open to the public. Even if one part of the streambed in a navigable stream is owned by the state and the remainder is private property, a person has a right to be anywhere on that stream, provided that person remains afloat and does not wade onto the privately-owned portion of the streambed without the landowner's permission.

5.6.2 Aspects of State Water Law That May Negatively Affect the Station

Water is regulated under the Alabama Water Resources Act, Ala. Code § 9-10B-1 et seq. (Brown-Kobil 2006). This Act disavows any intent to change existing water rights, which are conferred by common law (Elliott 2012).

Unless USFWS meets the definition of "beneficial use," Alabama law prohibits the Service from receiving a certificate of use if those refuges are only interested in instream flows. However, the mere issuance of a certificate of use does not confer any right or interest in the holder so it is debatable whether USFWS would want to explore how to meet state definitions of beneficial use (Brown-Kobil 2006).

There is no mechanism in Alabama law for USFWS to protest the issuance of a certificate which may adversely affect refuge water use beyond traditional common law methods of filing for a court injunction (litigation). A declaration of beneficial use is only required to certify that the user does not interfere with any other legal use that the user is aware of at the time of the application (Ala Code § 9-10B-20; see also Ala. Admin. Code r. 305-7-10.02(b)(3)).

Due to the way navigable waters are defined, neither the state nor a riparian landowner can prevent a floating gravel dredge from navigating the creek. The state could deny the dredge operator permission to remove state-owned mineral resources from the streambed below mean low water. Due to adverse impacts to stream habitat and aquatic functions, instream mining in state-owned waterbottoms is not allowed by ADCNR, although the mining of sand and gravel bars above mean low water can (and is in certain cases) permitted by ADEM. However, Section 10 of the Rivers and Harbors Act of 1899, as amended, prohibits the unauthorized alteration of any navigable water of the United States including the excavation or filling of any such water. The Act defined navigable waters as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use, to transport interstate or foreign commerce" (ADEM undated).

From Elliott (2012) and Butler (1985): The Alabama State Legislature has given no entity the power to comprehensively manage water resources. OWR can take action in some limited circumstances, but in receiving applications and issuing Certificates of Use (COUs), OWR serves largely a ministerial function and does not manage Alabama's water resources for long-term sustainability. After the passage of Alabama Water Resources Act (AWRA) in 1993, the Alabama Supreme Court stated that "Alabama does not have an agency devoted to the conservation and management of its water resources." This absence of regulatory authority contrasts sharply with other states following common-law riparian doctrine that have adopted statutes governing water law. Those states have recognized that the common law functions reasonably well in times of abundance, but not in drought conditions. Population growth, economic development, and less dependable water supplies (through pollution, climate change, or the like) have revealed systemic weaknesses in the common law.

Alabama's groundwater law does not promote long-term sustainable use, or considerations within the context of climate change. If groundwater withdrawal and usage patterns increase or change, or if changing climate prevents normal recharge of the state's aquifers, the American reasonable use rule provides no basis for rationing groundwater for sustained use (Elliott 2012).

5.6.3 Existing Formal Water Rights

Currently, Cahaba River NWR does not hold any formal water rights, other than Riparian Rights to the Cahaba River, as a land owner adjacent to the Cahaba River. The refuge currently does not have any active or historic permits for water withdrawal or use.

6 Assessment

This section highlights major water resources-related threats or issues of concern pertaining to the refuge. To provide context, a brief discussion of the primary driver of threats to the refuge's resource base is presented and then specific threats or issues of concern are detailed in two categories: urgent or immediate issues (those for which impacts are already strongly manifest) and longer term issues. Some recommendations to address these threats are also summarized.

6.1 Water Resource Issues of Concern

For many freshwater aquatic systems like those protected by Cahaba River National Wildlife Refuge, water quality and water quantity are the two most critical factors influencing the ability of managers to meet the primary purposes of refuge establishment.

Rapid urbanization and commercial development in the area south and southeast of Birmingham (Jefferson, Shelby and St. Clair counties) are the primary forces shaping water quality conditions and biological communities both directly in the upper Cahaba River drainage and indirectly in the lower Cahaba River drainage through material and pollutant transport (CRBCWP undated). Multiple water quality surveys have found high levels of nitrogen and phosphorus, heavy metals, low dissolved oxygen, organic enrichment, siltation, and chemical spills in the upper basin.

Water quality concerns on the refuge include upstream impacts from urban development (e.g., excess sediment and nutrients, water withdrawals, run-off, altered flows, point source and nonpoint source pollution), wastewater discharge from treatment plants, and impacts to both surface water and groundwater from legacy, current and future energy development in the watershed.

Water quantity concerns on the refuge include urban development, population growth, surface water and groundwater withdrawals, alteration of the natural flow regime ecological flows, and larger scale and long-term impacts from climate change on multiple factors influencing water quantity and quality.

6.1.1 Urgent/Immediate Issues

- <u>*Water Quantity*</u>:
    - The surface water intake for the city of Birmingham, AL is maintained by the Birmingham Water Works Board, and is located on the Cahaba River upstream of the refuge. The annual water use report for the USGS gage at Centreville, AL (USGS Gage 02424000) states that an average of 82 cfs is diverted upstream from the station (Howard et al. 2002; USGS 2012). The average amount diverted is highly seasonal; during periods of low flow, virtually all of the discharge of the river is removed at this point with a portion returned to the river as treated wastewater near U.S. Highway 31 (Howard et al. 2002). The flow on the Cahaba River, based on gage data from Centreville, AL, shows flow is partly regulated by Lake Purdy reservoir on the Little Cahaba River, and by several waste-water treatment plants (USGS 2012).
    - The Birmingham Water Works Board's current water withdrawal capacity is 184 mgd and demand is expected to grow to 222 mgd by 2075 as population growth increases in the Birmingham area (Bryant 2010).

- *Water Quality*:
    - One quarter of Alabama's population draws its water from, and/or discharges its wastewater into, the Cahaba River watershed. There are 12 major and 19 minor permitted wastewater discharge points, over 100 industrial discharge permits in the upper watershed of the Cahaba River, and over 40,000 septic systems within the watershed (ADEM 2006b). It is estimated that 27 million gallons of treated wastewater is released into the watershed daily with additional permitted capacity to allow over 43 million gallons/day (mg/d). Permit violations at major discharge locations, for nutrient or nutrient related parameters, have occurred (Howard et al. 2002).
    - Within the Cahaba River watershed there are 185 miles of streams that do not support, or only partially support, their designated uses (ADCNR 2005). U.S. EPA-designated §303(d) waters include 106 miles of the Cahaba River. Major Cahaba River tributaries such as Shades Creek (55 miles impaired), Little Shades Creek, and Patton Creek are also impaired. The impact of increased urbanization, along with mining and industrial development in the upper Cahaba River Basin, have degraded water quality and threaten the future of human health and the diverse, endemic, and imperiled aquatic communities found in the Cahaba River (ADCNR 2005).
    - Improving water quality is critical to the recovery of many of the federal trust species within the watershed. Freshwater mussels at certain life stages are more sensitive to certain pollutants (e.g., copper, ammonia, and pesticide constituents) at concentrations below what current U.S. EPA water quality criteria allow (Augspurger et al. 2007). The recovery of many federally listed species within the watershed, through re-introduction or augmentation, depends upon a documented improvement in the water quality of the system.
    - Nonpoint sources of nutrients in the Cahaba River basin are primarily due to anthropogenic activity strongly correlated to land use. Urban (residential, commercial, industrial, and transportation) land uses exhibit high total phosphorus concentrations in runoff compared to reference conditions. Specific anthropogenic sources can include land disturbance, fertilizer application, use of phosphate-containing detergents, and subsurface flow derived from approximately 40,000 onsite septic systems in the basin. Trends of land use in the characterized subwatersheds ranged from approximately 3.7% to over 44% urban classification (residential, commercial, industrial and transportation categories), although the majority of sites had 25% or more urban classification.
- *Energy Development:*
    - Currently, there are more than 1200 oil and gas wells found within the RHI, with numerous wells located within and upstream of the refuge acquisition boundary. Most of the wells within the refuge acquisition boundary were cancelled, dry and abandoned or plugged and abandoned, but there are active and producing wells (>380 wells) located in and adjacent to the northeast portion of the refuge acquisition boundary (Figure 20, Appendix J). The wastewater produced as a by-product of coal degasification can be high in total dissolved solids and in some cases can be saline. Water disposal is regulated by state and federal agencies and the disposal option (supplement to water supplies, subsurface injection, surface discharge) depends on the composition of the water. The primary disposal method in the basin is surface discharge (USGS 2000).

- In 1990, the Cahaba River was listed as one of the 10 most endangered Rivers by American Rivers due to proposed methane gas wells (American Rivers 1990). As new technologies become available for coal and other resource extraction, energy development in the watershed will continue to be a concern.
- Coal continues to be extracted from lands surrounding Cahaba River NWR. Direct and indirect impacts to the Cahaba River and its tributaries continue as a result of this resource extraction. For example, coal sludge (a by-product of processing coal) directly impacted tributaries to the Cahaba River including Piney Woods Creek and Caffee Creek, which resulted in fines and other enforcement cases (ADEM 2007c; ThinkQuest 2007). The risk of both surface water and groundwater degradation exist from extraction, processing, and transport of coal, oil, and gas within the watershed.

- *Invasive Species:*
  - Aquatic Invasive Species (AIS), particularly those species that may be impacting the distribution of native species in shoal habitats, is a concern. Currently, USGS (2013b) lists 16 aquatic invasive species documented in the Cahaba watershed (HUC 03150202). This list consists of predominantly introduced fishes, although one hydrozoan (*Craspedacusta sowerbyi*) and one mollusk (*Corbicula fluminea*) have been detected.
  - Invasive plant species (both terrestrial and aquatic) pose unique threats to the Cahaba River basin and the refuge. For example, beginning in 2007, managers within the Cahaba River basin noted concerns over the invasion of alligatorweed (*Alternanthera philoxeroides*), a herbaceous freshwater perennial plant that forms dense mats in water bodies, wetlands, low-lying and even upland areas (ALIPC 2011). This aggressive invasive aquatic plant, in concert with other stressors such as sedimentation, can negatively impact the Cahaba lily, other endemic plants, animals, and imperiled species dependent on shoal habitats by reducing flows, increasing flooding, and altering physical and chemical processes of the exposed rock and flowing water shoal habitats. To date, alligatorweed, while present in the refuge, has not become established on lands adjacent to the river. Patches of alligatorweed in pools below shoals or tree-falls have been washed downstream by highwater events (Randall Haddock, personal communication 11-26-2013).
  - Other invasive aquatic plants that directly threaten the Cahaba River basin include hydrilla (*Hydrilla verticillata*), Eurasian water milfoil (*Myriophyllum spicatum*), Chinese Privet (Ligustrum sinense) and Chinese Tallow (*Triadica sebifera*). Along with alligatorweed, these species are considered to be some of the worst invasive plants in Alabama since they degrade habitat for fish and wildlife, threaten endangered species, displace native species, and dramatically alter ecological processes (ALIPC 2011).
  - With climate change and watershed alteration, some native species are becoming nuisance/noxious. For example, the diatom *Didymosphenia geminata* is a single-celled alga (Bacillariophyceae) with increasing prevalence in North America (Spaulding and Elwell 2007). It is considered invasive in the Southern Hemisphere including New Zealand (Kilroy et al. 2004, 2005, 2008) and recently Argentina (Sastre et al. 2013). This diatom has been reported in the western U.S. for over 100 years, but more extensive, nuisance growths have recently become common and appearing with greater frequency in the eastern U.S. (Spaulding and Elwell 2007; Kumar et al. 2009). Nuisance blooms of *D. geminata* affect the diversity, abundance, and productivity of other aquatic

organisms. Kumar et al. (2009) found that mean temperature during the warmest quarter was the most important factor influencing *D. geminata* distribution, implying that the distribution of this species will be very sensitive to climatic change. Furthermore, the response of this species to climate change and watershed alteration is an example of the ability of stream organisms to adapt to the effects of environmental change (Williamson et al. 2008).

- With climate change and continued introductions from human activities, yet unknown introduced species may pose future risks to the refuge and the Cahaba River basin.

6.1.2 Longer-Term Issues

- *Unknown Impacts Related to Climate Change*:
  - Although the specific impacts climate change will have on the Cahaba River system are not known, climate change is likely to magnify the influences of other identified threats and challenges (Scott et al. 2008) currently impacting the system.
  - Climate models project continued warming in the southeastern United States and an increase in the rate of warming through 2100. The projected rates of warming are more than double those experienced since 1975, with the greatest temperature increases projected to occur in the summer. By 2080, projected mean temperature increases range from about 4.5°F under a low CO_2 emissions scenario to 9°F (10.5°F in summer) under a higher CO_2 emissions scenario (Karl et al. 2009).
  - Based upon information contained within the Report by the Climate Change Science Program (CCSP 2008), it is anticipated that Alabama will experience a slightly drier winter and summer, a slightly wetter spring, and a significantly wetter fall. Although overall precipitation levels are predicted to increase, higher temperatures will cause greater evaporation which, combined with the expected increase in severity of storm events, will lead to less water absorbed, retained and available for use for natural systems, businesses and the public.
  - Increases in temperature would increase water temperatures, placing additional stress on the system. These anticipated climate effects could dramatically alter the aquatic and terrestrial ecosystems of the Cahaba River basin.
  - Any change that exacerbates current in-stream flow, water quality, and water quantity challenges within the Cahaba River system will make recovery and management of federal trust resources (including the multiple federally listed aquatic species within the Cahaba system) more difficult.
  - Climate change along with continued introductions of non-native species as a result of human activities may result in yet unknown invasive species that pose future risks to the refuge and the Cahaba River basin.

- *Urban Expansion / Urbanization Within the Watershed*:
  - The growing human population within the Cahaba River watershed will continue to have direct negative effects on water quantity and water quality. Modifications within the Cahaba River system to support a growing population could include

increases to the region's water storage capacity, direct water diversions from the Cahaba River, increases in treated wastewater, and increased storm runoff.

- o Increased impervious surface as a result of urbanization within a watershed results in various hydrologic impacts to water resources. Impacts on stream flow include increased frequency of flooding and peak flow volumes, increased sediment loadings, loss of aquatic/riparian habitat, changes in stream physical characteristics (channel width and depth), decreased base flow, and increased stream temperature (Schueler 1987). In addition, increased urbanization increases pollution of waterways (including chemicals from roads, housing areas, and sewers, and sediments from construction). Increased urbanization includes the increased road density, and potentially more road/stream crossings that can impair stream flow, inhibit migration and movement of aquatic organisms, and drastically change stream hydrology.
- o During the previous two decades, the Cahaba River watershed has been one of the most rapidly developing urban areas due to its proximity to Birmingham. Bibb County and Shelby County were ranked 15th and 19th, respectively, as counties within large metropolitan areas with the largest number of imperiled species in the nation (Ewing 2005). The U.S. EPA GIS land change analysis for the Cahaba River watershed documented a dramatic increase in the "disturbed" land use class from 8.8% in 1990 to over 38% in 1998 (Howard et al. 2002). Continuing development within the watershed has led to water quality degradation, sedimentation and hydrologic modification of stream flows. These conditions continue to place stress on populations of aquatic species and negatively impact the Service's ability to recover the many trust resources found within the watershed.

▪ *Commercial Timber Operations*:

- o The South contains the most intensively managed forests in the United States. Over the last 50 years timber production more than doubled and the area of planted pine grew from virtually nonexistent to 39 million acres, or about 19% of forests (Wear and Greis 2012).
- o In Alabama, approximately 70% of the state (approximately 22.9 million acres) is forested and roughly 30% of these forests are in pine plantations (AFC 2013). The forest industry is the state's second largest manufacturing industry, producing an estimated $12.8 billion in 2010. Of timberland acreage, 85% is owned by non-industrial private landowners (AFC 2013).
- o There has been a significant conversion of native hardwood/pine forests into even-aged loblolly pine plantations throughout Alabama. This dependence on forest commodities has allowed Alabama to remain mostly forested but has come at a cost to many sensitive native species that depend upon older, less disturbed habitats. The loss of native hardwood/pine forests is the greatest conservation issue in this region for avian species (Demarest 2006).
- o Approximately 65% of the Cahaba River basin is forested (ADCNR 2005) and actively or passively managed for timber, primarily by corporate timber and investment companies. Most upland natural vegetation communities in the region have been cleared. The mature forest and the birds dependent on mature forest are less secure here (Southern Ridge and Valley Region) than in any other physiographic area in the Southern Appalachians (Demarest 2006). The long-term health of priority

bird populations is considered dependent on maintenance and management of remnant forest, as well as, aggressive restoration efforts (Demarest 2006).

- Changing harvest methods and plantation management are influencing watersheds in Alabama. Pine plantations are harvested at a much greater frequency. Genetic improvements in loblolly pine, more intensive management, and a shift from harvesting sawtimber to smaller diameter pulpwood sized trees has increased the frequency of harvest and, in turn, increased soil loss, sediment, and contaminants entering Alabama's waters. This increased frequency (<22 years vs. >35 years) of harvesting and replanting, and intensive forest management has also resulted in an increase in herbicide use in the watershed. Recent studies indicate that freshwater mussel glochidia are very susceptible to surfactants and certain active ingredients in pesticides (Bringolf et al. 2007; Augspurger et al. 2007) commonly used for site preparation in pine plantations. New uses of forest products (e.g., bio-fuels) to reduce reliance on fossil fuels may further increase harvest rates (timber market growth would focus on small diameter pines) and increase inputs of sediments and other associated contaminants into the watershed (Wear and Greis 2012).
- Invasive species influence how pine plantations are managed. Of the 380-plus recognized nonnative plants in southern forests and grasslands, 53 are rated high-to-medium risk for natural communities. These plants often out-compete native species and alter species composition of forests, resulting in impacts to forest productivity, diversity, and wildlife habitat (Wear and Greis 2012). Although additional invasion of southern forests by nonnatives is certain, the rate of spread, extent of damage, and the implications for forest conditions make invasive species the least certain of the factors affecting forests in the South (Wear and Greis 2012).
- A combination of socioeconomic and biophysical factors will reshape the forests of the South, and their interaction may amplify the direct effects. Forest futures will most strongly depend on combinations and interactions of the effects of four key factors: population growth, climate change, fiber markets, and invasive insect, disease, and plant species (Wear and Greis 2012).

- *Mining Operations*:
  - Past mining impacts include both surface mining and underground mining operations, influencing both surface and groundwater quality and quantity.
  - This history of mining in the watershed has led to the presence of fine coal particles being abundant in stream and river sediments as well as in upland waste piles. Coal particles regularly enter the river system from unreclaimed coal waste piles found in many upland areas throughout the watershed. Coal within the Cahaba basin is high in arsenic, nickel and strontium (USFWS 2009a).
  - New technologies may make it economically feasible to again mine coal at a large scale within the Cahaba River basin in the future.
- *Dams (Upstream and Downstream)*:
  - The presence of two navigational dams on the Alabama River inhibits upstream and downstream movement of fish. Impoundments between dams accumulate sediments that destroy the gravel and sand bars and riffle habitats of many freshwater fish species. Maintenance dredging associated with navigation has eliminated sand and gravel bars important for spawning, blocked many stream mouths, and led to down-

cutting occurring in the portions of the Cahaba River channel below the Fall Line. Pulse releases from hydroelectric dams have adversely altered tailwater habitat and water quality conditions within the State. Dams for water storage, even on tributary streams, affect flows within the Cahaba River.

- Fish biomass, abundance and diversity within the Alabama River and the Cahaba River has decreased substantially as a direct result of downstream dams, affecting distributions of biological communities at multiple trophic levels (USFWS 2009b).
- The primary adverse impact of existing dams and their impounded waters in the Cahaba River basin is to form barriers to the movement of many species of fishes, mussels, snails, insects, and crustaceans, fragmenting populations and eliminating genetic interchange between them. As a result, imperiled aquatic species surviving in the basin's unimpounded tributaries and mainstem river reaches have become isolated and virtually without avenues of immigration and emigration (USFWS 2000). Several species of fish (24 *spp*.) including paddlefish (*Polyodon spathula*), quillback (*Carpiodes cyprinus)*, highfin carpsucker (*Carpiodes velifer)*, southeastern blue sucker (*Cycleptus meridionalis)*, and smallmouth buffalo (*Ictiobus bubalus)* all have the ability to make long distance movements (Mettee et al. 2006), suggesting that fish passage operations could positively influence a number of species (Simcox 2012).
- Alabama has approximately 124,000 km of rivers and streams (Bayne 1998) and more navigable channels (2,313 km) than any other state (Mettee et al. 1996). Due to the abundance of water and a wide range of physiography, Alabama has one of the most diverse aquatic faunas in the United States, but also one of the highest numbers of imperiled fishes in the nation (Warren and Burr 1994; Lydeard and Mayden 1995). In a study of 51 southeastern US drainages over 20 years, Warren et al. (2000) attributed a 125% increase in the number of jeopardized species to dam construction and associated habitat modifications (e.g., flow alteration, impoundments, channelization, sedimentation). Extensive damming has led to the imperilment of 10% (31 species) of Alabama fishes (Bayne 1998; Simcox 2012).

6.2 Needs and Recommendations

1. *Partnerships*: Many agencies (including multiple programs within USFWS) and citizen groups are active partners in conservation, management and sustainability of the Cahaba River basin. In order to most effectively manage and protect this complex watershed, continued, enhanced, and expanded future support of these and other partnerships is critical.

2. *Water Quantity Information*: Streamflow data documenting the magnitude, frequency, timing, duration, and rate of change throughout the year are critical to guide management activities to meet the refuge's four primary purposes. As part of this data need, it is recommended that current USGS gages in the vicinity of the refuge (in particular, the downstream gage at Centerville [USGS gage ID 02424000] and upstream gages on Shades Creek [02423630] and the Cahaba River near Helena [02423555]) be maintained and an analysis of critical data gaps in gage data (for both surface water and groundwater) be completed in order to evaluate the need for additional gages and monitoring wells. Re-establishment of a stream gage at the location of former USGS gage 02423647 (Figure 15), near the current upstream refuge boundary, should be a high priority.

3. *Groundwater Information*: Research is needed to document and evaluate groundwater contributions to surface flow in the Cahaba River throughout the year. Analysis of aquifer hydrogeology and vulnerability to contamination for the physiographic region that includes the Upper and Lower Cahaba subwatersheds is also needed.

   Mooty and Kidd (1997) were unable to evaluate whether long-term groundwater level declines were occurring in Subarea 7, due to insufficient long-term groundwater-level measurements. As population growth increases in the watershed, and climate change influences aspects of both surface water and groundwater recharge and discharge, the need for long-term groundwater information will increase.

4. *Water Quality Monitoring*: Since the implementation of nutrient and pathogen TMDLs (ADEM 2006b) in the Cahaba River basin and the expected implementation of a sediment TMDL (ADEM 2012b), evaluation of TMDL effectiveness in the watershed will be monitored over time. ADEM has adopted a 5-year basin rotation for its water quality management program, which most recently conducted quality monitoring in the Cahaba River Basin in 2012 (ADEM 2012a). Assuming this schedule is maintained, basin-wide water quality monitoring activities will again take place in the Cahaba in 2017. Potential research could include biological sampling as well as nutrient and sediment modeling for the watershed.

   Research and outreach regarding Best Management Practices (BMPs), specifically highlighting both the correct implementation and evaluation of BMP effectiveness, are needed for reductions in sedimentation and excess nutrients/contaminants as a result of land use disturbance, including forestry practices and construction.

   Specific water monitoring objectives for the refuge should be developed and implemented, either as part of the Inventory and Monitoring Plan for the refuge or as a stand-alone document. Water monitoring efforts are critical for providing the baseline information needs of an adaptive management framework while also meeting refuge level, Regional, and National level Water Resources Inventory and Monitoring Goals and Objectives (USFWS 2010a; USFWS 2013). Specific tasks should target identified water quality threats including sediment, nutrients, and metals (from mining activities) while ideally supplementing (rather than duplicating) existing water monitoring work in the watershed. Research assessing sedimentation (e.g., total suspended solids, bedload transport, and turbidity) in relation to discharge is needed.

5. *Biological Monitoring and Research*: Additional biological monitoring of indicator species with documented life-history traits related to flow conditions (Richter et al. 2003) should be explored. Research to determine the flow requirements of species of management concern, as well as the impacts to aquatic and aquatic-dependent species due to altered flow regimes is critically needed to establish the in-stream flow requirements needed to achieve and sustain refuge purposes. Opportunities to establish research partnerships with the University of Alabama, Auburn University, ADEM, ADCNR, USGS, the Aquatic Biodiversity Center, and other potential partners to meet this need should be explored and supported. Such research could provide a basis for future effort(s) to establish formal water rights (requirements) for the refuge and/or to challenge proposed and future water uses that might adversely affect the refuge.

   Periodic monitoring tied to early detection and rapid response for aquatic invasive species (AIS) should be conducted within the refuge and in contributing watersheds. Opportunities to partner with organizations like the Alabama Invasive Plant Council, Auburn University, ADCNR, Southeast Exotic Plant and Pest Council (SE-EPPC), and other groups supporting education to prevent invasive species introductions/spread, as well as the use of innovative tools and technology for early detection and rapid response for AIS should be prioritized. Monitoring and assessment of invasive species (terrestrial and aquatic) is needed, including: presence/absence, extent, abundance, and effectiveness of control efforts. In addition, data are needed to quantify the impact on native communities and ecological processes, and the potential risk/susceptibility to future invasion such as habitat modeling to determine the habitat preferences and potential geographic distributions of invasive species in terrestrial (Stohlgren et al. 2006) and aquatic (Williamson et al. 2008) systems. With climate change, watershed alteration, and continued introductions from human activities, yet unknown introduced species may pose future risks to the refuge and the Cahaba River basin.

   Dam and Barriers: Depending on endemic and invasive species populations, consideration should be given to removing other barriers to potential fish host migration in the Cahaba River. The work related to the removal of the Marvel Slab, including the long-term evaluation of the recovery process for biological communities, can be used as a model for future restoration. Information gathered, including methods and protocols for assessment, should be applied to other activities that would benefit the fauna throughout the watershed.

   Efforts should continue to evaluate the effectiveness of fish passage structures and strategies on dams (downstream of the refuge) within the Alabama and Mobile River basins. Future research should focus on how the addition of attraction flow and any other lock modifications could be used to improve fish passage on the Alabama River.

6. *Wastewater Management*: Currently, one quarter of Alabama's population draws its water from and/or discharges its wastewater into the Cahaba River basin. As population growth increases in the watershed and the dispersal of homes shifts from a more rural to a more urban landscape, greater amounts of treated (and untreated) wastewater will be released into the system. Currently over 40,000 septic systems exist within the watershed (ADEM 2006b). With increased urbanization, it is likely this number may decrease, with resulting increases in wastewater discharges as more homes are built and hooked up to city sewer lines. ADEM currently supports outreach and education related to septic tank care and maintenance.

7. *Long-term Planning*: A Comprehensive Conservation Plan (CCP) is needed for Cahaba River NWR. Along with a CCP, support for the establishment of the Blue Trail along the Cahaba should be maintained. Consideration to pursue National Wild and Scenic River status for the Cahaba River or large tributaries in the drainage should be considered in order to afford greater protection to

these unique waters and recognition of the recreational and aesthetic value of the watershed. Developing an invasive species management plan (for terrestrial and aquatic invasive animals and plants) would be beneficial for the refuge, especially tied to risk management, early detection, and rapid response. All long-term planning should incorporate climate mitigation, resiliency, and adaptation strategies.

7 Literature Cited

[ADCNR] Alabama Department of Conservation and Natural Resources. 2003. Navigability Determinations for Certain Streams in Alabama. (as of 5/7/2003). 20 pp.

[ADCNR] Alabama Department of Conservation and Natural Resources. 2005. Conserving Alabama's Wildlife: A Comprehensive Strategy. ADCNR, Division of Wildlife and Freshwater Fisheries. Montgomery, AL. 322 pp. Available from: http://outdooralabama.com/research-mgmt/cwcs/outline.cfm

[ADCNR] Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Fisheries Section. 2012. 2012 Checklist of Fishes Occurring in the Freshwaters of Alabama (excel spreadsheet). Presented at the Third Alabama Nongame Wildlife Conference, July 23-24, 2012 in Auburn, AL.

[ADECA] Alabama Department of Economic and Community Affairs. Undated. Water Use Reporting Information. Accessed 25 April 2012. Available from: http://www.adeca.alabama.gov/Divisions/owr/Pages/WaterManagement.aspx#Program

[ADEM] Alabama Department of Environmental Management. 2001. Water Down Under: Alabama's Groundwater Resources. Available from: http://www.adem.state.al.us/MoreInfo/publications.cnt

[ADEM] Alabama Department of Environmental Management. 2004. Surface Water Quality Screening Assessment of the Cahaba and Black Warrior River Basins – 2002. Aquatic Assessment Unit – Field Operations Division, ADEM. Montgomery, AL. 379 pp. Available from: http://www.adem.state.al.us/programs/water/wqsurvey/2002CahabaBWRReport.pdf

[ADEM] Alabama Department of Environmental Management. 2006a. Water Quality in Alabama 2004-2005: 2006 Integrated Water Quality Assessment Report. Accessed 6 April 2012. Available from: http://www.adem.state.al.us/programs/water/waterquality.cnt. Direct Link: http://www.aces.edu/dept/fisheries/aww/twp/references/documents/WaterQualityinAlabamaIntegratedWaterQualityMonitoringandAssessment2006ReportADEM.pdf

[ADEM] Alabama Department of Environmental Management. 2006b. Nutrient Total Maximum Daily Loads (TMDLs) for the Cahaba River Watershed. September 2006. Available from: http://adem.alabama.gov/programs/water/wquality/tmdls/FinalCahabaRiverNutrientTMDLReport.pdf.

[ADEM] Alabama Department of Environmental Management. 2007a. Rivers and Streams Monitoring Program: 2007 Monitoring Summary for Mayberry Creek at George Mill Road in Bibb County. Ecological Reference Reach. 2pp. Available from: http://adem.alabama.gov/programs/water/wqsurvey/table/2007/2007MayberryCk.pdf

[ADEM] Alabama Department of Environmental Management. 2007b. Rivers and Streams Monitoring Program: 2007 Monitoring Summary for Shades Creek at Jefferson County Road 6 – Parkwood Drive. Ambient Monitoring Site. 2 pp. Available from: http://adem.alabama.gov/programs/water/wqsurvey/table/2007/2007ShadesCk.pdf

[ADEM] Alabama Department of Environmental Management. 2007c. Rivers and Streams Monitoring Program: 2007 Monitoring Summary for Piney Woods Creek at Shelby County Road 270. Basin Assessment Site. 2 pp. Available from: http://adem.alabama.gov/programs/water/wqsurvey/table/2007/2007PineyWoodsCk.pdf

[ADEM] Alabama Department of Environmental Management. 2009. National Pollutant Discharge Elimination System Individual Permit: Hope Coal Mine, Inc. – Piper Mine. Permit Number AL0079511. February 9, 2009. Accessed 8 February 2013. Available from: http://edocs.adem.alabama.gov/eFile/Default.aspx.

[ADEM] Alabama Department of Environmental Management. 2010. 2010 Integrated Water Quality Monitoring and Assessment Report: Water Quality in Alabama 2008 – 2009. Accessed 25 April 2012. Available from: http://www.adem.state.al.us/programs/water/waterforms/2010AL-IWQMAR.pdf.

[ADEM] Alabama Department of Environmental Management. 2011. Memorandum confirming coverage of Piper II Mine Reclamation Project under National Pollutant Discharge Elimination System General Permit ALR107849. August 31, 2011. Accessed 6 May 2013. Available from: http://edocs.adem.alabama.gov/eFile/Default.aspx.

[ADEM] Alabama Department of Environmental Management. 2012a. Draft Total Maximum Daily Load (TMDL) for Siltation and Habitat Alteration in the Upper Cahaba River Watershed (HUC 03150202). July 2012. Available from: http://adem.alabama.gov/programs/water/tmdls/7cahabatmdl.pdf.

[ADEM] Alabama Department of Environmental Management. 2012b. 2012 Integrated Water Quality Monitoring and Assessment Report: Water Quality in Alabama 2010-2012. Accessed March 28, 2013. Available from: http://adem.alabama.gov/programs/water/waterforms/2012AL-IWQMAR.pdf Additional waterbody segment classifications and special designations for Alabama waters can be found: http://adem.alabama.gov/programs/water/waterquality.cnt

[ADEM] Alabama Department of Environmental Management. 2012c. Facility Inspection, Piper Mine, NPDES Permit #AL007951. February 21, 2012. Accessed 6 May 2013. Available from: http://edocs.adem.alabama.gov/eFile/Default.aspx.

[ADEM] Alabama Department of Environmental Management. 2012d. Draft 303(d) list for Alabama. Available from: http://adem.alabama.gov/programs/water/wquality/Draft2012AL303dList.pdf

[ADEM] Alabama Department of Environmental Management. Undated. Clean Water Act (CWA) Section 401 Water Quality Certification (WQC). Statutory and Regulatory Authority. Accessed June 2013. Available from: http://www.adem.state.al.us/programs/water/401cert.cnt

[AFC] Alabama Forestry Commission. 2013. Alabama Forest Facts. Accessed December 2013. Available from: http://www.forestry.alabama.gov/forest_facts.aspx

[AHIC] Alabama Historic Ironworks Commission. 2006. Alabama Ironworks Source Book: A Guide to Alabama's 19th Century Charcoal Blast Furnaces and Ironworks. Accessed June 2013. Available from: http://www.alaironworks.com/index.htm

[ALIPC] Alabama Invasive Plant Council. 2011. Alabama's 10 Worst Invasive Weeds. Accessed December 2013. Available from: http://www.se-eppc.org/pubs/alabama.pdf

[ALNHP] Alabama Natural Heritage Program. 2012. Rare Species List for Bibb County. Auburn, Alabama. Last Updated Sep. 18, 2012. Accessed June 2013. Available from: http://www.alnhp.org/submit_query.php

American Rivers. 1990. America's Most Endangered and Threatened Rivers. 1025 Vermont Ave., NW, Suite 720, Washington, DC. Available from: http://www.americanrivers.org/rivers/map/cahaba-river-mer.html

Armes, E. 2011. The Story of Coal and Iron in Alabama. The University of Alabama Press, Tuscaloosa, Alabama. 686 pp. (reprinted from the 1910 publication from the Birmingham Chamber of Commerce)

[ASWCC]. Alabama Soil and Water Conservation Committee. 1998. Conservation Assessment worksheets completed by Local Soil and Water Conservation Districts. Alabama Soil and Water Conservation Committee, Montgomery, Alabama.

Atkins, J.B. 1996. Magnitude and Frequency of Floods in Alabama. U.S. Geological Survey Water Resources Investigations Report 95-4199. Tuscaloosa, Alabama. 238 pp.

Augspurger, T., F.J. Dwyer, C.G. Ingersoll, and C.M. Kane. 2007. Advances and opportunities in assessing contaminant sensitivity of freshwater mussel (Unionidae) early life stages. Editorial in Environmental Toxicology and Chemistry, Vol. 26, No. 10, Pages 2025–2028. Available from: http://onlinelibrary.wiley.com/doi/10.1897/07-011.1/pdf

Baker, W.H., R.E. Blanton and C.E. Johnston. 2013. Diversity within the Redeye Bass, *Micropterus coosae* (Perciformes: Centrarchidae) species group, with descriptions of four new species. Zootaxa 3635 (4): 379-401. Available from: http://dx.doi.org/10.11646/zootaxa.3635.4.3

Bayne, D.R. 1998. Alabama Surface Waters: A Treasure Taken for Granted. Alabama Issues: 75-82. Available from: http://www.aces.edu/dept/fisheries/natural-resources/documents/alasurfacewater.pdf

Benke, A.C. and C.E. Cushing (eds.), 2005. Rivers of North America. Elsevier Academic Press. 1168 pp.

Bennett, J.R. 1999. Tannehill and the Growth of the Alabama Iron Industry; Including the Civil War in West Alabama. Alabama Historic Ironworks Commission. McCalla, Alabama. 470 pp.

Bergstresser, Jack R., Sr. 1993. Raw Material Constraints and Technological Options in the Mines and Furnaces of the Birmingham District: 1876-1930. PhD Dissertation. Auburn University.

Blancher, E.C., S. Sklenar, and J. L. Wood. 1999. Nutrient Utilization During Lowflow Conditions along the Cahaba River Alabama. Proceedings of WEFTEC, October 1999. New Orleans, Louisiana.

Blancher, E.C., S. Sklenar, R. Park, and J.L. Wood. 2002. Determining the Linkages for a Nutrient TMDL in a Stream Listed as Use-Impaired for Endangered Species. National Total Maximum Daily Load Conference. Proceeding of Water Environment Federation Conference held in Phoenix, Arizona November 2002.

Bogan, A.E., J.M. Pierson, and P. Hartfield. 1995. Decline in the freshwater gastropod fauna in the Mobile Bay Basin. Pp. 249-252. *In:* E.T. LaRoe, G.S. Fans, C.E. Puckert, P.D. Doran, M.J. Mac (eds.). Our Living Resources, a report to the Nation on the distribution, abundance and health of U.S. plants, animals and ecosystems. U.S. Department of Interior, National Biological Survey, Washington, DC. 530 pp.

Boschung, H.T., Jr., and R.L. Mayden. 2004. Fishes of Alabama. Smithsonian Books, Washington, District of Columbia. 736 pp.

Brown-Kobil, N. 2006. Water Laws in Region 4. Office of the Solicitor: Division of Parks and Wildlife. Memo to Stephen Earsom dated April 6, 2006. 12 pp.

Bringolf, R.B., W.G. Cope, S. Mosher, M.C. Barnhart, and D. Shea. 2007. Contaminant Sensitivity of Freshwater Mussels – Acute and chronic toxicity of glyphosate compounds to glochidia and juveniles of *Lampsilis siliquoidea* (Unionidae). Environmental Toxicology and Chemistry, Vol. 26, No. 10, Pages 2094–2100. Available from: http://service004.hpc.ncsu.edu/toxicology/faculty/cope/PDFs/Bringolf%20et%20al.%20Mussel%20Glyphosate%20ETC%202007%20Vol.%2026%20pp.%202094-2100.pdf

Bryant, J.D. 2010. Birmingham Water Works prepares for new growth. June 14, 2010. The Birmingham News. Available from: http://blog.al.com/spotnews/2010/06/birmingham_water_works_prepare.html.

Buckner, M.M., W. Smith, and J.A. Takats. 2002. Tennessee, Cumberland, and Mobile River Basins at Risk: A Biological Assessment and Vision for the World Wildlife Fund's Southeast Rivers and Streams Project. World Wildlife Fund, Nashville, TN. 49 pp.

Buell, G. 2011. Data CD for Cahaba River NWR Refuge, including raw data, geodatabase, figures, plots and tables. 25 August 2011. USGS Georgia Water Science Center.

Butler, L.L. 1985. Allocating Consumptive Water Rights in a Riparian Jurisdiction: Defining the Relationship Between Public and Private Interests. Faculty Publications. Paper 138. Available from: http://scholarship.law.wm.edu/facpubs/138

Causey, L.V., Willmon, J.R. and J.S. Ellard. 1978. Water Availability in Bibb County, Alabama. Map 144. Geological Survey of Alabama.

[CBD] Center for Biological Diversity. 2010. Petition to List 404 Aquatic, Riparian and Wetland Species from the Southeastern United States as Threatened or Endangered Under the Endangered Species Act. April 20, 2010. 1145 pp. Available from: http://www.biologicaldiversity.org/publications/petitions/listing/ AND SPECIFICALLY: http://www.biologicaldiversity.org/programs/biodiversity/1000_species/the_southeast_freshwater_extinction_crisis/pdfs/SE_Petition.pdf

[CCSP] Climate Change Science Program. 2008. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P.Backlund, A.Janetos, D.Schimel, J.Hatfield, K.Boote, P.Fay, L.Hahn, C.Izaurralde, B.A.Kimball, T.Mader, J.Morgan, D.Ort, W.Polley, A.Thomson, D.Wolfe, M.G.Ryan, S.R.Archer, R.Birdsey, C.Dahm, L.Heath, J.Hicke, D.Hollinger, T.Huxman, G.Okin, R.Oren, J.Randerson, W.Schlesinger, D.Lettenmaier, D.Major, L.Poff, S.Running, L.Hansen, D.Inouye, B.P.Kelly, L.Meyerson, B.Peterson, R.Shaw. U.S. Department of Agriculture, Washington, DC., USA, 362 pp. Available from: http://www.climatescience.gov/Library/sap/sap4-3/final-report/.

Chandler, R.V. and J.D. Moore. 1987. Springs of Alabama. Geological Survey of Alabama Circular 134. 90 pp. Accessed 26 September 2012. Available from: http://www.gsa.state.al.us/documents/pubs/onlinepubs/Circulars/C134.pdf.

Coles, J.F., G. McMahon, A.H. Bell, L.R. Brown, F.A. Fitzpatrick, B.C. Scudder Eikenberry, M.D. Woodside, T.F. Cuffney, W.L. Bryant, K. Cappiella, L. Fraley-McNeal and W.P. Stack. 2012. Effects of urban development on stream ecosystems in nine metropolitan study areas across the United States: U.S. Geological Survey Circular 1373, 138 pp. Available from: http://pubs.usgs.gov/circ/1373/

Cowardin, L.M., Carter, V., Golet, F.C., and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service. Washington, D.C. 142 pp. Available from: http://el.erdc.usace.army.mil/emrrp/emris/emrishelp2/cowardin_report.htm, also http://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf

[CRBCWP] Cahaba River Basin Clean Water Partnership. Undated. Draft Cahaba River Basin Management Plan. Accessed 10 April 2012. Available from: http://adem.alabama.gov/programs/water/nps/files/CahabaBMP.pdf.

[CRS] Cahaba River Society. 1998. Cahaba: A Gift for Generations: an Historical Folio Revealing the Heart River of Alabama. Edited by Todd Keith. 44 pp.

Culbertson, W.C. 1964. Geology and Coal Resources of the Coal-Bearing Rocks of Alabama: Contributions to Economic Geology. Geological Survey Bulletin 1182-B. U.S. Department of the Interior, Geological Survey. Washington, D.C. 88 pp. http://pubs.usgs.gov/bul/1182b/report.pdf

Davenport, L.J. 2007. Climate change and its potential effects on Alabama's plant life. Accessed 3 January 2013. Available from: http://www.forestry.state.al.us/Carbon/Davenport_CLIMATECHANGE2007%20&%20Impact%20to%20AL%20Plants.pdf.

DeGaetano, A.T. and R.J. Allen. 2002. Trends in twentieth-century temperature extremes across the United States. Journal of Climate. 15: 3188-3205.

DeJarnette, D.W. 1986. Directory of Underground Coal Mines in Alabama. Circular 130. Alabama Geological Society. Tuscaloosa, Alabama. 188 pp. Available from: http://www.gsa.state.al.us/documents/pubs/onlinepubs/Circulars/C130part1of3.pdf

DeJarnette, S.S., B. Gillett, L. Hicks-Wells, and J.D. Moore. 2002. Ground-water Levels in Alabama: 1997-2001 Water Years (October 1, 1996 – September 30, 2001). Geological Society of Alabama. Circular 112Q. Tuscaloosa, Alabama. 322 pp.

Demarest, D. 2006. Partners in Flight Bird Conservation Plan for the Southern Ridge and Valley Region. 2006 Executive Summary. Available from: http://www.partnersinflight.org/bcps/pl_13sum.htm

Dickens, R.S. Jr., and J.L. McKinley. 1979. Frontiers in the Soil: The Archaeology of Georgia. Frontiers Publishing: Chapel Hill, North Carolina.

Elliott, H. 2012. Alabama's Water Crisis. Alabama Law Review. Vol. 63:2:383-406. Available from: http://www.law.ua.edu/pubs/lrarticles/Volume%2063/Issue%202/Elliott.pdf

Ellison, R.C. 1984. Bibb County Alabama: The First Hundred Years, 1818-1918. The University of Alabama Press, Tuscaloosa, AL. 304 pp.

El-Kaddah, D. and A. Carey. 2004. Water quality modeling of the Cahaba River, Alabama. Environmental Geology, Vol. 45(3): 323-338. January 2004.

[EPA] United States Environmental Protection Agency. 2006. Addendum [to Howard et al. 2002. Cahaba River: Biological and Water Quality Studies: Birmingham, AL, March/April, July and September, 2002. USEPA Science and Ecosystem Support Division, Athens, GA. 211 pp.]. 5 pp. Available from: http://www.epa.gov/region4/sesd/reports/2002-0809/addendum.pdf

[EPA] United States Environmental Protection Agency. Reach Access Database (RAD). 2010. Alabama 303(d) Impaired Waterbodies. Accessed April 2012 from: http://epamap32.epa.gov/radims/.

[EPA] United States Environmental Protection Agency. 2013. Priority Watersheds for the Southeast. January 2013. Available from: http://www.epa.gov/region04/water/watersheds/priority.html. Cahaba Watershed (03150202) Profile: http://cfpub.epa.gov/surf/huc.cfm?huc_code=03150202

[EPA] United States Environmental Protection Agency. Undated. Integrated Compliance Information System (ICIS). Accessed 2012. Available from: http://www.epa.gov/compliance/data/systems/icis/

Ewing, R., J.Kostayack, D.Chen, B.Stein, and M.Ernst. 2005. Endangered by Sprawl: How Runaway Development Threatens America's Wildlife. National Wildlife Federation, Smart Growth America, and NatureServe. Washington, D.C. January 2005. 68 pp. Available from: http://www.nwf.org/pdf/Wildlife/EndangeredbySprawl.pdf

Federal Register. 1991. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species (Notice of Review). Federal Register 56:225 (November 21, 1991) pp. 58804 to 58836. http://ecos.fws.gov/docs/federal_register/fr1973.pdf

Federal Register. 1994. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species (Notice of Review). Federal Register 59:219 (November 15, 1994) pp. 58982 to 59028. http://ecos.fws.gov/docs/federal_register/fr2729.pdf

Federal Register. 2013. Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for Georgia rockcress and Designation of Critical Habitat (Proposed Rule). Federal Register 78: 177 (September 12, 2013) pp. 56192 to 56201. Available from: http://www.gpo.gov/fdsys/pkg/FR-2013-09-12/pdf/2013-22129.pdf

[FHA] Federal Highways Administration. 2012. Climate Change Adaptation, Regional Climate Change Effects: Useful Information for Transportation Agencies. Federal Highway Administration, Washington, DC. Accessed July 2013. Available from: http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/climate_effects/effects03.cfm

Fobian, T.B., M.L. Buntin, J.T. Garner, and P.D. Johnson. 2011. Survey of Freshwater Mussels in the Lower Cahaba River Basin: Bibb, Dallas, and Perry Counties, Alabama. Fiscal Year 2010 Annual Report. Alabama Department of Conservation and Natural Resources Division of Wildlife and Freshwater Fisheries, Fisheries Division, and the Alabama Aquatic Biodiversity Center. 21 pp.

Freeman, P. 2011. Monitoring Freshwater Mussels and Snails at a Habitat Restoration Site Associated with a Low-head Dam Removal on the Cahaba River, Bibb County, Alabama, 2005-2010. The Nature Conservancy in Alabama. Birmingham, AL. 10 pp.

Futato, Eugene M. 1989. An Archaeological Overview of the Tombigbee River Basin, Alabama and Mississippi. Report of Investigations 59. University of Alabama State Museum of Natural History, Division of Archaeology. 438 pp.

Godwin, James C. 2010. Amphibian and Reptile Inventory of the Cahaba River National Wildlife Refuge. Alabama Natural Heritage Program, Auburn University, AL. Unpublished report for the U.S. Fish and Wildlife Service. 124 pp. + Appendix.

Groisman, P. and R. Knight. 2008. Prolonged dry episodes over the conterminous United States: New tendencies emerging during the last 40 years. Journal of Climate. 21 (1850-1862).

[GSA] Geological Survey of Alabama. 1986. Drought-related Impacts on Water Uses in North Alabama: Executive Summary. GSA Circular 127A. An Executive Summary, Supplemental to Circular 127B. University of Alabama. May 1986.

[GSA] Geological Survey of Alabama. 2006a. Geologic map of Alabama, digital version 1.0: Alabama Geological Survey Special Map 220A [adapted from Szabo, M. W., Osborne, W. E., Copeland, C. W., Jr., and Neathery, T. L., 1988, Geologic map of Alabama (1:250,000): Alabama Geological Survey Special Map 220]. Accessed 8 January 2013. Available from: http://www.gsa.state.al.us (specifically http://www.gsa.state.al.us/gsa/gis_data.aspx).

[GSA] Geological Survey of Alabama. 2006b. State Oil and Gas Board. Coal Systems. Accessed June 2013. Available from: http://www.gsa.state.al.us/gsa/coal_sys.html

[GSA] Geological Survey of Alabama. 2010. Groundwater Assessment Program. Groundwater Level Records for periodic monitoring wells. Accessed June 2013. Available from: http://www.gsa.state.al.us/gsa/water/periodic_wells.html

[GSA] Geological Survey of Alabama. 2013. Statewide Crayfish Assessment. Ecosystems Investigations Program. Available from: http://www.gsa.state.al.us/gsa/eco/current_crayfish.html

[GSA] Geological Survey of Alabama. undated. Special Map 231 Aquifer Recharge Areas. Accessed 25 April 2012. Available from: http://www.gsa.state.al.us/documents/hydrogeology/aquifers_map.pdf.

Harper, R.M. 1943. Forests of Alabama. Monograph 10. Geological Survey of Alabama. Tuscaloosa, AL. 230 pp.

Harris, S.C., P.K. Lago, and P.E. O'Neil. 1984. Trichoptera of the Cahaba River System in Alabama. Entomological News. Vol. 95 (3): 103-112. Geological Survey of Alabama, Reprint Series 60. Tuscaloosa, AL. 11 pp. Available from: http://www.gsa.state.al.us/documents/pubs/onlinepubs/Reprint_series/RS60.PDF

Hartfield, E. 2004. Freshwater Mussels of Cahaba River National Wildlife Refuge. U.S. Fish and Wildlife Service, Ecological Services, Jackson, MS.

Hatcher, R.D., Jr., P.H. Osberg, A.A. Drake, Jr., P. Robinson, and W.A. Thomas. 1990. Tectonic map of the U.S. Appalachians, Geological Society of America, Decade of North American Geology.

Howard, H.S., B. Quinn, M.C. Flexner, and R.L. Raschke. 2002. Cahaba River: Biological and Water Quality Studies, Birmingham, Alabama. March/April, September and July, 2002. U.S. Environmental Protection Agency, Region 4, Science and Ecosystem Support Division, Ecological Support Branch. Athens, GA. 211 pp. (plus 5 page addendum issued in 2006). Available from: http://www.epa.gov/region4/sesd/reports/2002-0809/cahaba.pdf

Hudson, C. 1976. The Southeastern Indians. University of Tennessee Press. Knoxville, TN. 573 pp.

Hunter, J.A. and P.H. Moser. Ground-water Availability in Jefferson County, Alabama. Geological Survey of Alabama. Tuscaloosa, AL. 69 pp.

Hutson, S.S., T.M. Littlepage, M.J. Harper, and J.O. Tinney. 2009. Estimated use of water in Alabama in 2005: U.S. Geological Survey Scientific Investigations Report. 2009-5163, 210 pp. Accessed June 2013. Available from: http://pubs.usgs.gov/sir/2009/5163/, as well as from: http://al.water.usgs.gov/infodata/wateruse.html

[IPCC] Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri and A. Reisinger (eds.). IPCC. 104 pp.

Jelks, H.L., S.J. Walsh, N.M. Burkhead, S. Contreras-Balderas, E. Díaz-Pardo, D.A. Hendrickson, J. Lyons, N.E. Mandrak, F. McCormick, J.S. Nelson, S.P. Platania, B.A. Porter, C.B. Renaud, J.J. Schmitter-Soto, E.B. Taylor, and M.L. Warren, Jr. 2008. Conservation Status of Imperiled North American Freshwater and Diadromous Fishes. Fisheries 33(8):372-407.

Jenkins, N.J. and R.A. Krause. 1986. The Tombigbee Watershed in Southeastern Prehistory. The University of Alabama Press. Tuscaloosa, Alabama. 158 pp.

Johnson, G.C., R.E. Kidd, C.A. Journey, H. Zappia, and J.B. Atkins. 2002. Environmental Setting and Water Quality Issues of the Mobile River Basin, Alabama, Georgia, Mississippi, and Tennessee. U.S. Geological Survey, National Water-Quality Assessment Program. Water-Resources Investigations Report 02-4162. 70 pp. Available from: http://pubs.usgs.gov/wri/wri024162/

Johnson, P.D. 2012a. Proposed Reintroduction of the Southern Combshell, *Epioblasma penita* (Conrad, 1834) in the Cahaba River, Bibb County, Alabama, and the Mobile River Basin Mollusk R/A Activity Reporting Form. Alabama Aquatic Biodiversity Center, ADCNR. August 2012. 15 pp (with maps and photos).

Johnson, P.D. 2012b. Proposed Reintroduction of the *Medionidus parvulus* Coosa Moccasinshell (Lea, 1860) in the Little Cahaba River, Bibb County, AL, and the Mobile River Basin Mollusk R/A Activity Reporting Form. Alabama Aquatic Biodiversity Center, ADCNR. Sept. 2012. 16 pp (with maps and photos).

Johnson, P.D., A.E. Bogan, K.M. Brown, N.M. Burkhead, J.R. Cordeiro, J.T. Garner, P.D. Hartfield, D.A.W. Lepitzki, G.L. Mackie, E. Pip, T.A. Tarpley, J.S. Tiemann, N.V. Whelan and E.E. Strong. 2013. Conservation Status of Freshwater Gastropods of Canada and the United States, Fisheries, 38:6, 247-282. Available from: http://dx.doi.org/10.1080/03632415.2013.785396

Johnson, P.D., J.D. Sides, S.W. McGregor, S.A. Ahlstedt, J.T. Garner, R.S. Butler, and S.F. Novak. 2005. Inventory of Freshwater Mollusks in the Cahaba River Basin, Alabama. Alabama Aquatic Biodiversity Center, Alabama Division of Wildlife and Freshwater Fisheries. Marion, Alabama. 153 pp.

Johnson, P.D., J.D. Sides, S.W. McGregor, S.A. Ahlstedt, J.T. Garner, R.S. Butler, and S.F. Novak. 2010. Inventory of Freshwater Mollusks in the Cahaba River Basin, Alabama. Alabama Aquatic Biodiversity Center, Alabama Division of Wildlife and Freshwater Fisheries. Marion, Alabama. 153 pp.

Johnson, P.D., J.D. Sides, S.W. McGregor, S.A. Ahlstedt, J.T. Garner, R.S. Butler, and S.F. Novak. 2011. Inventory of Freshwater Mollusks in the Cahaba River Basin, Alabama. Alabama Aquatic Biodiversity Center, Alabama Division of Wildlife and Freshwater Fisheries. Marion, Alabama. 153 pp.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. U.S. Global Change Research Program. Cambridge University Press. 196 pp. Available at: http://oceanservice.noaa.gov/education/pd/climate/teachingclimate/climate_impacts_report.pdf

Kaufman, T.R., and R.D. Wise. 1978. Wild and Scenic River Study Report: Cahaba River, Alabama. U.S. Department of Agriculture, U.S. Forest Service, Atlanta, Georgia. 179 pp.

Kilroy, C. 2004. A new alien diatom, *Didymosphenia geminata* (Lyngbye) Schmidt: its biology, distribution, effects and potential risks for New Zealand fresh waters. National Institute of Water and Atmospheric Research. Report: CHC2004-128. Christchurch, New Zealand. 40 pp. http://www.biosecurity.govt.nz/files/pests/didymo/didymo-preliminary-org-ia-nov-04.pdf

Kilroy, C., B. Biggs, and N. Blair, P. Lambert, B. Jarvie, K. Dey, K. Robinson, and D. Smale. 2005. Ecological studies on *Didymosphenia geminata*. Christchurch, New Zealand: National Institute of Water and Atmospheric Research Ltd. Report CHC2005-123, Project MAF05505. 79 pp. Available at: http://www.biosecurity.govt.nz/files/pests/didymo/didymo-ecology-jan-06.pdf

Kilroy C., T.H. Snelder, O. Floerl, C.C. Vieglas, and K.L. Dey. 2008. A rapid technique for assessing the suitability of areas for invasive species applied to New Zealand's rivers. Diversity and Distributions. 14: 262–272. Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1472-4642.2007.00406.x/pdf

Knight, Vernon James. 2013. An Archaeological Sketch of Moundville. Moundville Archaeological Museum. Accessed June 2013. Available from: http://moundville.ua.edu/moundville/

Knight, Vernon James, Jr. 2010. Mound Excavations at Moundville: Architecture, Elites, and Social Order. University of Alabama Press. Tuscaloosa, Alabama. 424 pp.

Konikow, L.F. 2013. Groundwater Depletion in the United States (1900-2008). U.S. Geological Survey Scientific Investigations Report 2013−5079, 63 pp. Available from: http://pubs.usgs.gov/sir/2013/5079

Kopaska-Merkel, D.C. and J.D. Moore. 2000. Water in Alabama (including basic water data). Circular 122O. Geological Survey of Alabama, Hydrogeology Division. Tuscaloosa, Alabama. 91 pp.

Kopaska-Merkel, D.C., L.S. Dean and J.D. Moore. 2005. Hydrogeology and Vulnerability to Contamination of Major Aquifers in Alabama: Area 4. Circular 199D. Geological Survey of Alabama. Tuscaloosa, Alabama. 111 pp. Available from: http://www.gsa.state.al.us/documents/pubs/onlinepubs/Circulars/area4rpt.pdf

Kristofik, E.M. 2012. Occurrence and Habitat Use of Bats in Central Alabama Forests. M.S. Thesis. Auburn University, Auburn, Alamaba. 79 pp. Available from: http://etd.auburn.edu/etd/bitstream/handle/10415/3008/Kristofik_Thesis_Final.pdf?sequence=2

Kumar, S., S.A. Spaulding, T.J. Stohlgren, K.A. Hermann, T.S. Schmidt, and L.L. Bahls. 2009. Potential Habitat Distribution for the Freshwater Diatom *Didymosphenia geminata* in the Continental US. Frontiers in Ecology and the Environment. 7(8): 415-420, doi: 10.1890/080054. Available from: http://www.esajournals.org/doi/pdf/10.1890/080054

Laitta, M.T., K.J. Legleiter, and K.M. Hanson. 2004. The National Watershed Boundary Dataset. Hydro Line. Summer 2004. ESRI. Accessed 30 May 2013. Available from: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_021601.pdf.

Langbein, W.B. and K.T. Iseri. 1960. General Introduction and Hydrologic Definitions. US Government Printing Office. 29 pp.

Lewis, W. David. 1975. Iron and Steel in America. The Hagley Museum and Library. Greenville, Delaware, reprinted in 1986. 64 pp.

Lydeard, C. and R.L. Mayden. 1995. A Diverse and Endangered Aquatic Ecosystem of the Southeast United States. Conservation Biology. Vol. 9 (4): 800-805. August 1995.

Markwith, S.H. and M.J. Scanlon. 2007. Multiscale Analysis of *Hymenocallis coronaria* (Amaryllidaceae) Genetic Diversity, Genetic Structure, and Gene Movement Under the Influence of Unidirectional Stream Flow. American Journal of Botany. 94(2): 151-160.

Master, L.L., S.R. Flack, and B.A. Stein (eds.). 1998. Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity. The Nature Conservancy. Arlington, Virginia. 77 pp. Available from: http://www.natureserve.org/library/riversoflife.pdf

McGregor, S.W. and J.T. Garner, 2004. Results of Qualitative Sampling for Protected Mussel Species at Selected Stations in the Cahaba and Coosa Rivers, Alabama, 2004. Geological Survey of Alabama Open File Report 0505. 22 pp. Accessed April 2012. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_0505.pdf.

McGregor, S.W. and J.T. Garner, 2005. Results of Qualitative Sampling for Protected Mussel Species at Selected Stations in the Cahaba River System, Alabama, 2005. Geological Survey of Alabama Open File Report 0524. 17 pp. Accessed April 2012. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_0524.pdf.

Menne, M.J., Williams, Jr., C.N. and R.S. Vose. Undated. National Climatic Data Center, National Oceanic and Atmospheric Administration. United States Historic Climatology Network: Long-Term Daily and Monthly Climate Records from Stations Across the Contiguous United States. Available from: http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn_map_interface.html.

Mettee, M.F., P.E. O'Neil, and J.M. Pierson. 1996. Fishes of Alabama and the Mobile Basin. Oxmoor House, Birmingham, Alabama. 820 pp.

Mettee, M.F., P.E. O'Neil, T.E. Shepard, and S.W. McGregor. 2006. Fish movements and fish passage at Claiborne and Millers Ferry locks and dams on the Alabama River, Alabama. Geological Survey of Alabama. Circular 202. 22 pp.

Mirarchi, R.E., J.T. Garner, and M.F. Mettee. 2004. Alabama Wildlife: Imperiled Aquatic Mollusks and Fishes. University of Alabama Press, Tuscaloosa, AL. 255 pp.

Mohr. C.T. 1901. Plant Life in Alabama, an Account of the Distribution, Modes of Association, and Adaptions of the Flora of Alabama, Together with a Systematic Catalogue of the Plants Growing in the State. Reprint of Vol. VI, Contributions from the U.S. National Herbarium, July 31, 1901, U.S. Department of Agriculture; Washington, D.C. Alabama Edition, Alabama Geological Survey. Tuscaloosa. 921 pp.

Mooty, W.S. and R.E. Kidd, 1997. Ground-Water Resources of the Cahaba River Basin in Alabama – Subarea 7 of the Apalachicola-Chattahooche-Flint and Alabama-Coosa-Tallapoosa River Basins. U.S. Geological Survey Open File Report 96-470. Accessed 16 April 2012. Available from: http://pubs.usgs.gov/of/1996/ofr96-470/pdf/ofr96-470.pdf.

NatureServe. 2010. Cahaba River Basin (HUC 3510202). Digital Distribution Maps of the Freshwater Fishes in the Conterminous United States. Version 3.0. Arlington, VA, U.S.A. Distribution of Native U.S. Fishes by Watershed. Accessed June 2013. Available from: http://www.natureserve.org/getData/dataSets/watershedHucs/hucTable.jsp?huc=3150202

[NCSL] National Conference of State Legislatures. State Water Withdrawal Regulations. Accessed June 2013. http://www.ncsl.org/issues-research/env-res/state-water-withdrawal-regulations.aspx

Neuendorf, K.E., J.P. Mehl, Jr., and J.A. Jackson, eds. 2005. Glossary of Geology, Fifth Edition. American Geological Institute, Alexandria, Virginia.

[NOAA] National Oceanic and Atmospheric Administration. 1986. Climatological data annual summary, Alabama. Asheville, NC. National Climatic Data Center. Volume 92:13. 24 pp

[NOAA] National Oceanic and Atmospheric Administration. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 2. Climate of the Southeast U.S. NOAA Technical Report NESDIS 142-2. Washington, DC. 103 pp.

[NOAA] National Oceanic and Atmospheric Administration. Undated. Enhanced Fujita Tornado Damage Scale. Accessed July 2013. Available from: http://www.spc.noaa.gov/faq/tornado/ef-scale.html

O'Neil, P.E. and T.E. Shepard. 2000. Water Quality Assessment of the Lower Cahaba River Watershed, Alabama. Geological Survey of Alabama. Bulletin 167. Tuscaloosa, Alabama.135 pp.

O'Neil, Patrick E., 2002. A Biological Assessment of Selected Sites in the Cahaba River System, Alabama. Geological Survey of Alabama, in partial fulfillment of USEPA Contract No. 2R-0117-NAGF.

O'Neil, P.E. and T.E. Shepard. 2007. Delineation of Ichthyoregions in Alabama for Use with the Index of Biotic Integrity: Geological Survey of Alabama Open-File Report 0711. Geological Survey of Alabama, Water Investigations Program. Tuscaloosa, AL. 34 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_0711.pdf

O'Neil, P.E. and T.E. Shepard. 2009. Calibration of the Index of Biotic Integrity for the Southern Plains Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 0908. Geological Survey of Alabama, Water Investigations Program. Tuscaloosa, AL. 122 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_0908.pdf

O'Neil, P.E. and T.E. Shepard. 2010. Calibration of the Index of Biotic Integrity for the Southern Plains Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 1004. Geological Survey of Alabama, Ecosystems Investigation Program. Tuscaloosa, AL. 131 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1004.pdf

O'Neil, P.E. and T.E. Shepard. 2011a. Calibration of the Index of Biotic Integrity for the Ridge and Valley/Piedmont Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 1109. Geological Survey of Alabama, Ecosystems Investigations Program. Tuscaloosa, AL. 145 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1109.pdf

O'Neil, P.E. and T.E. Shepard. 2011b. Calibration of the Index of Biotic Integrity for the Plateau Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 1111. Geological Survey of Alabama, Ecosystems Investigations Program. Tuscaloosa, AL. 122 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1111.pdf

O'Neil, P.E. and T.E. Shepard. 2011c. Calibration of the Index of Biotic Integrity for the Hills and Coastal Terraces Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 1116. Geological Survey of Alabama, Ecosystems Investigations Program. Tuscaloosa, AL. 140 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1116.pdf

O-Neil, P.E. and T.E. Shepard. 2012. Calibration of the Index of Biotic Integrity for the Southern Plains Ichthyoregion in Alabama. Geological Survey of Alabama Open File Report 1210. Geological Survey of Alabama, Ecosystems Investigations Program. Tuscaloosa, AL. 131 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1210.pdf

O'Neil, P.E., T.E. Shepard, and E.A. Wynn. Undated. Alabama Ichthyoregions. Geological Survey of Alabama Special Map (based on O'Neil and Shepard 2007). Available from: http://www.gsa.state.al.us/gsa/eco/pdf/Ichthyoregion_Map_New_ver1.0_Large.pdf

O'Neil, P.E., T.E. Shepard, and M.R. Cook. 2006. Habitat and biological assessment of the Terrapin Creek watershed and development of the Index of Biotic Integrity for the Coosa and Tallapoosa River systems: Alabama Geological Survey Open-File Report 0601. 210 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_0601.pdf

Pierson, J.M., W.M. Howell, R.A. Stiles, M.F. Mettee, P.E. O'Neill, R.S. Suttkus, and J.S Ramsey. 1989. Fishes of the Cahaba River System in Alabama. Geological Survey of Alabama, Tuscaloosa, Alabama, Bulletin 134. 181 pp.

Pitt, R.E. 2000. Water Quality Conditions in the Cahaba River and Likely Pollutant Sources. Accessed 4 January 2013. Available from: http://unix.eng.ua.edu/~rpitt/Publications/MonitoringandStormwater/Cahaba%20problems%20and%20sources.PDF.

[PRISM] Parameter-elevation Regressions on Independent Slopes Model. 2010. Downloaded 4/6/2012 from http://prismmap.nacse.org/nn/. PRISM Climate Group, Oregon State University. Available from: http://www.prism.oregonstate.edu/.

QORE, Inc. 2004. Final Report: Piper Mine Site Reclamation, Cahaba River National Wildlife Refuge, Bibb County, Alabama. QORE Job No. 25458, Report No. 271952. February 24, 2005. 91 pp.

Richter, B.D., R. Mathews, D.L. Harrison, and R. Wigington. 2003. Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. Ecological Applications 13(1): 206-224. http://www.ag.auburn.edu/auxiliary/alcfwru/fisheries/fish7380/richter_paper.pdf

Sastre, A.V., N.H. Santinelli, G.A. Bauer, M.G.Ayestaran, and N.M. Uyua. 2013. First record of the invasive diatom Didymosphenia geminate (Lyngbye) Schmidt in a Patagonian Andean river of Argentina. BioInvasions Records. Volume 2, Issue 1 (11-17). Available from: http://www.reabic.net/journals/bir/2013/1/BIR_2013_1_Sastre_etal.pdf

Satz, R.N. 2002. American Indian Policy in the Jacksonian Era. University of Nebraska Press, Lincoln, Nebraska. 343 pp.

Sax, J.L., B.H. Thompson, Jr., J.D. Leshy, R.H. Abrams. 2006. Legal Controls of Water Resources: Cases and Materials. Fourth Edition (American Casebook Series). Thomson / West Academic Publishing. St. Paul, MN. 1104 pp.

Schneider, W.J. 1968. Water Data for Metropolitan Areas :A Summary of Data from 222 Areas in the United States. U.S. Geological Survey, Water Supply Paper 1871. U.S. Government Printing Office, Washington, D.C. 404 pp.

Schotz, A. 2007. Cahaba River National Wildlife Refuge Natural Community and Rare Plant Survey. Alabama Heritage Program, Montgomery, AL. Accessed 25 April 2012. Available from: http://www.fws.gov/cahabariver/pdf/Cahaba_River_Final_%20Report_Public.pdf.

Schueler, Thomas. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC.

Schuster, G.A. and C.A. Taylor. 2004. Report on the Crayfishes of Alabama: Literature and Museum Database Review, Species List with Abbreviated Annotations and Proposed Conservation Statuses. Illinois Natural History Survey, Center for Biodiversity Technical Report 2004 (12). Champaign, IL. 53 pp. Available from: https://www.ideals.illinois.edu/bitstream/handle/2142/10234/inhsbiodv02004i00012_opt.pdf?sequence=2

Scott, J.M., B.Griffith, R.S.Adamcik, D.M.Ashe, B.Czech, R.L.Fischman, P.Gonzalez, J.J.Lawler, A.D.McGuire, and A.Pidgorna. 2008. National Wildlife Refuges. In: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, pp. 5-1 to 5-100. Available from: http://www.climatescience.gov/Library/sap/sap4-4/final-report/.

[SERCC] The Southeast Regional Climate Center. 2013. Historical Climate Summaries for Alabama. The University of North Carolina, Chapel Hill, NC. Accessed June 2013. Available from: http://www.sercc.com/climateinfo/historical/historical_al.html

[SERCC] The Southeast Regional Climate Center. Undated. Tornado Climatology of the Southeast U.S. University of North Carolina, Chapel Hill, NC. Accessed June 2013. Available from: http://www.sercc.com/tornado_climatology

[SERFC] Southeast River Forecast Center. 2009. Southeast Flood Climatology Resources. National Weather Service, Peachtree City, GA. Accessed June 2013. Available from: http://www.srh.noaa.gov/serfc/?n=climohydro

Shepard, Thomas E., Patrick E. O'Neil, Stuart W. McGregor, Maurice F. Mettee, and Steven C. Harris, 1994. Biomonitoring and Water Quality Studies in the Upper Cahaba River Drainage of Alabama, 1989-1994. Geological Survey of Alabama. Bulletin 165. Montgomery, Alabama.

Shepherd, M., T.Mote, J.Dowd, M.Roden, P.Knox, S.C.McCutcheon, and S.E. Nelson. 2011. An Overview of Synoptic and Mesocale Factors Contributing to the Disastrous Atlanta Flood of 2009. Bulletin of the American Meteorological Society. 92 (July 2011): 861-870. Available from: http://journals.ametsoc.org/doi/pdf/10.1175/2010BAMS3003.1

Simcox, B. 2012. Migratory Characteristics and Passage Efficiency of Fishes at Two Dams on the Alabama River, Alabama. Masters Thesis, Auburn University, Auburn, Alabama. Fisheries & Allied Aquaculture. 92 pp. Available from: http://www.ag.auburn.edu/fish/wp-content/uploads/formidable/Simcox-Brandon-Thesis.pdf

Slack, J.R., A.M. Lumb and J.M. Landwehr. 1992. Hydro-Climatic Data Network (HCDN): Streamflow Data Set, 1874 – 1988. USGS Open-File Report 92-129. Available from: http://pubs.usgs.gov/wri/wri934076/.

Smith, J.B., G.A. Schuster, C.A. Taylor, E.A. Wynn, and S.W. McGregor. 2011. A Preliminary Report on the Distribution and Conservation Status of the Alabama Crayfish Fauna. Geological Survey of Alabama Open-File Report 1102. Ecosystems Investigation Program. Tuscaloosa, AL. 190 pp. Available from: http://www.gsa.state.al.us/gsa/eco/pdf/OFR_1102.pdf

Spaulding, S.A. and L. Elwell. 2007. Increase in Nuisance Blooms and Geographic .Expansion of the Freshwater Diatom *Didymosphenia geminata*. U.S. Geological Survey Open-File Report 2007-1425, 38 pp. Available from: http://www.fort.usgs.gov/Products/Publications/22046/22046.pdf

Squire, J. 1890a. Report on the Cahaba Coal Field. The Brown Printing Company, Montgomery, Alabama. Available from: http://books.google.com

Squire, J. 1890b. Map of the Cahaba Coal Field. Bien and Co., New York. On-line archival collection accessed June 2013. Available from: http://alabamamaps.ua.edu/historicalmaps/geology/index1900.html

[SSURGO]. Undated-a. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Bibb County, Alabama. Available from: http://soildatamart.nrcs.usda.gov .

SSURGO. Undated-b. SSURGO 2.2.6 Table Column Descriptions. Accessed 10 June 2013. Available from: ftp://ftp-fc.sc.egov.usda.gov/NSSC/SSURGO/SSURGO%20Metadata%20-%20Table%20Column%20Descriptions%20Report.pdf.

Stein, B. A. 2002. States of the Union: Ranking America's Biodiversity. A NatureServe Report prepared by The Nature Conservancy. Arlington, Virginia: Nature Serve. 27 pp. Available from: http://www.natureserve.org/library/stateofunions.pdf

Stohlgren, T.J., D.Barnett, C.Flather, P.Fuller, B.Peterjohn, J.Kartesz, and L.L. Master. 2006. Species Richness and Patterns of Invasion in Plants, Birds, and Fishes in the United States. Biological Invasions (2006) 8(3): 427-447. Available from: http://download.springer.com/static/pdf/662/art%253A10.1007%252Fs10530-005-6422-0.pdf?auth66=1387042295_5fd3afdcea0fbb4aeb8e6543d891eba2&ext=.pdf

Stricklin, V.E. 1994. Streamflow and Water-Quality Data for Lake Purdy and Its Tributaries, Jefferson and Shelby Counties, Alabama, Water Years 1987-1991. U.S. Geological Survey Open-File Report 93-498. Tuscaloosa, AL. 36 pp. Available from: http://pubs.usgs.gov/of/1993/0498/report.pdf

Swift, C.C., C.R. Gilbert, S.A. Bortone, G.H. Burgess, and R.W. Yerger. 1986. Zoogeography of the fishes of the southeastern United States: Savannah River to Lake Pontchartrain. *In:* C.H. Hocutt and E.O. Wiley (eds.), The zoogeography of North American freshwater fishes. John Wiley and Sons, New York, NY. (213-266); 866 pp.

[TCF] The Cahaba Foundation. 2013. Old Cahawba. Accessed June 2013. Available from: http://cahabafoundation.org/cahawba.html

ThinkQuest. 2007. http://library.thinkquest.org/06aug/00051/SLUDGE.html

Tiner, R.W. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish and Wildlife Service. National Wetland Inventory. Washington, D.C.

[TNC] The Nature Conservancy. 2012. Restoring Connectivity Between the Gulf of Mexico, Alabama River and Cahaba River in Alabama. The Nature Conservancy/NOAA Community-based Habitat Restoration Final Report. Award Number: #NA10NMF4630081. November 30, 2012. 40 pp.

[TNC and USACE] The Nature Conservancy and the U.S. Army Corps of Engineers. 2009. Marvel Slab Low-head Dam Removal Section 206 Aquatic Ecosystem Restoration Cahaba River, Bibb County, Alabama. Presentation. Accessed 25 April 2012. Available from: http://www.sam.usace.army.mil/pd/gpc/2009/Marvel%20Slab%20Low-head%20Dam%20Removal.pdf

[USDA] U.S. Department of Agriculture. 2005. National Inventory and Assessment Procedure – For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings. Forest Service National Technology and Development Program. 7700 – Transportation Management. November 2005. 81 pp. Available from: http://stream.fs.fed.us/publications/PDFs/NIAP.pdf

[USDA] U.S. Department of Agriculture. 2008. Soil Survey of Bibb County, Alabama. Accessed 26 April 2012. Available from: http://soildatamart.nrcs.usda.gov/manuscripts/AL007/0/Bibb.pdf.

[USDA] U.S. Department of Agriculture. Undated. Hydric Soils – Introduction. Accessed 10 June 2013. Available from: http://soils.usda.gov/use/hydric/intro.html.

[USFWS] U.S. Fish and Wildlife Service. 2000. Mobile River Basin Aquatic Ecosystem Recovery Plan. Atlanta, GA. 128 pp.

[USFWS] U.S. Fish and Wildlife Service. 2006. Draft Environmental Assessment: Piper Interpretive Trail. Cahaba River National Wildlife Refuge. Bibb County, Alabama. USFWS. March 2006. 16 pp.

[USFWS] U.S. Fish and Wildlife Service. 2007. Cahaba River National Wildlife Refuge Habitat Management Plan. Accessed April 2012. Available from: http://www.fws.gov/cahabariver/pdf/Cahaba%20River%20HMP-Final.pdf.

[USFWS] U.S. Fish and Wildlife Service. 2009a. Water Resources Assessment for Cahaba River NWR. Tabular summary completed by FWS Refuge Staff – initial assessment for the Eastern Waters Team. 17 pp.

[USFWS] U.S. Fish and Wildlife Service. 2009b. National Wildlife Refuge and National Fish Hatchery Selection Ranking Criteria: Impacts of Climate Change on Water Resources, Tier I – Most Vulnerable, Cahaba River National Wildlife Refuge. 8-14-2009. Eastern Waters Team, 2009 Climate Change Vulnerability Assessment Report, Attachment G. 25 pp.

[USFWS] U.S. Fish and Wildlife Service. 2010a. Operational Blueprint for Inventory and Monitoring on National Wildlife Refuges: Adapting to Environmental Change. 45 pp.

[USFWS] U.S. Fish and Wildlife Service. 2010b. Draft Environmental Assessment and Land Protection Plan for the Proposed Expansion of Cahaba River National Wildlife Refuge and the Proposed Establishment of Cahaba River Conservation Area: Bibb, Chilton, Jefferson, Perry, and Shelby Counties, Alabama. U.S. Department of the Interior, Fish and Wildlife Service. Southeast Region, Atlanta, GA. June 2010. 70 pp. Available from: http://www.fws.gov/southeast/planning/PDFdocuments/CahabaRiverEALAP/Cahaba%20River%20EA%20LPP%20edited.pdf

[USFWS] U.S. Fish and Wildlife Service. 2011. Service's Cahaba River National Wildlife Refuge expansion proposal tabled to make way for long-term planning effort. Press Release 4 May 2011. Available from: http://www.fws.gov/southeast/news/2011/11-037.html.

[USFWS] U.S. Fish and Wildlife Service. 2012a. Piper Highwall Reclamation Project, Cahaba NWR, Bibb County, Alabama. Letter dated 10 July 2012 from Richard Kanaski, FWS Regional Archaeologist to Elizabeth Brown, Deputy SHPO at the Alabama Historical Commission. 21 pp.

[USFWS] U.S. Fish and Wildlife Service. 2012b. Piper II Mine Reclamation Water and Soil Contamination Report. Prepared by Guardian Systems, Inc. for USFWS. 10 May 2012.

[USFWS] U.S. Fish and Wildlife Service. 2013. 7-Year Inventory and Monitoring Plan. USFWS National Wildlife Refuge System. NRPC, Fort Collins, Colorado. 50 pp.

[USFWS] U.S. Fish and Wildlife Service. Undated-a. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Accessed April 2012. Available from: http://www.fws.gov/wetlands/

[USFWS] U.S. Fish and Wildlife Service. Undated-b. Piper II Abandoned Mine Land Project, Cahaba River National Wildlife Refuge Environmental Contaminants Monitoring and Quality Assurance Project Plan.

[USGS] U.S. Geological Survey. 1959. Argo Quadrangle, Alabama (Topographic) (1:24000). Series V844. http://geonames.usgs.gov/pls/topomaps/f?p=262:18:6362687798625701::NO:RP

[USGS] U.S. Geological Survey. 1991. National Water Summary 1988-1989: Hydrologic Events and Floods and Droughts. USGS Water-Supply Paper 2375. Compiled by R.W. Paulson, E.B Chase, R.S. Roberts and D.W. Moody. 604 pp. Available from: http://pubs.usgs.gov/wsp/2375/report.pdf

[USGS] U.S. Geological Survey. 1996. Coal Fields of the Conterminous United States. USGS Open-File Report OF 96-92. Accessed June 2013. Available from: http://pubs.usgs.gov/of/1996/of96-092/.

[USGS] U.S. Geological Survey. 2000. Water Produced with Coal-Bed Methane. USGS Fact Sheet FS-156-00. November 2000. Accessed May 2013. http://pubs.usgs.gov/fs/fs-0156-00/fs-0156-00.pdf.

[USGS] U.S. Geological Survey. 2010. National Hydrography Dataset Pre-staged Subregion NHDH0315. October 2010.

[USGS] U.S. Geological Survey. 2012. Water-Data Report for 02424000 Cahaba River at Centreville, AL. http://wdr.water.usgs.gov/wy2012/pdfs/02424000.2012.pdf. Accessed June 2013 through the annual water data report mapper (http://wdr.water.usgs.gov/adrgmap/index.html)

[USGS] U.S. Geological Survey. 2013a. U.S. Geological Survey. National Water Information System. Accessed 2013. Available from: http://waterdata.usgs.gov/nwis.

[USGS] U.S. Geological Survey. 2013b. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [12/10/2013].

van der Schalie, H. 1938. The Naiades (Fresh-water Mussels) of the Cahaba River in Northern Alabama. Occasional Papers of the Museum of Zoology. University of Michigan, Ann Arbor, MI. 29 pp. http://deepblue.lib.umich.edu/bitstream/handle/2027.42/56831/OP392.pdf?sequence=1

Walker, J.H. 1993. The Struggle and the Joy: An American Coal Town Piper, Alabama. Birmingham Public Library Press, Birmingham, Alabama. 248 pp.

Walthall, J.A. 1980. Prehistoric Indians of the Southeast: Archaeology of Alabama and the Middle South. The University of Alabama Press. Tuscaloosa, Alabama. 300 pp.

Wang, H., R. Fu, A. Kumar, and W. Li. 2010. Intensification of summer rainfall variability in the southeastern United States during recent decades. Journal of Hydrometerology. 11 (1007-1018).

Ward, A. K., G. M. Ward, and S. C. Harris. 1992. Water Quality and Biological Communities of the Mobile River Drainage, Eastern Gulf of Mexico Region. Pages 279-304 in C. D. Becker and D. A. Neitzel, (eds.). Water Quality in North American River Systems. Battelle Press, Columbus, Ohio.

Warren, M. L., and B. M. Burr. 1994. Status of Freshwater Fishes of the United States: Overview of an Imperiled Fauna. Fisheries 19(1): 6-18.

Warren, M. L., S.J. Walsh, H.L. Bart, R.C. Cashner, Jr., D.A. Etnier, B.J. Freeman, B.R. Kuhajda, R.L. Mayden, H.W. Robinson, S.T. Ross and W.C. Starnes. 2000. Diversity, Distribution, and Conservation Status of the Native Freshwater Fishes of the Southern United States. Fisheries 25:7-29.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7, Bethesda, Maryland. 251 pp.

Wear, D.N. and J.G. Greis. 2012. The Southern Forest Futures Project: Summary Report. United States Department of Agriculture Forest Service, Southern Research Station. General Technical Report SRS-168. Southern Research Station, Asheville, NC. 68 pp.

Weather Warehouse. Undated. Past Monthly Weather Data for Centreville, AL ("Centreville) 1916 – 1974 and Brent, AL ("Centreville Wsmo") 1974 – 2013. Accessed January 2013. Available from: http://weather-warehouse.com/WeatherHistory/PastWeatherData_Centreville_Centreville_AL_January.html and http://weather-warehouse.com/WeatherHistory/PastWeatherData_CentrevilleWsmo_Brent_AL_January.html

Welch, E.B. 1992. Ecological Effects of Wastewater: Applied limnology and pollutant effects. Second Edition. Chapman and Hall, London. 436 pp.

Whelan, N.V., P.D. Johnson, and P.M. Harris. 2012. Rediscovery of *Leptoxis compacta* (Anthony, 1854) (Gastropoda: Cerithioidea: Pleuroceridae). PLoS ONE 7(8):e42499.doi:10.1371/journal.pone. 0042499. 6 pp. Available from: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0042499

White, Marjorie Longenecker. 1981. The Birmingham District, An Industrial History and Guide. Birmingham Historical Society, Birmingham, Alabama. 1981.

Wigley, T.M.L. 1999. The science of climate change; global and U.S. perspectives. Pew Center on Global Climate Change, Arlington, VA. 48 pp.

Williams, J.D., A.E. Bogan and J.T. Garner. 2008. Freshwater Mussels of Alabama and the Mobile Basin in Georgia, Mississippi, and Tennessee. The University of Alabama Press, Tuscaloosa, AL. 908 pp.

Williamson C.E., W. Dodd, T.K. Kratz, and M.A. Palmer. 2008. Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes. Frontiers in Ecology and the Environment 6(5): 247–254. Available from: http://www.esajournals.org/doi/pdf/10.1890/070140

Wynn, T.D. 2012. Habitat Specific Production of a Fall Line River Shoal Macroinvertebrate Assemblage. PhD Dissertation. University of Alabama Department of Biological Sciences, Tuscaloosa, Alabama. 140 pp.

8 Appendices

Appendix A	August 14, 2012 WRIA Kick-off Meeting Agenda, Summary, and Participant List
Appendix B	Listed and Petitioned Species within the Cahaba Basin (8-Digit HUC - 03150202)
Appendix C	Piper II Mine Reclamation Plan
Appendix D	Selected USGS and GSA Surface and Groundwater Quantity Monitoring Sites in RHI
Appendix E	Selected USGS and ADEM Surface Water Quality Monitoring Sites in RHI
Appendix F	USGS Surface Water Quality Monitoring Data for USGS 02423647 Site on Cahaba River near West Blocton, AL (1976 – 1983)
Appendix G	GSA Groundwater Well Hydrographs within or near RHI
Appendix H	USGS Groundwater Quality Monitoring Sites in RHI
Appendix I	Water Availability in Bibb County, Alabama, Geological Survey of Alabama Map 144 (Causey et al. 1978)
Appendix J	GSA Permits for Oil and Gas Wells within Refuge Acquisition Boundary
Appendix K	NPDES Permits within RHI