UPPER SAVANNAH RIVER BASIN PLAN 2025

DRAFT



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Name and Organization

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Tonya Bonitatibus, Savannah Riverkeeper
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John Hains, Friends of Lake Keowee Society
Katie Hottel, Upstate Forever
Daniel Milam, Milam Farms
Jill Miller, SC Rural Water Association
Dan Murph, Murph Investments, LLC
Reagan Osbon, City of Westminster
Billy Owens, Lake Hartwell Sail and Power Squadron
Jeff Phillips, Greenville Water
Melisa Ramey, Seneca Light and Water
Cole Rogers, Delux Construction, Inc.
Harold Shelley, Friends of the Savannah River Basin
Alan Stuart, Duke Energy
Mark Warner, McCormick and Abbeville County Economic Development
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Will Williams, Western SC Economic Development Parternship
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The Upper Savannah RBC

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Acronyms

ACE	Ashepoo-Combahee-Edisto
AMI	advanced metering infrastructure
AMR	automated meter reading
ARJWS	Anderson Regional Joint Water System
AWWA	American Water Works Association
BMP	best management practice
BRIC	Building Resilient Infrastructure and Communities
BRWD	Bethlehem Roanoke Water District
cfs	cubic feet per second
CMOR	Condition Monitoring Observer Report
COG	Council of Government
CPW	Commission of Public Works
CUA	Capacity Use Area
CWWMG	Catawba-Wateree Water Management Group
DCP	Drought Contingency Plan
DCWC	Dacusville -Cedar Rock Water Company
DMA	Drought Management Area
DRC	Drought Response Committee
EDA	Economic Development Administration
EF	Enhanced Fujita
EIA	U.S. Energy Information Agency
EPA	U.S. Environmental Protection Agency
GAEPD	Georgia Environmental Protection Division
EQIP	Environmental Quality Incentives Program
F	Fahrenheit
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FSA	Farm Service Agency
GDP	gross domestic product
GDNR	Georgia Department of Natural Resources
gpm	gallons per minute
HMGP	Hazard Mitigation Grant Program
HUC	hydrologic unit code
in.	inches
IN	industrial water user
IR	agricultural (irrigation) water user
IWNP	intelligent water and nutrient placement
IRA	Inflation Reduction Act
LEED	Leadership in Energy and Environmental Design

LEPA	low elevation precision application
LESA	low elevation spray application
LIP	Low Inflow Protocol
MESA	mid-elevation spray application
MG	million gallons
MGD	million gallons per day
MGM	million gallons per month
MI	mining water user
MIF	minimum instream flow
mph	miles per hour
MRLC	Multi-Resolution Land Characteristics Consortium
msl	mean sea level
NA	not available/applicable
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NDMC	National Drought Mitigation Center
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PCB	polychlorinated biphenyl
PFAS	per- and polyfluoroalkyl substances
PPAC	Planning Process Advisory Committee
psi	pounds per square inch
P&R	permitted and registered
RBC	River Basin Council
RCWD	Rural Community Water District
RMA	Risk Management Agency
SCDA	South Carolina Department of Agriculture
SCDES	South Carolina Department of Environmental Services
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCFC	South Carolina Forestry Commission
SC ORFA	South Carolina Office of Revenue and Fiscal Affairs
SCO	State Climatology Office
SEPA	Southeastern Power Administration
SMS	soil moisture sensor
SPI	Standard Precipitation Index
sq mi	square mile
SWAM	Simplified Water Allocation Model
TMDL	Total maximum daily load
TNC	The Nature Conservancy
UIF	unimpaired flow
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture

USBEA	U.S. Bureau of Economic Analysis
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WBIC	Weather-based irrigation controller
WD	Water District
WS	water supply water user
WWQA	Watershed Water Quality Assessment

Chapter 1 Introduction

1.1 Background

The South Carolina Water Resources Planning and Coordination Act mandates that the South Carolina Department of Natural Resources (SCDNR) develop a comprehensive water resources policy for the state of South Carolina. SCDNR developed the first state water plan—the *South Carolina Water Plan*—in 1998. In 2004, the plan was updated following what is recognized as one of the worst multi-year droughts on record, which ended in 2002. One of the recommendations from the *South Carolina Water Plan, Second Edition* was forming advisory committees to develop comprehensive water resource plans for each of the state's four major river basins: Ashepoo-Combahee-Edisto (ACE), Pee Dee, Santee, and Savannah. In 2014, when the development of surface water quantity models to support the planning process began, SCDNR and the South Carolina Department of Health and Environmental Control (SCDHEC) decided to further subdivide the basins based on SCDHEC's delineations used for the Water Quality Assessments. The eight planning basins were the Broad, Catawba, Edisto, Pee Dee, Salkehatchie, Saluda, Santee, and Savannah. In 2022, SCDNR made two adjustments to the planning basins. In the Saluda basin, the drainage area just below the confluence of the Broad and Saluda Rivers, which is generally below the Fall Line, was added to the Santee basin. The Savannah basin was subdivided into two planning basins and the portion below Lake Thurmond was combined with the Salkehatchie basin to form the Lower Savannah-Salkehatchie basin, as shown in Figure 1-1.

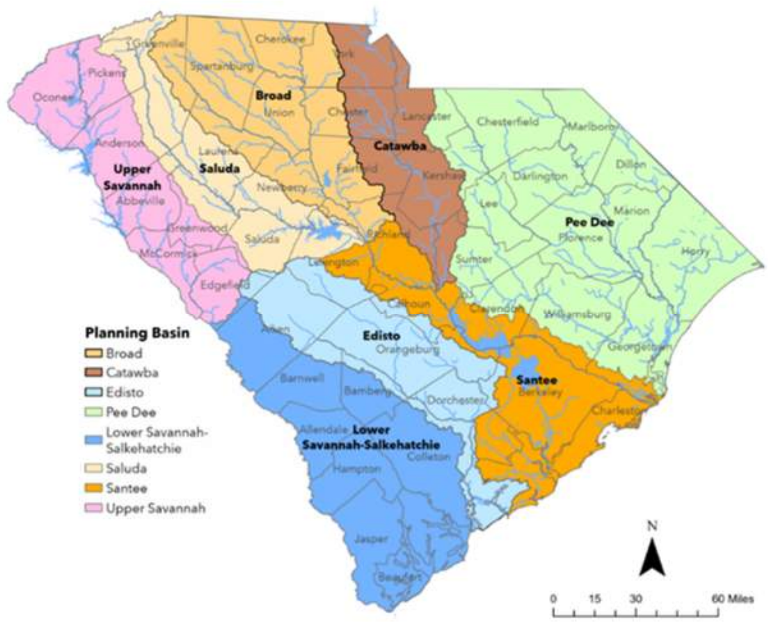


Figure 1-1. Planning basins of South Carolina.

Each of these water resource plans is called a River Basin Plan, which is defined in the *South Carolina State Water Planning Framework* (SCDNR 2019a; referred to hereafter as the Planning Framework) as "a collection of water management strategies supported by a summary of data and analyses designed to ensure the surface water and groundwater resources of a river basin will be available for all uses for years to come, even under drought conditions." The next update to the State Water Plan will build on the analyses and recommendations developed in the eight River Basin Plans.

River basins are seen as a natural planning unit for water resources since surface water in each basin is relatively isolated from water in other basins by natural boundaries. Each River Basin Plan will include data, analysis, and water management strategies to guide water resource development in the basin for a planning horizon of 50 years. Specifically, a River Basin Plan answers four questions:

1. What is the basin's current available water supply and demand?
2. What are the current permitted and registered water uses within the basin?
3. What will be the water demand in the basin throughout the planning horizon, and will the available water supply be adequate to meet that demand?
4. What water management strategies will be employed in the basin to ensure the available supply meets or exceeds the projected demand throughout the planning horizon?

In each river basin, a River Basin Council (RBC) is established and tasked with developing a plan that fairly and adequately addresses the needs and concerns of all water users following a cooperative, consensus-driven approach. The Upper Savannah River basin is the fifth of the eight river basins to begin and complete the process that culminated in developing this plan. River basin planning is expected to be an ongoing, long-term process, and this plan will be updated every 5 years.

1.2 Planning Process

The river basin planning process in South Carolina formally began with the development of the eight surface water quantity models starting in 2014 and the update of the Coastal Plain Groundwater Model in 2016. In March 2018, SCDNR convened the Planning Process Advisory Committee (PPAC). Over the next year and a half, SCDNR and the PPAC collaboratively developed the Planning Framework, which defines river basin planning as the collective effort of the numerous organizations and agencies performing various essential responsibilities, as described in the bullets that follow. A more complete description of the duties of each entity are provided in Chapter 3 of the Planning Framework.

- RBC: A group of approximately 25 members representing diverse stakeholder interests in the basin. Each RBC includes at least one representative from each of the eight broadly defined stakeholder interest categories shown in Figure 1-2. The RBC is responsible for developing and implementing the River Basin Plan; communicating with stakeholders; and identifying recommendations for policy, legislative, regulatory, or process changes.

- PPAC and WaterSC: The PPAC was a diverse group of water resource experts established to develop and help implement the Planning Framework for state and river basin water planning. The PPAC was dissolved in 2024 and the WaterSC Water Resources Working Group (WaterSC) was established by Executive Order 2024-22 to advise the South Carolina Department of Environmental Services (SCDES) on developing the new State Water Plan and facilitate additional collaboration with ongoing water planning efforts and existing initiatives.

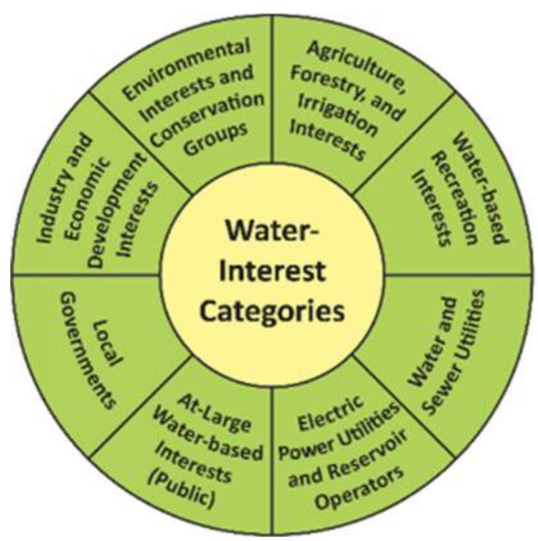


Figure 1-2. RBC water-interest categories.

- State and Federal Agencies:
  - SCDNR was the primary oversight agency for the river basin planning processes until July 1, 2024 when the Water Division of SCDNR moved to the newly formed SCDES. Key duties of SCDNR, which now fall to SCDES, include appointing members to the RBCs; educating RBC members on critical background information; providing RBCs and contractors with data, surface water models, and groundwater models; hiring contractors; and reviewing and approving the final River Basin Plans.
  - SCDES (formerly SCDHEC) is the regulatory agency that administers laws regarding water quality and use within the state and now oversees water planning activities. Key duties of SCDES include ensuring recommendations are consistent with existing laws and regulations, serving as an advisor for recommended changes to existing laws and regulations, directing the river basin planning effort, and developing the State Water Plan.
  - Other State Agencies: Representatives from other state agencies, such as the Department of Agriculture, Department of Commerce, Forestry Commission, Rural Infrastructure Authority, and the Energy Office, may be asked to attend RBC meetings in an advisory role.
  - Federal Agencies: Representatives from federal agencies, such as the U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), and Southeastern Power Administration (SEPA), may be asked to attend RBC meetings as formal advisors. Representatives from other federal agencies may be asked to attend RBC meetings in an advisory role.
- Contractors: SCDES hired contractors to perform administrative, facilitative, technical, authorship, and public outreach functions. Specific roles included:
  - Coordinator: Performs administrative functions. Coordination of RBC meetings and other activities has been shared by representatives from CDM Smith and Clemson University, with assistance from SCDES (collectively, the Planning Team). The Planning Team met at least monthly in between RBC meetings.
  - Facilitator and Author: Guides RBC meetings in a neutral manner to encourage participation and provides River Basin Plan authorship services. CDM Smith served in these roles for the Upper Savannah RBC.
  - Public Outreach Coordinator: Engages stakeholders and the public in the planning process. Clemson University served in this role for the Upper Savannah RBC.
- Groundwater and Surface Water Technical Advisory Committees: SCDES-appointed groups with specific technical expertise intended to enhance the scientific and engineering aspects of the planning process.
- Subcommittees and Ad Hoc Groups: The Upper Savannah RBC elected not to form any subcommittees during the initial, 2-year process of developing this plan.
- The Public and Stakeholders: The public was invited to attend and provide comments at RBC meetings and designated public meetings. Additional detail on public participation is described in Chapter 1.4.

The creation of the Upper Savannah RBC began with two public meetings organized by SCDNR on April 10 and 11, 2023, in Anderson and McCormick, respectively. The goal of these meetings was to describe the need and process for river basin planning to stakeholders and solicit applications to join the Upper

Savannah RBC. SCDNR accepted applications through May 2023 and selected RBC appointees in June 2023, based on their credentials, knowledge of their interest category, and their connection to the basin (i.e., RBC members must live, work, or represent a significant interest in the water resources of the basin). The diverse membership of the RBC is intended to allow for a variety of perspectives during development of the River Basin Plan. Table 1-1 lists the Upper Savannah RBC members (at the time the Final River Basin Plan was issued) and their affiliations, appointment dates, and term lengths. Term lengths are staggered to ensure continuity in the planning process. After serving an initial term, RBC members may be reappointed to serve additional terms subject to SCDES approval, not to exceed three consecutive terms total.

Table 1-1. Upper Savannah RBC members and affiliations.

Name	Organization	Position	Interest Category	Appointment Date and Term Length (Years)
Jon Batson	Anderson County	Stormwater Manager	Local Governments	July 2023 (4)
Mack Beaty, IV	Beaty Farms	Owner	Agriculture, Forestry, and Irrigation	July 2023 (4)
Tonya Bonitatibus	Savannah Riverkeeper	Riverkeeper	Environmental	July 2023 (3)
Cheryl Daniels	McCormick Commission of Public Works (CPW)	General Manager	Water and Sewer Utilities	July 2023 (4)
John Hains	Friends of Lake Keowee Society	Board Member	Environmental	July 2023 (3)
Katie Hottel	Upstate Forever	GIS/Clean Water Manager	Environmental	July 2023 (2)
Daniel Milam	Milam Farms	Owner	Agriculture, Forestry, and Irrigation	July 2023 (2)
Jill Miller	SC Rural Water Association	Executive Director	At-Large	July 2023 (2)
Dan Murph	Murph Investments, LLC	President	At-Large	July 2023 (3)
Reagan Osbon	City of Westminster	Assistant to City Administrator	Local Governments	July 2023 (4)
Billy Owens	Lake Hartwell Sail and Power Squadron	Executive Officer	Water-based Recreational	July 2023 (2)
Jeff Phillips	Greenville Water	Director of Water Resources	Water and Sewer Utilities	July 2023 (2)
Melisa Ramey	Seneca Light and Water	Water Treatment Plant Operator	Water and Sewer Utilities	July 2023 (2)
Cole Rogers	Delux Construction, Inc.	Superintendent	Industry and Economic Development	July 2023 (2)
Harold Shelley	Friends of the Savannah River Basin	Facilitator	At-Large	July 2023 (2)
Alan Stuart	Duke Energy	Senior Project Manager	Electric-Power Utilities	July 2023 (4)
Mark Warner	McCormick and Abbeville County Economic Development	Director	Industry and Economic Development	July 2023 (4)

Table 1-1. Upper Savannah RBC members and affiliations (Continued).

Name	Organization	Position	Interest Category	Appointment Date and Term Length (Years)
Scott Willett	Anderson Regional Joint Water System (ARJWS)	Executive Director	Water and Sewer Utilities	July 2023 (4)
Will Williams	Western SC Economic Development Partnership	President/CEO	Industry and Economic Development	July 2023 (4)
Tonya Winbush	Veterans of Foreign Wars/Adopt-A-Stream	Member	At-Large	July 2023 (3)

The Upper Savannah RBC began meeting in July 2023, and continued meeting monthly using a hybrid format that allowed for virtual participation when needed. Meetings were held at different locations in the basin in Starr, Anderson, Seneca, and North Augusta.

The planning process was completed in four phases, as specified in the Planning Framework. During the mostly informational phase (Phase 1), RBC members heard presentations from subject matter experts representing SCDNR, SCDES, USGS, Clemson University, The Nature Conservancy, and CDM Smith. Presentation topics included water legislation and permitting; hydrology, monitoring, and low-flow characteristics; climatology; the South Carolina Drought Response Act; freshwater aquatic resources; State Scenic Rivers; Federal Energy Regulatory Commission (FERC) licensing; and the relationships between streamflow and ecologic health.

Phase 2 of the planning process focused on assessing past, current, and future surface water availability. The RBC reviewed historical and current water use, and 50-year planning scenario results from the surface water quantity model (referred to as the Simplified Water Allocation Model or SWAM). Potential water shortages and issues were identified and discussed.

During Phase 3, water management strategies to address water availability issues were identified, evaluated, selected, and prioritized by the RBC based on their effectiveness, as determined by modeling and feasibility criteria such as cost, environmental impact, and socioeconomic impact.

Legislative, policy, technical, and planning process recommendations were considered during Phase 4 of the planning process, which culminated in developing this River Basin Plan.

Upper Savannah RBC members participated in two field trips in fall 2023 to better understand the water resources of the basin, how water is withdrawn and used to support agriculture and public water supply needs, and its importance in energy production. In October 2023, the RBC visited the Simpson Station to learn about agriculture and irrigation research at the Clemson Research Education Centers. In December 2023, the RBC toured the Lake Jocassee Dam and Hydro Facility. Photos from the field trips are shown in Figure 1-3. Prior to their meeting in March 2024, the RBC also witnessed the Lake Hartwell Dam spillway test performed by the USACE.

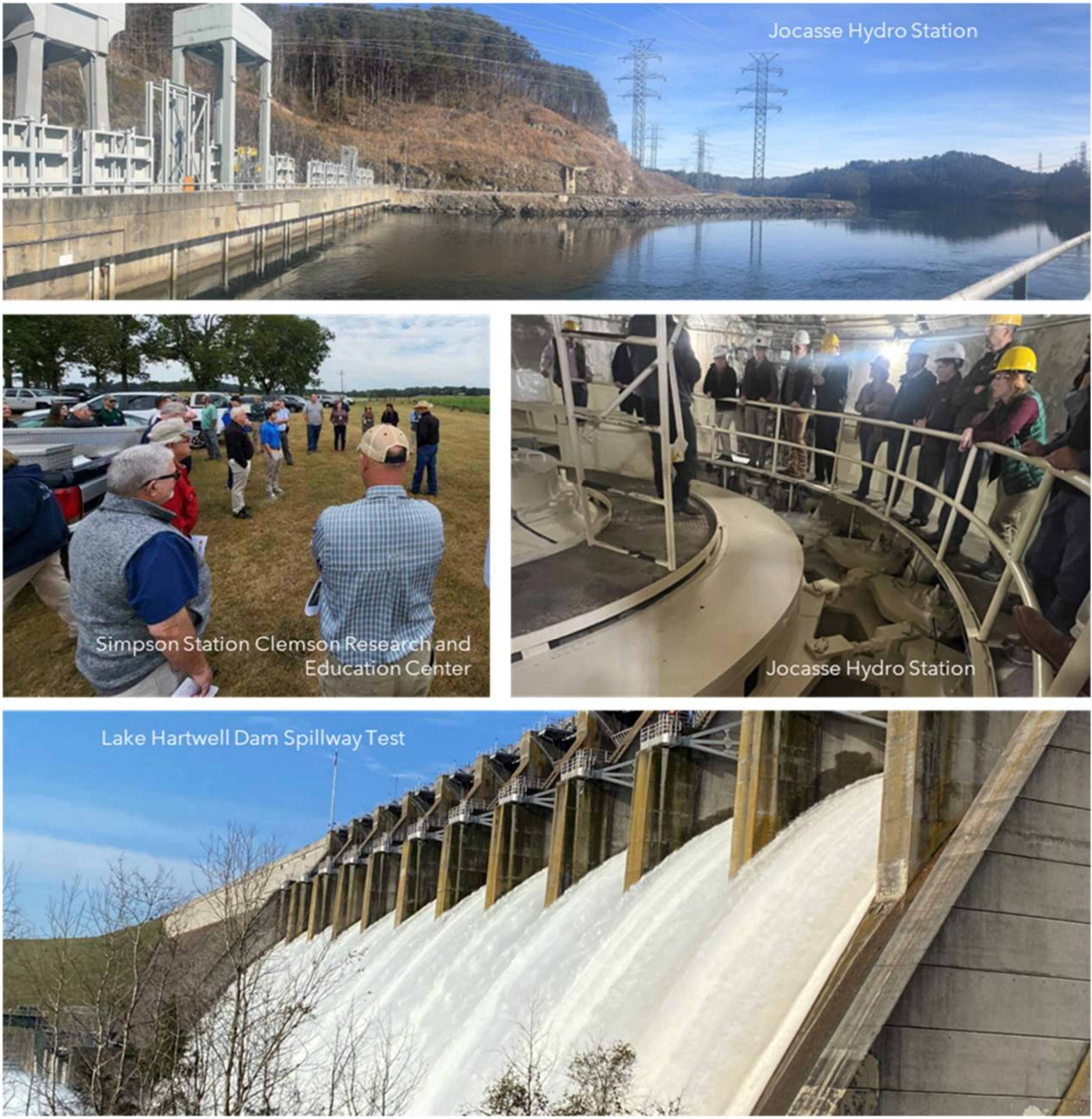


Figure 1-3. RBC field trips.

1.3 Vision and Goals

During Phase 1 of the planning process, the Upper Savannah RBC developed a vision statement establishing the desired outcome of the planning process, and actionable goals supporting their vision for the Upper Savannah River basin. The vision statement and goals are listed in Table 1-2.

Table 1-2. Upper Savannah RBC Vision Statement and Goals.

Vision Statement
A resilient Upper Savannah River Basin that collaboratively, sustainably, and equitably manages and balances human and ecological needs.
Goals
1 Within 24 months, develop water use strategies, policies, and legislative recommendations for the Upper Savannah River Basin in order to: **a. Ensure water resources are maintained to support current and future human and ecosystem needs.** **b. Improve the resiliency of the water resources and help minimize disruptions within the basin.** **c. Promote balance between development, industry, and economic growth in areas with adequate water resources.** **d. Advocate for responsible land use practices.** **e. Identify funding sources.**
2 Develop and implement an education and communication plan to promote the strategies, policies, and recommendations developed for the Upper Savannah River Basin.
3 Enhance collaboration between all stakeholders and water interest groups, including Georgia and the Lower Savannah-Salkehatchie River Basin.

1.4 Public Participation

Public participation is a vital component of the river basin planning process. All RBC meetings are open to the public. To promote visibility and encourage participation, meeting notices are posted on the SCDES Water Planning web page (https://des.sc.gov/programs/bureau-water/hydrology/water-planning) and are distributed to an email list. Meeting agendas, minutes, summaries, presentations, and recordings are posted on the SCDES website and are available to the public.

In addition to the RBC meetings, dedicated public meetings were also held to distribute information and solicit feedback.

- The first two public meetings were held on April 10 and 11, 2023, in Anderson and McCormick, respectively. At these meetings, the public was informed of the basin planning process and the plan for public participation. RBC membership applications were solicited at this meeting.

- The third public meeting was held on April 21, 2025, in Anderson. A summary of the plan was provided to attendees and a public comment period was opened, which included a verbal comment period at the meeting followed by a 30-day written comment period. Written comments received from the public and the RBC's responses to those comments are included in Appendix D.

1.5 Previous Water Planning Efforts

1.5.1 Drought Planning

The South Carolina State Climatology Office is responsible for drought planning in the state. The South Carolina Drought Response Act and supporting regulations establish the South Carolina Drought Response Committee (DRC) as the drought decision-making entity in the state. The DRC is composed of state agencies and local members representing various stakeholder interests. To help prevent overly broad response to drought, SCDNR split the state into four drought management areas (DMAs). The Upper Savannah River basin is largely within the West (Savannah Basin) DMA but has portions of its eastern area in the Central (Santee Basin) DMA. The DRC monitors drought indicators, issues drought status updates, determines nonessential water use, and issues declarations for water curtailment as needed. In addition to establishing the DRC, the South Carolina Drought Response Act also requires all public water suppliers to develop and implement their own drought plans and ordinances. Drought management plans developed by the public water suppliers in the Upper Savannah River basin are further discussed in Chapter 8.

In the Savannah River basin, the USACE also has responsibility for drought planning, and has developed and implemented drought strategies and contingency plans over the years. In 1986, the Savannah District USACE developed a Short-Range Drought Water Management Strategy to address the water shortage conditions in basin. The short-range strategy served as a prelude to the development of a long-term drought strategy, the Savannah River Basin Drought Contingency Plan (DCP) in March 1989. The DCP was developed to address the effects of the Savannah District water control management activities on the managed impoundments and the downstream portion of the river, and to assist Georgia and South Carolina in drought contingency planning in their water management responsibilities for the Savannah River Basin. That DCP was modified in 2006 by revising the management actions that would be taken at various lake levels. The intent of the updated DCP was to respond earlier in a drought to preserve additional water in the lakes, thereby delaying the time when the conservation pools would be depleted.

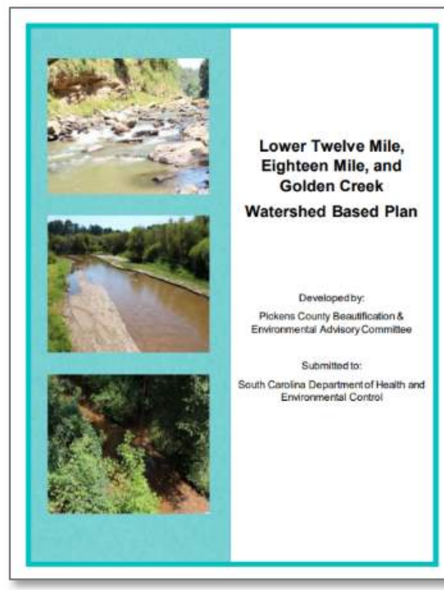
Water management during droughts has been a major issue and the USACE was requested to examine the DCP as part of the second interim of the Savannah River Basin Comprehensive Study. The draft of the study report tentatively recommended having no seasonal variation in drought trigger levels, raising the trigger levels by 3 to 6 feet, and further restricting the flow of water from Thurmond Dam earlier during drought; however, the recommendation was not implemented since the second interim Comprehensive Study ended prior to completion.

1.5.2 Watershed-Based Plans

Watershed-based plans have been developed for various watersheds throughout South Carolina to document sources of pollution and present a course of action to protect and improve water quality within a watershed. While this first iteration of the Upper Savannah River Basin Plan focuses on water quantity issues, previous planning efforts within the Upper Savannah River basin that addressed water quality are worth noting. Water quality considerations may be more fully developed in future updates to the Upper Savannah River Basin Plan. In addition to the watershed-based plans described below, Upstate Forever is developing a watershed-based plan for the Rocky River watershed, with an estimated completion date of Spring 2026 (Hottel 2025).

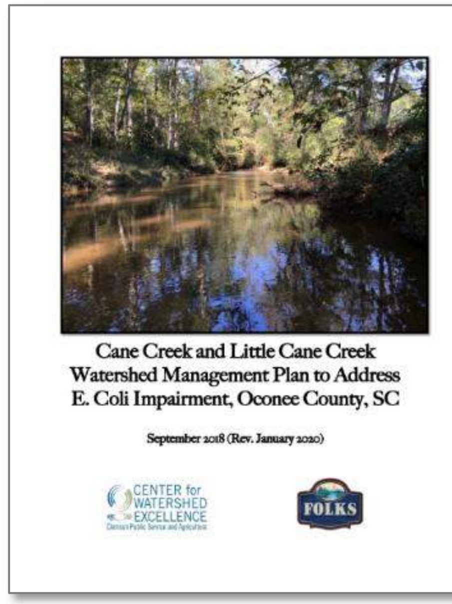
In 1992, SCDHEC initiated its Watershed Water Quality Management program to better coordinate river basin planning and water quality management. Watershed-based management allows SCDES to address congressional and legislative mandates and improve communication with stakeholders on existing and future water quality issues. In the Savannah River basin, Watershed Water Quality Assessments (WWQAs) were completed in 1993, 1997, 2003, and 2010. The WWQAs of the Savannah River basin describe, at the watershed level, water-quality-related activities that may potentially have an adverse impact on water quality. As of 2016, the WWQAs have been replaced by the SC Watershed Atlas (https://gis.dhec.sc.gov/watersheds/), which allows users to view watershed information and even add data, create layers from selected features, and export data for use outside of the application. Chapter 3 presents more information on current water quality impairments in the basin.

Lower Twelve Mile, Eighteen Mile, and Golden Creek Watershed Based Plan



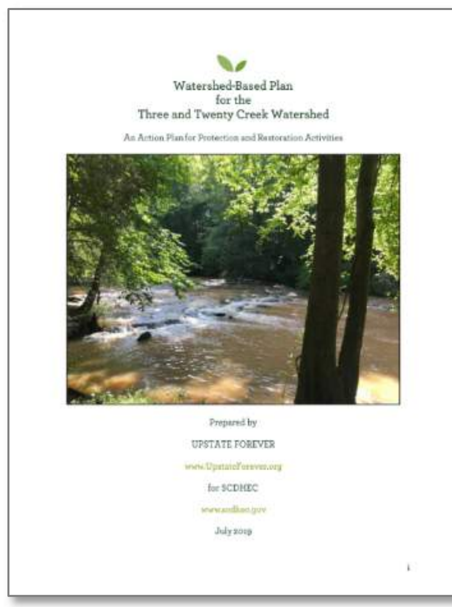
In 2016, a watershed-based plan was developed for the 69,165-acre watershed containing Lower Twelve Mile, Eighteen Mile, and Golden Creek (Pickens County Beautification & Environmental Advisory Committee 2016). The plan identifies stormwater runoff as the primary source of pollution impacting water quality, with contributions from point sources permitted to discharge bacteria and malfunctioning septic systems. A total of 32.4 stream miles within the three sub-watersheds have been declared impaired for their designated use resulting from bacterial loading. Elevated levels of *E.coli* have contributed to the degradation of sub-watersheds, and ten bacteria total maximum daily loads (TMDLs) were written to correspond with reaches associated with each of the SCDES monitoring stations. At the time of publication, eight of the TMDLs were "not supported" and two had achieved water quality standards and deemed "fully supported." The watershed plan identifies septic system, agricultural, urban, and wildlife best management practices (BMPs) as steps for reducing bacteria pollution.

Cane Creek and Little Cane Creek Watershed Management Plan to Address *E. Coli* Impairment, Oconee County, SC



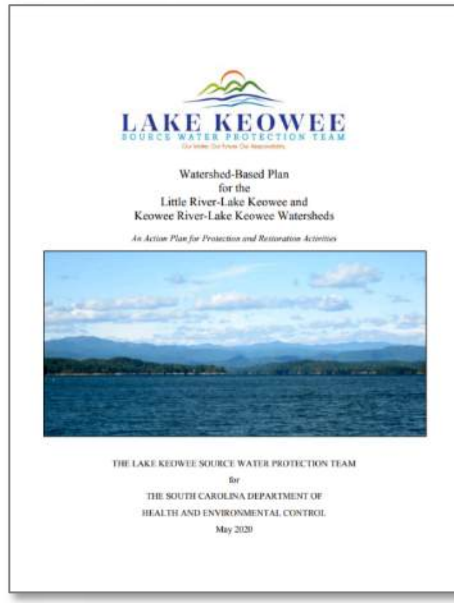
In 2020, a watershed-based plan was developed by Clemson University to address impairments caused by bacteria loadings to the Cane and Little Cane Creek Watershed, which is the largest and most urban drainage basin to Lake Keowee (Clemson Center for Watershed Excellence and the Friends of Lake Keowee Society 2020). This area includes downtown Walhalla in Oconee County. The primary recommendation is an overhaul of how water is management around Sertoma Field, including replacement of sewer infrastructure as well as tributary naturalization. The plan encourages landowners to stabilize riparian corridors, especially in lower parts of the watershed. Other recommended projects to address existing sources of bacteria loading include repairing septic systems and sewer tie-ins, improving grease handling, catch basin maintenance, wild pig management, improving buffers around pastures and paddocks, and stormwater conveyance retrofits. Best education practices are also included to engage stakeholders.

Watershed-Based Plan for the Three and Twenty Creek Watershed



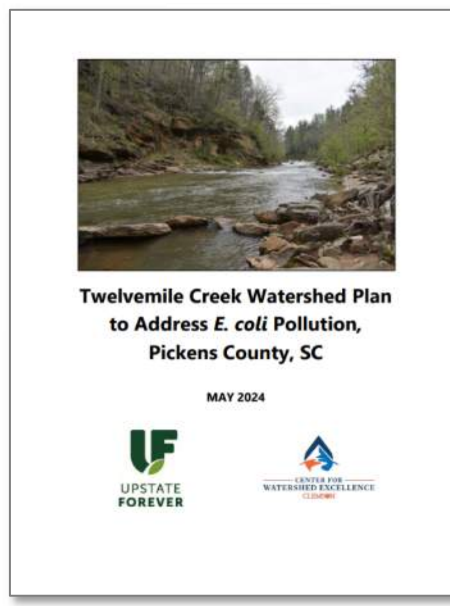
In 2019, a watershed-based plan was developed by Upstate Forever to address sources of sediment, bacteria, and nutrient pollution in the 105,765-acre watershed located in Anderson and Pickens Counties, which drains to Lake Hartwell and serves as a drinking water supply for ARJWS (Upstate Forever 2019). Primary sources of bacteria were identified as faulty septic systems, agricultural activities, pet waste, and wildlife. Nutrient and sediment impairments were associated with development and urban activities, agricultural activities, wastewater, and industrial discharges. The plan recommends implementation of land protection, septic system repair/replacements, agricultural BMPs, stormwater BMPs, shoreline management, voluntary dam removal, pet waste stations, and wildlife BMPs. The plan also identified land that should be protected or improved to provide the most benefit to water quality and developed a targeted public outreach and education strategy.

Watershed-Based Plan for the Little River-Lake Keowee and Keowee River-Lake Keowee Watershed



In 2020, a watershed-based plan was developed for 184,000-acre watershed located in Oconee and Pickens Counties, which drains to Lake Keowee and serves as a drinking water source for Greenville Water and Seneca Light & Water (The Lake Keowee Source Water Protection Team 2020). Three TMDLs have been developed in the focus area, with primary sources of bacteria identified as faulty septic systems, agricultural activities, pet waste, and wildlife. The plan also states that while no monitoring stations indicate elevated nutrients or sediment, the watershed is prime for significant development over the next 20 years, so the plan proactively also addresses potential sources of nutrients and sediments such as urbanization, agricultural activities, shoreline erosion, and inadequate riparian buffers. Pollutant mitigation strategies identified for bacteria, sediment, and/or nutrient load reduction include septic repair/restoration, agricultural BMPs, pet waste stations, land protection, and riparian buffer restoration. The plan also identified land that should be protected or improved to provide the most benefit to water quality and developed a targeted public outreach and education strategy.

Twelvemile Creek Watershed Plan to Address *E. coli* Pollution, Pickens County, SC



In 2024, a watershed-based plan was developed for the 154-square mile watershed in Pickens County which drains to Lake Hartwell (Upstate Forever and Clemson Center for Watershed Excellence 2024). The predominantly rural watershed has struggled with bacteria impairments dating back to 1998. Excessive sediment and nutrient loading also affect the ecology, flow, and water quality of Twelvemile Creek. Minimizing sediment into the waterways was identified as a critical measure to controlling bacteria. The plan recommends an integrated watershed and wastewater plan be developed for Pickens County, which would bring together stakeholders to study area growth and drinking and wastewater utility needs, in balance with conservation goals. The plan identified specific projects in the categories of implementing riparian buffer zoning ordinances, septic system repair/replacement cost-share programs, land protection, agricultural BMPs and establishing an agritourism district, wetlands assessment and restoration, park infrastructure and stormwater improvement projects, trash reporting outreach and engagement, and feral hog management.

1.6 Organization of this Plan

The Planning Framework outlines a standard format that all river basin plans are intended to follow, providing consistency in the organization and content. Consistency between river basin plans will facilitate the eventual update of the State Water Plan. Following the format outlined in the Planning Framework, the Upper Savannah River Basin Plan is divided into 10 chapters, described as follows:

- **Chapter 1: Introduction** – Chapter 1 provides an overview of the river basin planning purpose and process. Background on the basin-specific history and vision for the future is presented. The planning process is described, including the appointment of RBC members and the roles of the RBC, technical advisory committees, subcommittees, ad hoc groups, state and federal agencies, and contractors.

- **Chapter 2: Description of the Basin** – Chapter 2 presents a physical and socioeconomic description of the basin. The physical description includes a discussion of the basin's land cover, geography, geology, climate, natural resources, and agricultural resources. The socioeconomic section describes the basin's population, demographics, land use, and economic activity, as these factors influence the use and development of water resources in the basin.

- **Chapter 3: Water Resources of the Basin** – Chapter 3 describes the surface and groundwater resources of the basin and the modeling tools used to evaluate their availability. Monitoring programs, current projects, issues of concern, and trends are noted.

- **Chapter 4: Current and Projected Water Demand** – Chapter 4 summarizes the current and projected water demands within the basin. Demands for public water supply, thermoelectric power, industry, agriculture, and other uses are presented along with their permitted and registered withdrawals. The chapter outlines the methodology used to develop demand projections and the results of those projections.

- **Chapter 5: Comparison of Water Resource Availability** – Chapter 5 describes the methodology and results of the basin's surface water availability analysis. This chapter presents planning scenarios that were developed, and the performance measures used to evaluate them. Any water shortages or reaches of interest identified through this analysis are described. The projected water shortages identified in this chapter serve as the basis for the water management strategies presented in Chapter 6.

- **Chapter 6: Water Management Strategies** – Chapter 6 presents the water management strategies developed to address potential water shortages, increase water availability, extend the water supply, and build resilience. For each water management strategy considered, Chapter 6 includes a description of the measure, results from a technical evaluation (as simulated in the surface water quantity model, if applicable), feasibility for implementation, and a cost-benefit analysis.

- **Chapter 7: Water Management Strategy Recommendations** – Chapter 7 presents the final recommendations for water management strategies based on the analysis and results presented in Chapter 6. The chapter discusses the selection, prioritization, and justification for each of the recommended strategies. Any remaining shortages or concerns are also discussed in this chapter.

- **Chapter 8: Drought Response** –The first part of the chapter discusses existing drought management plans, ordinances, and drought management advisory groups. The second part presents drought response initiatives and recommendations developed by the RBC.

- **Chapter 9: Policy, Legislative, Regulatory, Technical, and Planning Process Recommendations** – Chapter 9 presents overall recommendations intended to improve the planning process and/or the results of the planning process. Recommendations to address data gaps encountered during the planning process are presented along with recommendations for revisions to the state's water resources policies, legislation, and agency structure.

- **Chapter 10: River Basin Plan Implementation** – Chapter 10 presents a 5-year implementation plan and long-term planning objectives. The 5-year plan includes specific objectives, action items to reach those objectives, detailed budgets, and funding sources. The long-term planning objectives include other recommendations from the RBC that are less urgent than those in the implementation plan. There will be a chapter in future iterations of this plan that details progress made on planning objectives outlined in previous plan iterations.

Richard B. Russell Dam

Chapter 2
Description of the Basin

2.1 Physical Environment

2.1.1 Geography

The Upper Savannah River basin covers nearly 7,000 square miles (sq mi) across the states of North Carolina, South Carolina, and Georgia. The basin is split predominantly between South Carolina and Georgia, covering approximately 3,200 sq mi in South Carolina and 3,700 sq mi of land area in Georgia. The South Carolina portion accounts for 10 percent of the state's total area. The basin extends over 140 miles from the central Blue Ridge Mountains to the confluence of the Savannah River and Stevens Creek, 12 miles downstream of the Lake Thurmond dam (SCDNR 2009; Georgia River Network 2018). Beyond the Stevens Creek confluence, the Upper Savannah River basin flows into the Lower Savannah–Salkehatchie River basin, which outlets into the Atlantic Ocean near the city of Savannah, Georgia. In South Carolina, the river basin spans approximately 40 miles at its widest point and consists of significant portions of Abbeville, Anderson, Edgefield, Greenwood, and Pickens Counties. Oconee and McCormick Counties lie entirely within the basin. A small portion of Saluda County is also present in the river basin, as shown in Figure 2-1 and Table 2-1. Unless otherwise mentioned, this chapter of the Upper Savannah River Basin Plan covers only the South Carolina portion of the basin.

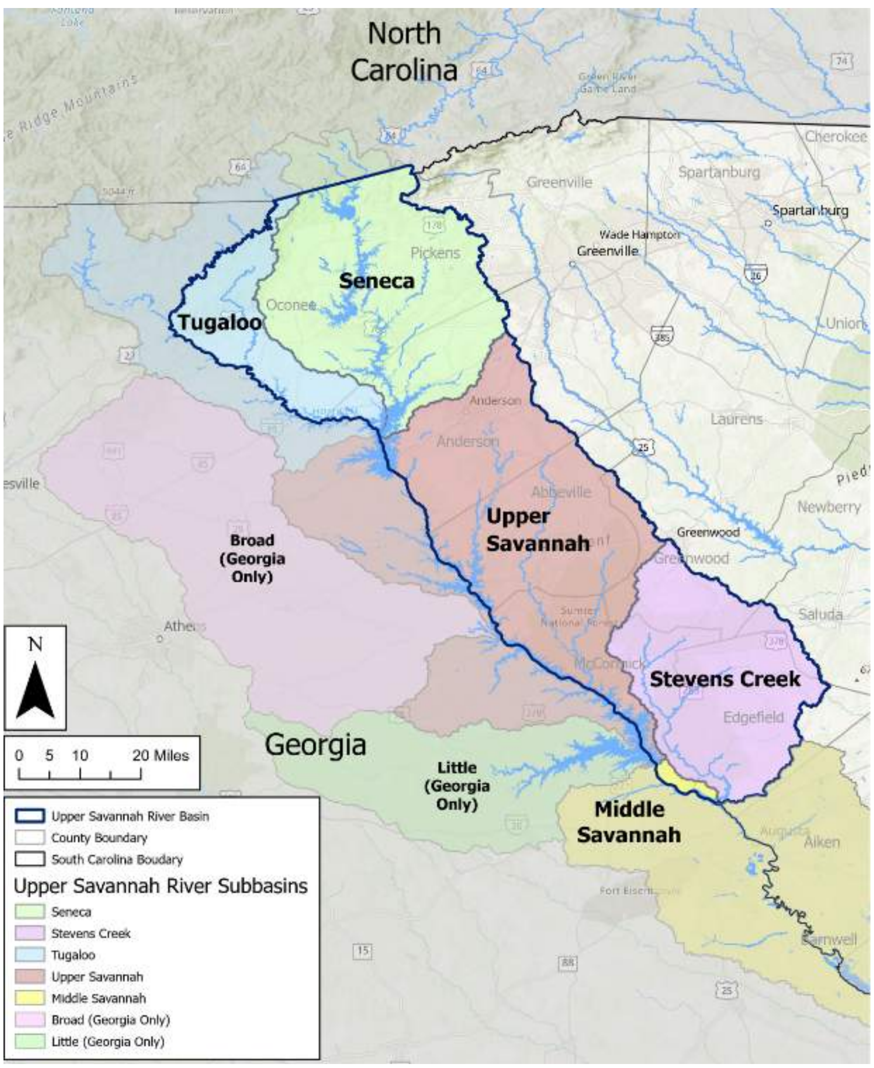


Figure 2-1. The Upper Savannah River basin and surrounding counties.

Table 2-1. Counties of the Upper Savannah River basin.

County[1]	Percentage of County in Upper Savannah River Basin	Percentage of Upper Savannah River Basin by County
Abbeville	92.4%	14.8%
Anderson	82.7%	19.7%
Edgefield	80.9%	12.8%
Greenwood	47.3%	6.9%
McCormick	100.0%	12.3%
Oconee	100.0%	21.1%
Pickens	69.3%	11.1%
Saluda	7.9%	1.1%

[1] Less than 0.01 percent of Aiken County is also located in the Upper Savannah River basin.

The character of the water bodies within the Upper Savannah River basin changes, moving from the upper reaches to the lower reaches of the basin. In the upper reaches of the basin, the Tallulah and Chattooga River systems are primarily mountainous and characterized by periodic rapids and high-velocity flows. Since 1950, the middle and lower reaches of the basin, consisting of the Seneca and Savannah Rivers, have been almost entirely impounded. These reaches, therefore, possess the hydrological characteristics of reservoir submergence and low-velocity flows (SCDNR 2013). The Upper Savannah River basin is the most regulated in South Carolina, and five of the largest reservoirs by volume in South Carolina (Lake Jocassee, Lake Keowee, Lake Hartwell, Lake Russell, and Lake Thurmond) dominate its hydrology (SCDNR 2013). These reservoirs are important for recreation, drinking water, flood control, both conventional and pumped-storage hydroelectric/nuclear power generation, and thermoelectric generation.

Five major subbasins divide the Upper Savannah River planning basin: the Tugaloo, Seneca, Upper Savannah, Middle Savannah, and Stevens Creek subbasins. Following are descriptions of each of these subbasins.

Tugaloo Subbasin

The Tugaloo subbasin forms the northwestern part of the Upper Savanah watershed and supplies many of its headwaters. The Tugaloo River is the main water body within the Tugaloo subbasin, which spans parts of Georgia, South Carolina, and North Carolina. The river is fed by the Tallulah River in Georgia and the Chattooga River in South Carolina, and several major reservoirs exist along these rivers. In Georgia, the Tallulah River forms Lake Burton and Lake Rabun. Along the border of Georgia and South Carolina, the Tugaloo River forms Lake Tugaloo, Lake Yonah, and eventually combines with the Seneca River to form the western branch of Lake Hartwell. The Chattooga River is one of the longest free-flowing mountain rivers in the southeastern United States, and its steep incline gives the river some of the region’s most remarkable whitewater rafting and trout fishing. The Chattooga was designated a Wild and Scenic River by the United States Congress in 1974 (United States Department of Agriculture [USDA] Forest Service 2023).

Seneca Subbasin

The Seneca subbasin forms the northeastern part of the Upper Savannah watershed and is one of its most mountainous and regulated regions. The subbasin spans the mountains and foothills of the Blue Ridge in

South Carolina's Anderson, Oconee, and Pickens Counties, with a small portion also occurring in North Carolina. The Seneca River system feeds the subbasin, which is almost entirely impounded, forming the major reservoirs of Lake Jocassee, Lake Keowee, and, after merging with the Tugaloo River, Lake Hartwell.

Upper Savannah Subbasin

Forming the central part of the Upper Savannah watershed and spanning both South Carolina and Georgia, the Savannah River feeds this subbasin. The confluence of the Tugaloo and Seneca Rivers forms the Savannah River, which flows to the outfall of the Lake Hartwell dam. Farther downstream, the Savannah River is dammed to create Lake Russell and again dammed to create Lake Thurmond. The subbasin ends at the Lake Thurmond dam.

Middle Savannah Subbasin

Only a small part of the Middle Savannah subbasin contributes to the Upper Savannah planning watershed within South Carolina. This part is the Upper Savannah basin's southern extreme. This watershed consists of the 12-mile reach of the Savannah River that lies between the Lake Thurmond dam and the confluence of the Savannah River and Stevens Creek.

Stevens Creek Subbasin

The Stevens subbasin is enclosed entirely within the state of South Carolina and is fed by Stevens Creek. The creek drains into the Savannah River approximately 12 miles south of the Lake Thurmond dam, just north of the city of Augusta, Georgia. The Upper Savannah watershed ends at the confluence of the Savannah River and Stevens Creek, where the Lower Savannah–Salkehatchie watershed begins. This is also the location of Stevens Creek dam.

2.1.2 Land Cover

Land use and land cover in the Upper Savannah River basin varies from rural farmland and forested areas to small- and moderate-sized urban areas. As a result, woodland is the dominant land cover in the basin, as shown in Figure 2-2 (Multi-Resolution Land Characteristics Consortium [MRLC] 2024a). The basin is predominantly rural, and its main population centers are the small-to-moderately sized cities of Anderson, Greenwood, Clemson, Seneca, and Abbeville.

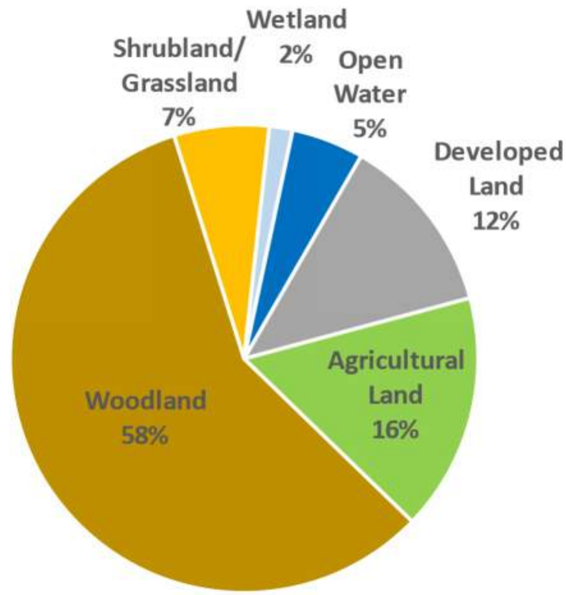


Figure 2-2. 2023 Upper Savannah River Basin land cover (MRLC 2024a).

Table 2-2, derived from MRLC's National Land Cover Database (NLCD), provides a more detailed summary of land cover types in the basin, and includes changes in land cover area from 2001 to 2023 (MRLC 2024a, 2024b). In that time, developed land

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increased by more than 58 sq mi, while agricultural land (composed of hay/pasture and cultivated crops) collectively decreased by more than 28 sq mi. Nearly all of the net agricultural losses were driven by a more than 27 sq mi loss in hay/pastureland. Woodland areas (represented by deciduous, evergreen, and mixed forests) likewise collectively decreased by almost 49 sq mi. In this case, an increase in deciduous forest was overcome by a 66 sq mi loss in evergreen and mixed forests. A less significant compositional change can be seen in shrubland (represented by shrub and herbaceous grassland), as shrub land cover increased by 14 sq mi in the basin. Often, shrublands are temporarily created through silvicultural practices, such as clearing standing timber and replanting new trees, as well as through fire. The extent of these shrublands can vary each year depending on the amount of timber harvested and the intensity of the forest fires (USGS 2020). Wetlands remained stable or possessed slight decreases, and a minor increase in open water is likely the product of the water level in the existing reservoirs at the time of the survey, as well as the production of new water retention ponds and dams from land development.

Table 2-2. Upper Savannah River basin land cover and trends (MRLC 2024a, 2024b).

NLCD Land Cover Class	2001 Area (sq mi)	2023 Area (sq mi)	Change from 2001 to 2023 (sq mi)	Percentage Change from 2001 to 2023	Percentage of Total Land (2023)
Open Water	149.3	160.0	10.7	7.2%	5.0%
Developed, Open Space	235.0	257.2	22.1	9.4%	8.0%
Developed, Low Intensity	78.7	104.3	25.5	32.4%	3.3%
Developed, Medium Intensity	17.1	25.1	8.0	46.9%	0.8%
Developed, High Intensity	5.5	7.9	2.5	44.6%	0.2%
Barren Land	8.4	4.1	-4.3	-51.2%	0.1%
Deciduous Forest	691.0	708.7	17.7	2.6%	22.2%
Evergreen Forest	858.2	826.9	-31.4	-3.7%	25.9%
Mixed Forest	350.1	315.0	-35.1	-10.0%	9.9%
Shrub/Scrub	83.0	90.4	7.3	8.8%	2.8%
Herbaceous	112.7	119.6	6.9	6.1%	3.7%
Hay/Pasture	540.4	512.8	-27.6	-5.1%	16.1%
Cultivated Crops	12.6	11.8	-0.8	-6.3%	0.4%
Woody Wetlands	51.7	50.1	-1.6	-3.0%	1.6%
Emergent Herbaceous Wetlands	0.9	1.0	0.1	16.3%	<0.1%
Total Land Area	**3,195**	**3,195**	**0.0**	**–**	**100.0%**

2.1.3 Geology

South Carolina is divided into three major physiographic provinces based on geologic characteristics: the Blue Ridge, the Piedmont, and the Coastal Plain. The Upper Savannah River basin lies within the Blue Ridge and Piedmont provinces. As the basin flows from its headwaters to its outlet, high hills and mountains in the north give way to rolling hills in the south. Figure 2-3 depicts a generalized geologic map of the Upper Savannah River basin.

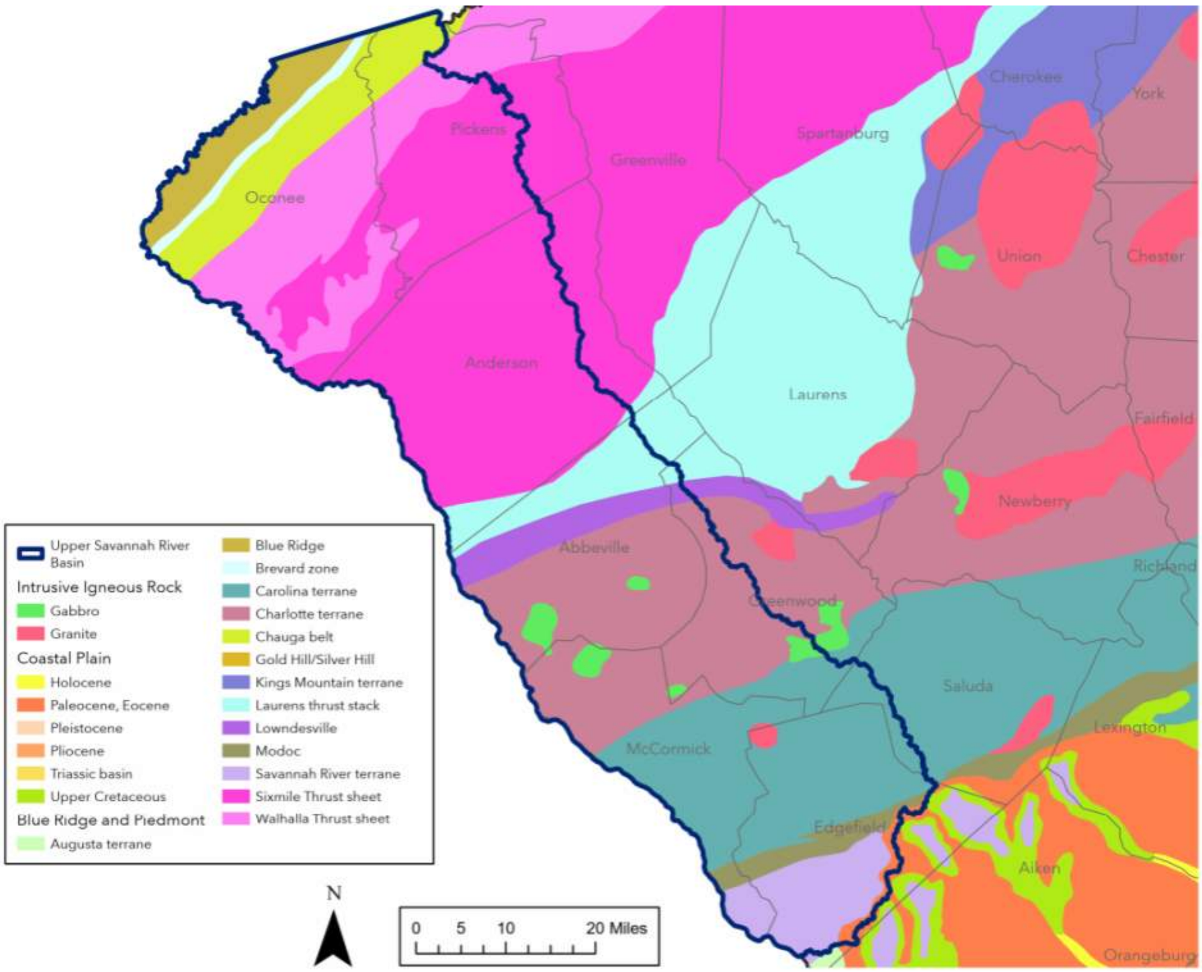

Figure 2-3. Generalized geological map of the Upper Savannah River Basin (SCDNR 2023a).

The Piedmont province consists mostly of saprolite, weathered bedrock, and overlying crystalline rock. The saprolite layer can range from 10 to 150 feet in thickness and possesses a high porosity but low permeability. These characteristics mean saprolite typically absorbs and slowly releases rainwater into fractures within the underlying rock that can be tapped by wells. However, in the Piedmont province, these fractures are small; therefore, the underlying bedrock cannot form aquifers. Wells within this region typically yield less than 50 gallons per minute (gpm) (SCDNR 2009). Well yields can be far higher locally, and wells in topographically high places generally yield less than those in valleys where water recharge and rock fractures are more common. Because of these relatively low yields, groundwater is not a significant source of water in the Upper Savannah River basin. Total groundwater withdrawals reported to SCDES account for less than 1 percent of the entire water usage of the basin (SCDHEC 2022a; SCDNR 2023b). Groundwater discharges into surface water are more common in the upper parts of the basin where rainfall is higher.

2.2 Climate

2.2.1 General Climate

Much like the rest of the Carolinas, the South Carolina part of the Upper Savannah River basin's climate is humid subtropical, with hot summers and mild winters. Figure 2-4 shows the average annual temperature and the annual average precipitation for the Upper Savannah River basin, based on the current climate normals (1991 through 2020). The South Carolina State Climatology Office (SCO) "Climate" webpage provides current climate normals maps for South Carolina for the parameters of temperature (average, maximum, and minimum) and precipitation at annual, seasonal, and monthly time steps (SCDNR SCO 2021).

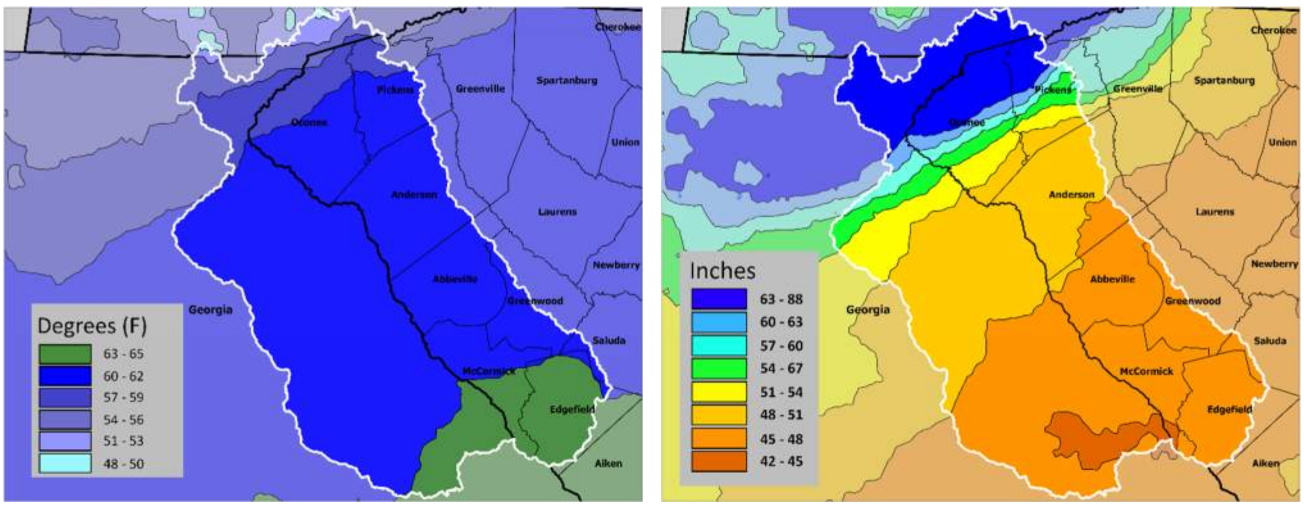

Figure 2-4. Normal annual average temperature and precipitation (1991 through 2020) for the Upper Savannah River basin.

The average annual temperature in Upper Savannah River basin ranges from 48 to 65 degrees Fahrenheit (°F), with temperatures increasing from the upper basin to the lower basin. In the South Carolina part of the basin, average annual temperature ranges from 54°F to 65°F. The annual average precipitation for the entire basin, including the South Carolina part of the basin, ranges from 42 to over 63 inches (in.), with precipitation totals decreasing from the upper basin to the lower basin. Parts of the basin with the highest annual average rainfall are in areas with higher elevations.

Temperature and precipitation values are not constant throughout the basin, and they are not consistent for a given location throughout the year. Figure 2-5 and Figure 2-6 show the monthly variation in temperature and precipitation at two meteorological stations: Walhalla station in Oconee County and Anderson Regional Airport station in Anderson County. These two stations were selected because of their long-term records (data have been collected at Walhalla since 1896 and at Anderson Regional Airport since 1949). The Walhalla station is missing data for 2000 for both temperature and precipitation. Anderson Regional Airport is missing one year of temperature data (1987) and six years of precipitation data (1959 through 1961, 1986 through 1987, and 1989). The missing annual values are because of one or more months of missing data during each of those years, which affects the annual average for that specific year. The annual average values of temperature and precipitation for each station presented may not match their locations on the basin climatology images of Figure 2-4 because of the differences in the periods of record of the data. The long-term station data range from 1949 through 2023, while the data used for Figure 2-4 are based on the current climate normals (1991 through 2020).

At both stations, temperature oscillates throughout the year, with July generally being the warmest month for both stations (average monthly temperatures of 77.2°F at Walhalla and 80.0°F at Anderson Regional Airport) and January being the coldest month (average monthly temperatures of 41.8°F at Walhalla and 42.8°F at Anderson Regional Airport). When comparing the climographs for Walhalla and Anderson Regional Airport as shown in Figures 2-5 and 2-6), the average monthly temperatures at Walhalla are 1.5°F to 3°F cooler than Anderson Regional Airport.

At both stations, precipitation varies throughout the year. The wettest climatological month for both stations is March. Walhalla's average precipitation in March is 5.97 in. while Anderson Regional Airport's average precipitation is 4.71 in. Walhalla's driest month is November (average monthly precipitation of 4.32 in.) while Anderson Regional Airport's driest month is October (average monthly precipitation of 3.04 in.). Generally, Walhalla receives more rainfall, with monthly totals 1.00 to 1.70 in. higher than Anderson Regional Airport.

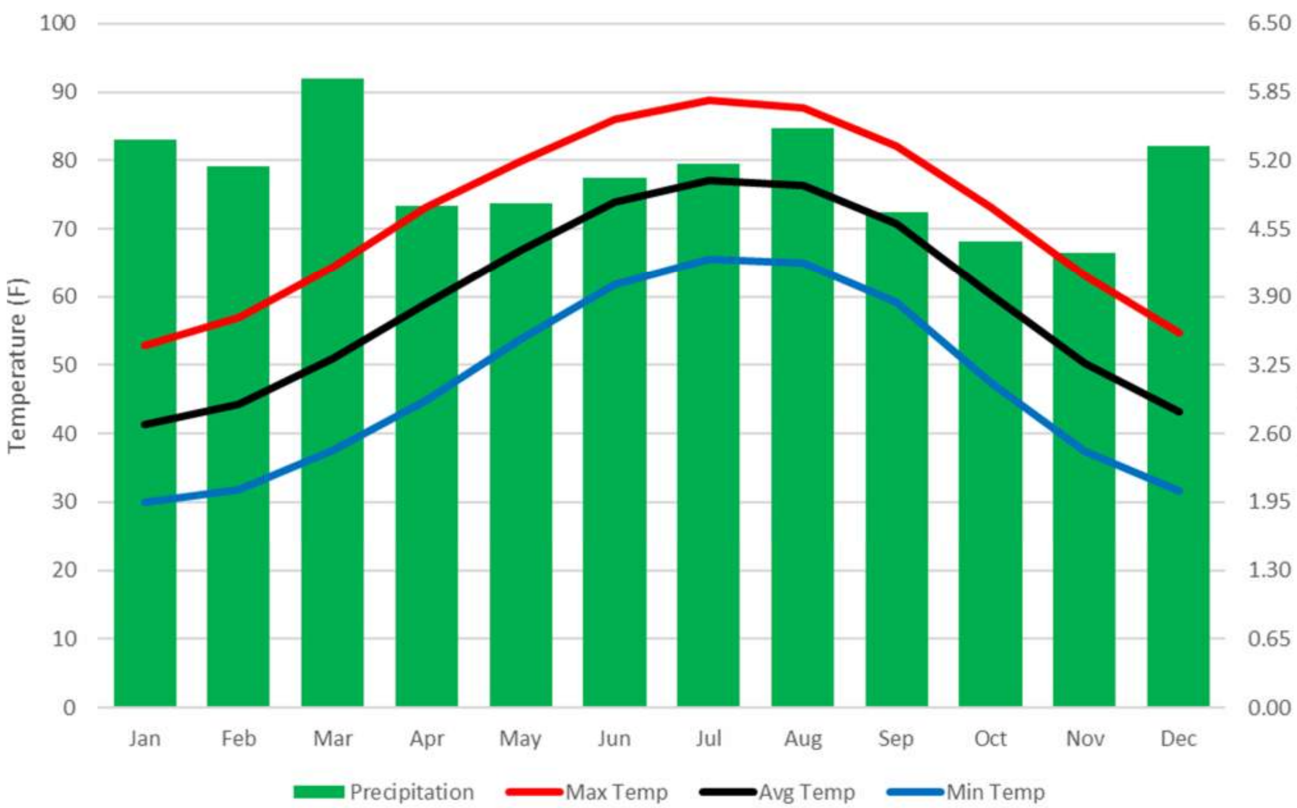

Figure 2-5. Monthly climate averages for Walhalla, from 1949 through 2023 (SCDNR SCO 2023a).

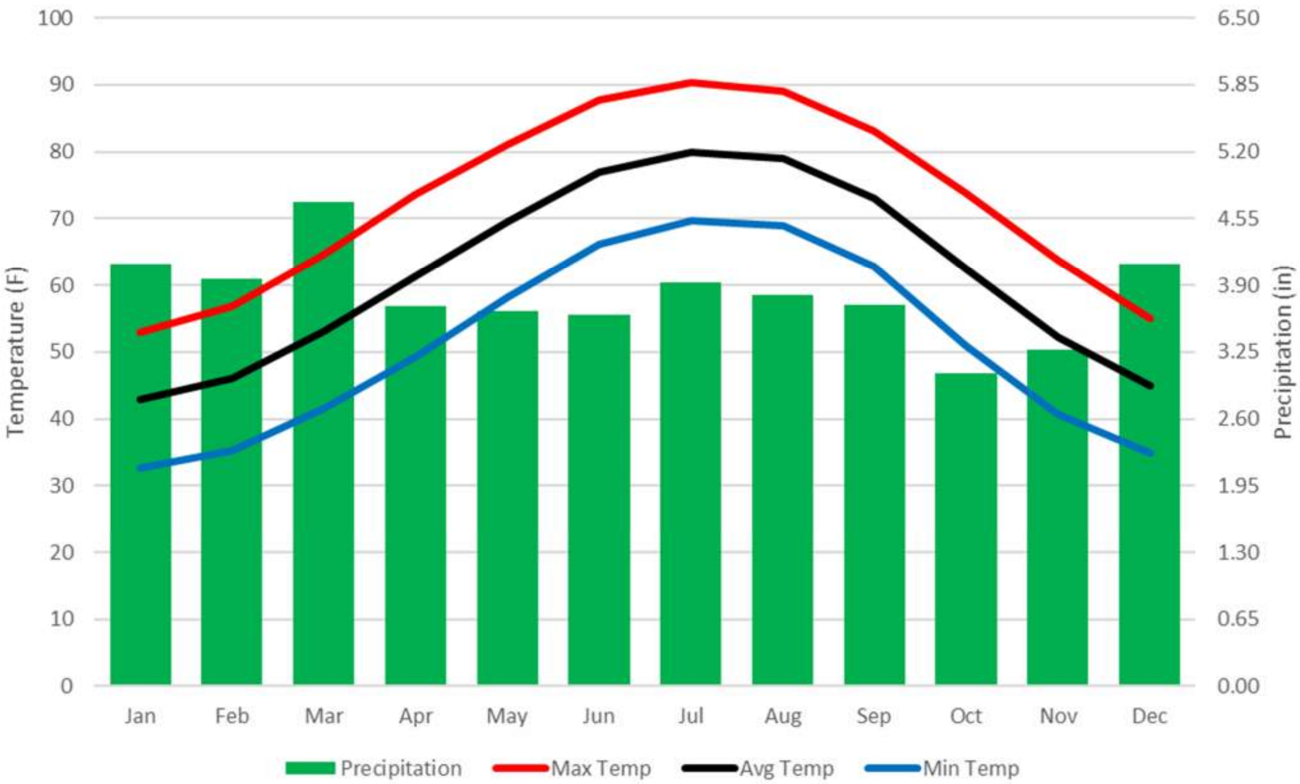

Figure 2-6. Monthly climate averages for Anderson Regional Airport, 1949 through 2023 (SCDNR SCO 2023a).

The annual average temperature and precipitation for the Carolinas and the Upper Savannah River basin have varied (National Oceanic and Atmospheric Administration [NOAA] 2023a; SCNDR SCO 2023a). Figure 2-7 shows the annual average temperature time series for Walhalla and Figure 2-8 shows the same for Anderson Regional Airport. Figures 2-7 and 2-8 show years with annual average temperatures above the 1949 through 2023 average annual temperatures. Through this period, Walhalla has an annual average temperature of 59.6°F (Figure 2-7) and Anderson Regional Airport has an annual average temperature of 61.8°F (Figure 2-8). Table 2-3 shows the warmest and coldest five years for both stations. The two stations share 1990 and 2016 as two of their top five warmest years, and share 1966 and 1976 as two of their top five coldest years. Other than Anderson Regional Airport's warmest year (1975), these two stations' warmest years all took place after 1990. Contrastingly, each of these station's top five coldest years took place prior to 1990.

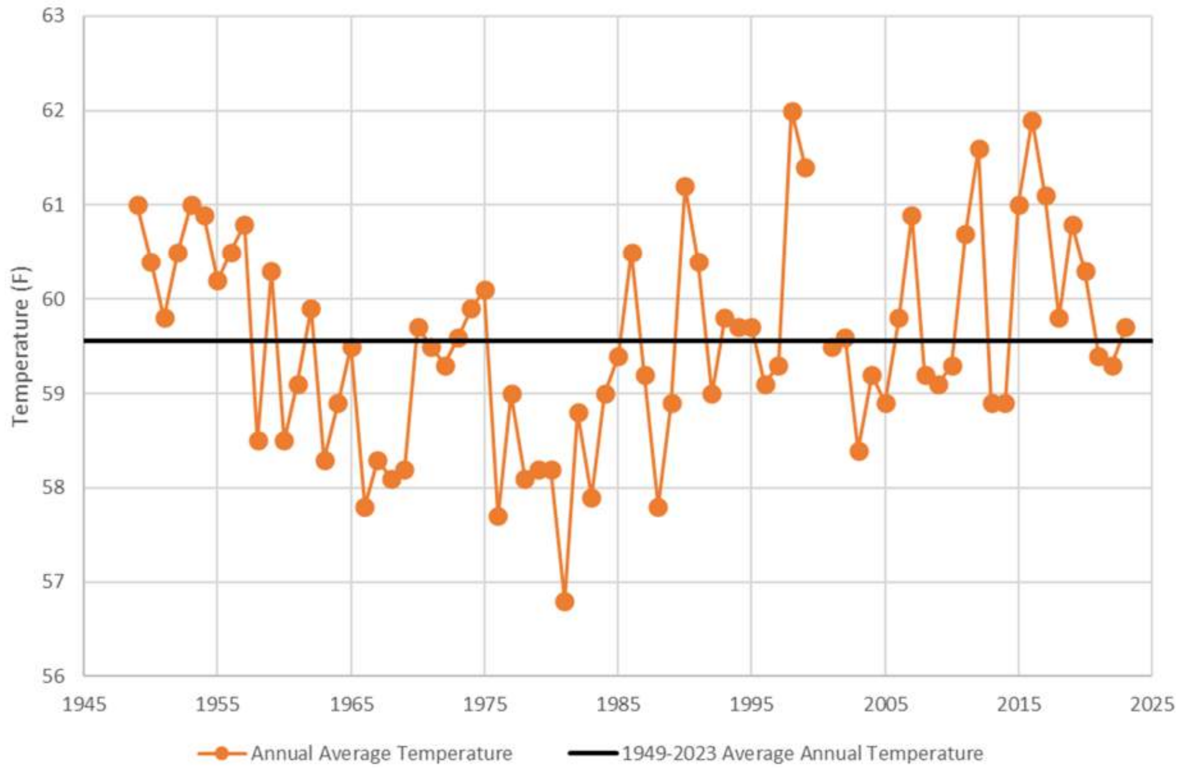

Figure 2-7. Annual average temperature for Wahalla, 1949 through 2023 (SCDNR SCO 2023a).

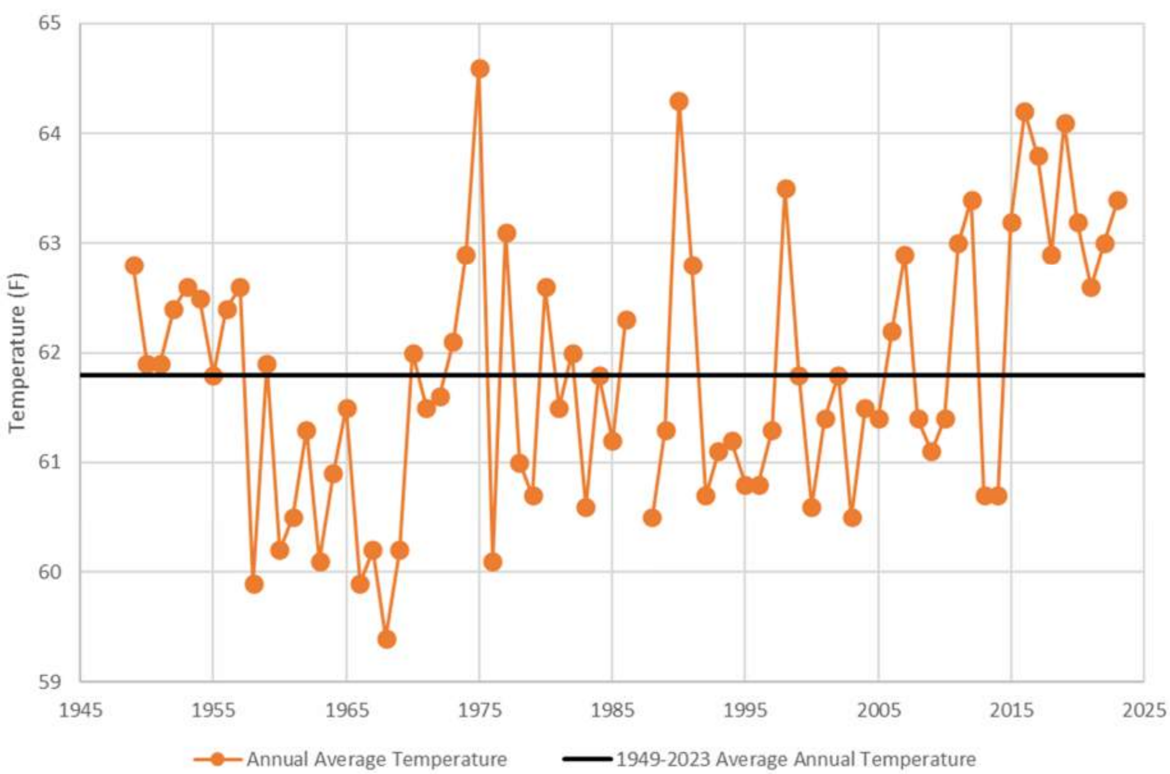

Figure 2-8. Annual average temperature for Anderson Regional Airport, 1949 through 2023 (SCDNR SCO 2023a).

Table 2-3. Five warmest and coldest years for Walhalla and Anderson Regional Airport from 1948 through 2023 (SCNDR SCO 2023a).

Year Rank	Warmest		Coldest	
	Walhalla	Anderson Regional Airport	Walhalla	Anderson Regional Airport
1	1998 (62.0°F)	1975 (64.6°F)	1981 (56.8°F)	1968 (59.4°F)
2	2016 (61.9°F)	1990 (64.3°F)	1976 (57.7°F)	1958 (59.9°F)
3	2012 (61.6°F)	2016 (64.2°F)	1966 (57.8°F)	1966 (59.9°F)
4	1999 (61.4°F)	2019 (64.1°F)	1988 (57.8°F)	1963 (60.1°F)
5	1990 (61.2°F)	2017 (63.8°F)	1983 (57.9°F)	1976 (60.1°F)

Figure 2-9 shows the annual precipitation time series for Walhalla and Figure 2-10 shows the same for Anderson Regional Airport. Through this period, Walhalla had an average annual precipitation of 60.74 in. (Figure 2-9) and Anderson Regional Airport had an average annual precipitation of 45.81 in. (Figure 2-10).

Table 2-4 shows the driest and wettest five years for both stations. Walhalla and Anderson Regional Airport share three of their top five driest years on record (2016, 2007, and 1988). Both 2016 and 2007 are the driest and second driest years (respectively) for both stations. Both years were part of notable droughts in South Carolina history, the 2015 to 2016 drought and 2007 to 2009 drought. Walhalla and Anderson Regional Airport also share three of their top five wettest years on record (2018, 2013, and 1964). Anderson's wettest year on record is 1964, which matches the wettest year on record for the state of South Carolina. However, this is only the fourth wettest year on record for Walhalla.

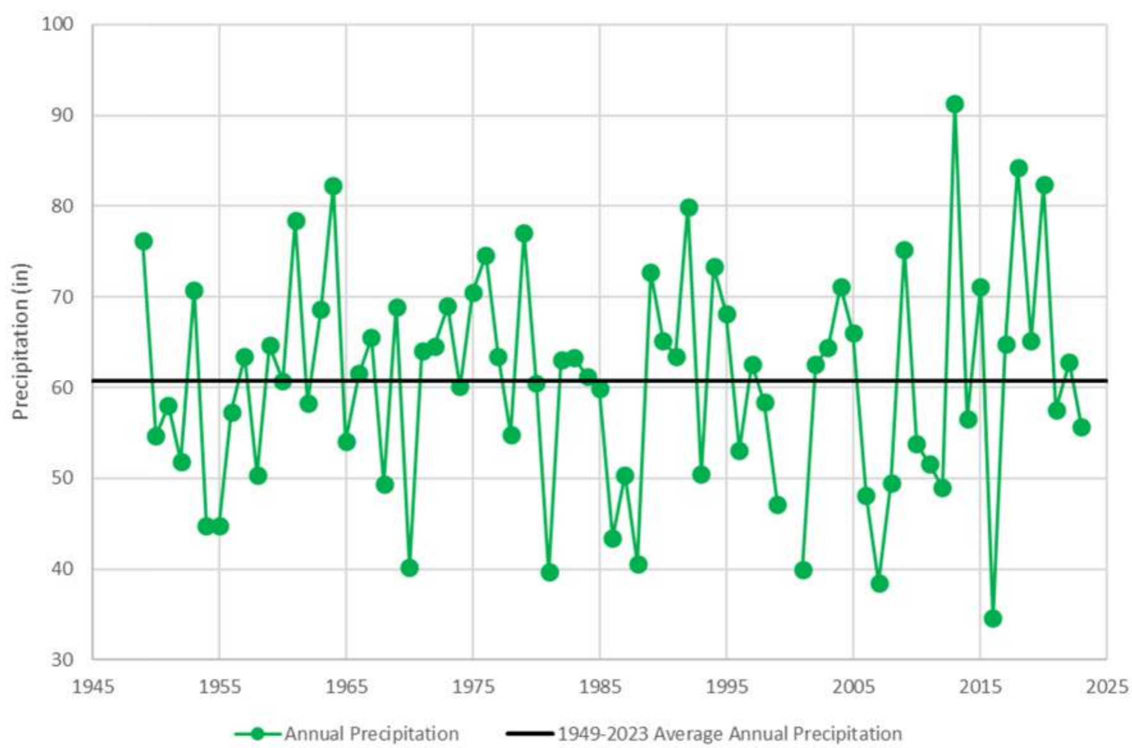

Figure 2-9. Annual precipitation for Wahalla, 1949 through 2023 (SCDNR SCO 2023a).

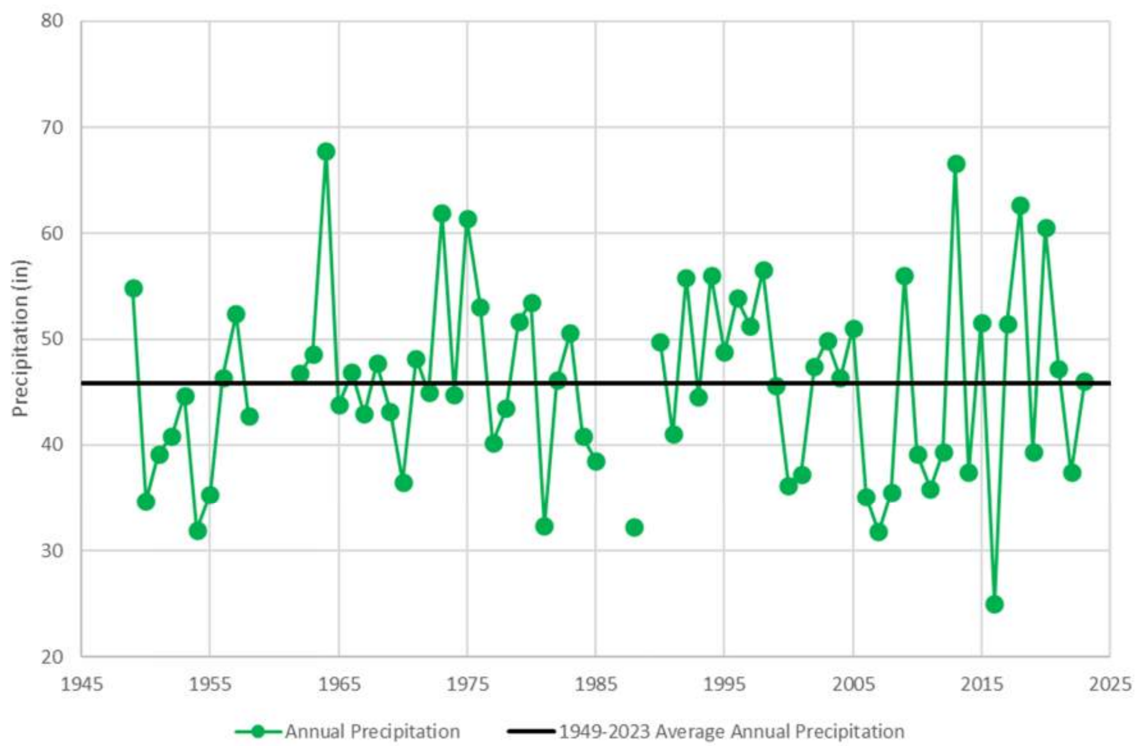

Figure 2-10. Annual precipitation for Anderson Regional Airport, 1949 through 2023 (SCDNR SCO 2023a).

Table 2-4. Five wettest and driest years Walhalla and Anderson Regional Airport from 1949 through 2023 (SCNDR SCO 2023).

Year Rank	Driest		Wettest	
	Walhalla	Anderson Regional Airport	Walhalla	Anderson Regional Airport
1	2016 (34.60 in.)	2016 (25.07 in.)	2013 (91.36 in.)	1964 (67.79 in.)
2	2007 (38.49 in.)	2007 (31.80 in.)	2018 (84.27 in.)	2013 (66.59 in.)
3	1981 (39.67 in.)	1954 (31.95 in.)	2020 (82.37 in.)	2018 (62.74 in.)
4	2001 (39.89 in.)	1988 (32.25 in.)	1964 (82.26 in.)	1973 (61.91 in.)
5	1970 (40.23 in.)	1981 (32.32 in.)	1992 (79.95 in.)	1975 (61.40 in.)

2.2.2 Severe Weather

Severe weather, including thunderstorms, tornadoes, and tropical cyclones, can impact some or all portions of the Upper Savannah River basin.

Severe Thunderstorms and Tornadoes

There are between 45 and 63 thunderstorm days across the Upper Savannah River basin annually, with typically more thunderstorm days occurring in the upper and lower sections of the basin than the middle section (NOAA 2023b). Although the number of thunderstorm days varies across the basin, the potential impact from each storm is equal across the basin. While thunderstorms occur throughout the year, severe thunderstorms are more common during climatological spring (March, April, May) and summer (June, July, and August). For a thunderstorm to be considered severe, it must produce wind gusts of at least 58 miles per hour (mph), hailstones of 1 in. diameter or larger, or a tornado. Tornadoes are violently rotating columns of air that descend from thunderstorms and contact the ground.

Most of South Carolina's tornadoes are short-lived EF-0 and EF-1 tornadoes, the lowest strengths on the Enhanced Fujita (EF) Scale, with winds between 65 and 110 mph. However, even a tornado with the lowest intensity rating is dangerous and poses a significant risk to lives and property. Table 2-5 shows the number of tornadoes by intensity ranking, confirmed within the basin between 1950 and 2023. (For reference, the EF Scale became operational in 2007, replacing the original Fujita [F] Scale used since 1971; historical data are referenced to the EF Scale for simplicity). Most of the basin's tornadoes are rated EF-0 and EF-1. Since 1950, the basin has experienced 141 tornadoes, with 31 of them being of significant strength (EF-2 or higher). The strongest tornado to affect the basin was an EF-4 tornado in 1973 that started in Abbeville County and ended in Greenwood County. No part of the Upper Savannah basin nor South Carolina has experienced an EF-5 tornado. The South Carolina SCO collected the tornado figures from *NOAA National Centers for Environmental Information Storm Events Database* (NOAA 2023c) and from the National Weather Service (NWS) Greenville-Spartanburg's *Historic Tornadoes in the Carolinas and Northeast Georgia Database* (NWS 2023).

Table 2-5. Count of Tornadoes in the Upper Savannah basin by intensity ranking 1950 through 2023 (SCDNR SCO 2023a).

EF Scale	Wind Speed	Count
EF-0	65–85 mph	58
EF-1	86–110 mph	52
EF-2	111–135 mph	23
EF-3	136–165 mph	7
EF-4	166–200 mph	1
EF-5	200+ mph	0
Total Number of Tornadoes in the Basin		141

Tropical Cyclones

South Carolina has an 86 percent chance of being impacted by tropical cyclones each year. Tropical cyclones are warm-core, non-frontal synoptic-scale cyclones, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center. Tropical cyclones include tropical depression, tropical storm, and hurricanes. Tropical cyclones can cause storm surge, damaging wind, precipitation-induced flooding (flash flooding and riverine flooding), and tornadoes. These impacts can occur near and far from the storm's center, because tropical cyclones have an average size of 300 miles in diameter. For example, tornadoes produced by tropical cyclones form in the outer rainbands, which can be hundreds of miles from the storm's center.

In 2024, Tropical Cyclone Helene's wind field extended over 200 miles from the center of circulation, nearly 400 miles wide. Tropical storm-force gusts were reported across much of the state, including most of the Midlands and Lowcountry; a 75-mph hurricane-strength gust occurred at Beaufort Marine Corps Air Station. Many Upstate stations reported gusts over 60 mph, with estimated wind gusts over 80 mph in the region. Helene's preliminary peak rainfall in South Carolina of 19.69 inches near Jocassee in Oconee

County ranks third among rainfall from tropical cyclones in South Carolina's history. This total ranks behind the 22.02 inches of rain recorded in Moncks Corner (Berkeley County) in August 2024 from Tropical Storm Debby and ahead of the 17.45 inches reported at the same Jocassee station in August 1994 from Tropical Storm Beryl.

In 2021, the remnants of Tropical Storm Fred passed through Georgia and North Carolina with the strength of a tropical depression. While the storm's center did not pass through South Carolina, as shown in Figure 2-11, it produced 10 tornadoes in South Carolina, three of which were in the Upper Savannah River basin (all at EF-0 strength). Tornadoes produced by tropical cyclones form in the outer rainbands, which can be hundreds of miles from the storm's center. The remnants of Hurricane Nate (2017) produced seven tornadoes across the basin as it moved across Tennessee and the Ohio River Valley.

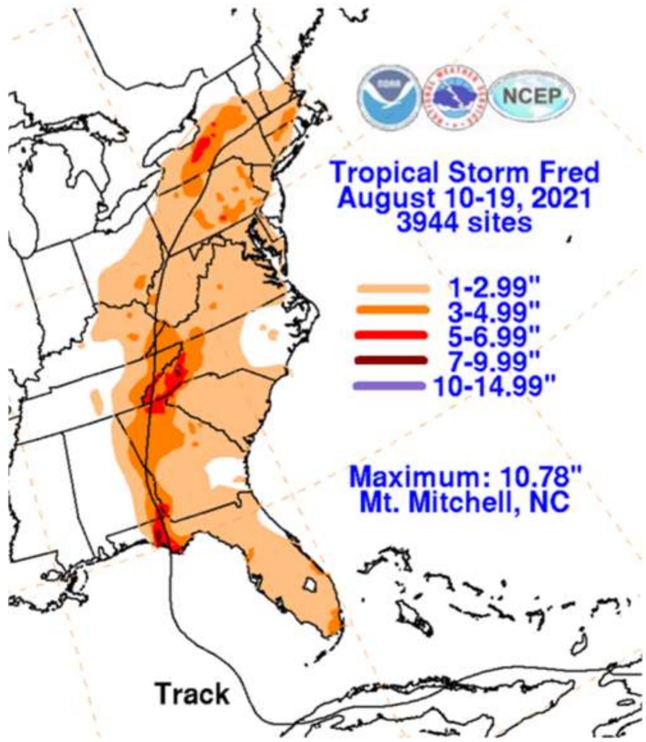

Figure 2-11. Track and precipitation from Tropical Storm Fred 2021.

Courtesy of NOAA's Weather Prediction Center.

Since 1851 and prior to Hurricane Helene in 2024, 31 tropical cyclones have tracked through the Upper Savannah River basin, meaning the storm's center crossed through part of the basin. Seventeen of these storms were unnamed storms (pre-1951) and 14 were named storms (the naming of tropical storms and hurricanes started in 1951). Of these 31 cyclones, 14 were of tropical depression strength (maximum wind of 38 mph) and eight were of tropical storm strength (maximum wind of 39 to 73 mph). There have not been any tropical cyclones that have tracked through the basin at hurricane strength (maximum wind of 74 mph or greater). Because of the spatial extent of tropical cyclones, there have been multiple storms of various strength that have affected the Upper Savannah River basin that did not actually track through it.

For more information on tropical cyclones that have affected South Carolina, visit the SCDNR SCO Hurricane and Tropical Storms Database (SCDNR SCO 2023b).

Winter Storms

Multiple winter weather events, such as winter precipitation (snow, sleet, ice accumulation, and freezing rain accretion [accumulation]) and extreme cold, have impacted the Upper Savannah River basin. The basin has a 30 to 90 percent probability of a snow event each year, with mean annual snow accumulations ranging from 1 to 8 inches, depending on location within the basin. Annual snow probability and mean annual snowfall both decrease from the upper to the lower basins. The mountains have the highest chance for snow each year and generally the highest snow accumulations compared to the rest of the basin. The largest snowfall total in the Upper Savannah River basin is 15.00 inches at Long Creek in Oconee County, occurring on January 7, 1988 (SCDNR SCO 2023c). While other portions of the basin have not received snow accumulation that large, there have been other snow events that have affected some or the entire basin. In February 1979, all stations within the basin received snow, with totals ranging from 4 inches at Calhoun Falls (Abbeville County) to 8.1 inches at Long Creek (Oconee County). Another event where all the stations in the basin received snow was in February 2004, where totals ranged from 1.6 inches at Abbeville 1.2 NW (Abbeville County) to 7.00 inches at Jocassee WNW (Oconee County).

Winter weather events are usually high-impact situations in South Carolina because of their infrequent sub-seasonal, seasonal, and annual occurrence. Winter precipitation mainly impacts travel and transportation; however, heavy snow accumulations and ice accretions have caused impacts to trees, power lines, and built structures. Since 1990, there have been seven freezing rain and ice events that have each caused more than $100,000 in property damage to South Carolina, including impacts within the Upper Savannah basin. Impacts from these events are mainly from ice accretions over half an inch. Damage to powerlines, leading to power outages, as well as damage to roofs and trees, were the most common impacts. However, during some of these events, ice accretions on roads led to car accidents and fatalities. Table 2-6 provides the dated of notable winter storms and the estimated damage in dollars to the entire state (SCDNR SCO 2023d).

Table 2-6. Winter storms that have caused significant ice accretion and damage in South Carolina since 1990.

Event Date	Estimated Damage in Dollars*
December 27–28, 1992	$500,000–5 million $500,000–5 million (crop)
March 13, 1993	$45 million $38 million (crop)
January 2–3, 1999	$1.45 million
December 4–5, 2002	$100 million
January 25–27, 2004	$54 million
January 29–30, 2010	$180,000
January 9–11, 2011	$716,000

*Amounts refer to property damage unless otherwise stated.

Extreme cold or freeze events can have significant impacts as well. Since 1958, 91 cold or freeze events have affected at least some part of the state, with over half of those events impacting at least a portion of the Upper Savannah River basin. Generally, these events cause impacts to water lines that are close to or above the ground that are more susceptible to freezing. Water lines that freeze typically burst, which can cause water loss and flooding inside structures. While these types of events have occurred on a more localized scale often, these types of impacts occurred on a large scale in the Upper Savannah River basin during cold events in January 1986, January 1994, January 2003, and more recently in December 2022. During each one of these events, minimum temperatures across the basin dropped below 15°F, with multiple stations in the upper portion of the basin experiencing minimum temperatures of below 10°F (not accounting for windchill). The most recent extreme cold event, December 23 to 26, 2022, caused many water lines to freeze and burst as minimum temperatures in the basin ranged from -1°F to 9°F. Beyond the internal water damage to homes and buildings, the amount of line breaks caused some water systems to experience a significant drop in water supplies. This extreme cold event highlights how other natural hazards besides drought can cause issues to water supplies, infrastructure, and delivery.

For more information about winter weather events that have affected South Carolina, visit the SCO's *South Carolina Winter Weather Database* (SCDNR SCO 2023d).

Flooding

The general definition of a flood is the temporary condition of a partial or complete inundation of typically dry land. There are three common types of flooding: fluvial, pluvial, and coastal. Fluvial flooding, also known as riverine flooding, is the flooding of typically dry areas caused by an increased water level of an established lake, river, or stream when the water overflows its banks. The damage from fluvial flooding can be widespread, extending miles away from the original body of water. This type of flooding is caused by excessive freshwater from a severe or prolonged rain event. Pluvial flooding occurs when rainfall events cause flooding in an area independent of an overflowing body of water. This can occur when drainage systems are overwhelmed or as flash floods caused by heavy rainfall or from a sudden release of water upstream or uphill. Coastal flooding occurs when seawater inundates land; this can be caused by wind-driven storm surge or tsunamis.

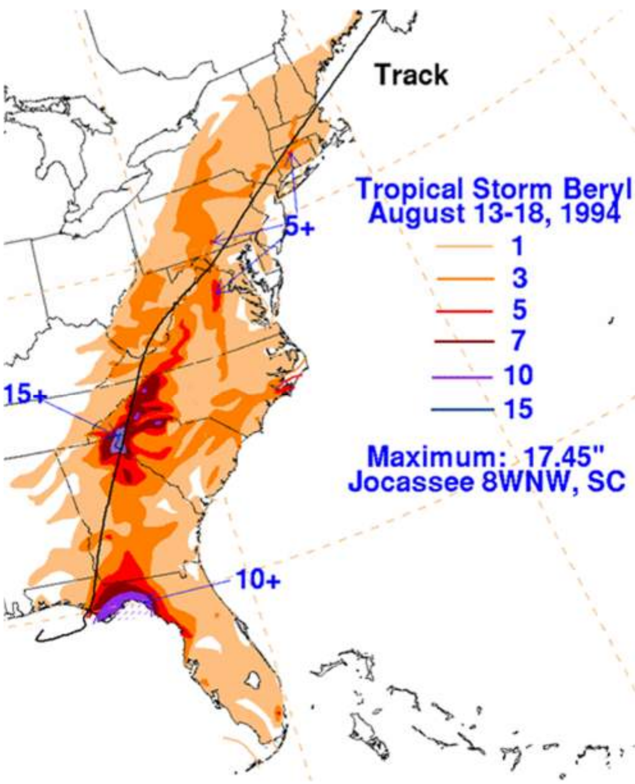

Figure 2-12. Track and precipitation from Tropical Storm Beryl 1994.
Courtesy of NOAA's Weather Prediction Center.

Two examples of significant flooding in the basin are from Tropical Storm Beryl (1994) and Tropical Storm Jerry (1995). Both storms caused significant flooding in the Upper Savannah basin, as well as other parts of the state. The entire Upper Savannah River basin received rain from Beryl (1994), with totals ranging from 3.00 inches to over 15.00 inches across the basin between August 16 and 18, as shown on Figure 2-12. The high precipitation caused an increase in streamflow throughout the basin. Many streams that normally have a daily median flow of less than 100 cubic feet per second (cfs) had peak daily flows above 1,000 cfs. Streamflow on the Chattooga River near Clayton, Georgia (USGS Gage 02177000) peaked at 17,500 cfs on August 17 (roughly 50 times greater than the median daily statistic, 350 cfs), as shown on Figure 2-13 (USGS 2023a). Although Hurricane Beryl caused significant flooding in the Upper Savannah River basin, it also caused significant impacts to other portions of the state.

More information on historical riverine flooding events across the state can be found in the Keystone Riverine Flooding Events in South Carolina report produced by the SCO (SCDNR SCO 2023e).

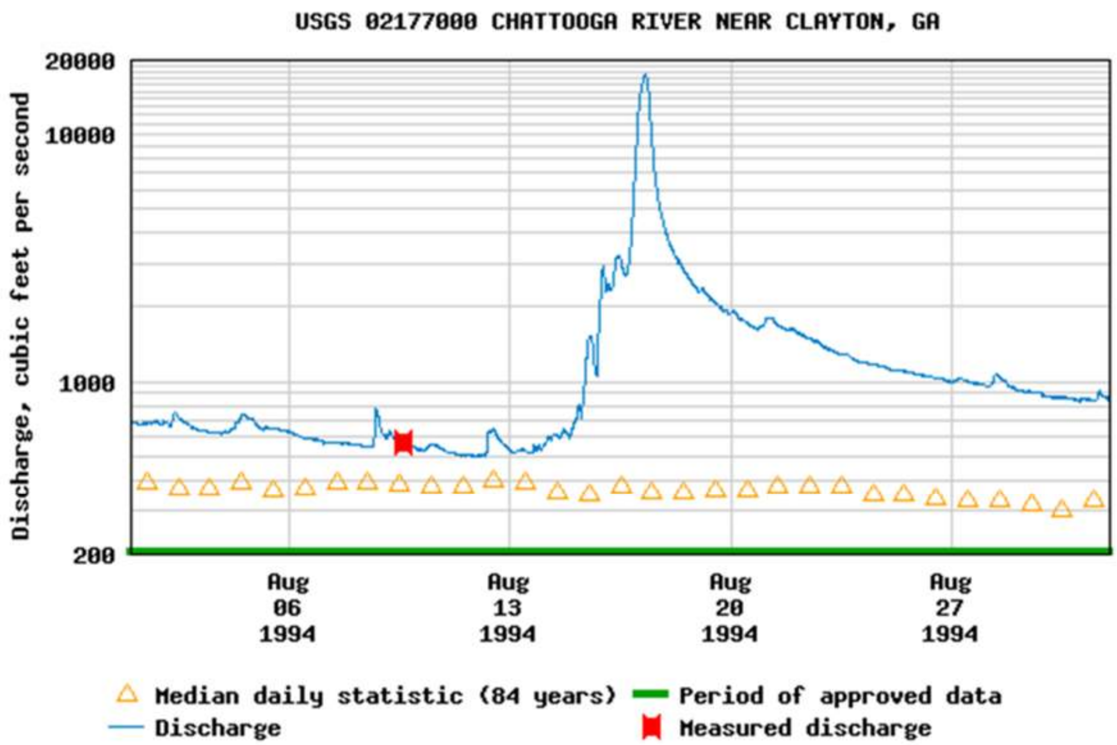

Figure 2-13. Chattooga River near Clayton, Georgia, daily discharge between August 1 and 31, 1994 (USGS 2023a).

2.2.3 Drought

Drought is a normal part of climate variability that occurs in every climate. Drought results from a lack of precipitation over an extended period, often resulting in a water shortage for some activity, sector, or the environment. In contrast to other environmental hazards, droughts often develop slowly over weeks, months, or years. Three main categories physically define drought: meteorological, agricultural, and hydrological. These categories help determine the economic, ecological, and societal impacts of droughts in communities.

Figures 2-14 and 2-15 show the annual Standard Precipitation Index (SPI) value for the Walhalla and Anderson Regional Airport stations from 1945 to 2022 (the latest SPI data available for these stations). The SPI is a drought index that compares accumulated rainfall over a given period (here, 12 months) to the historical average, where the index values are standard deviations from the mean. Anything equal to or less than -1.0 is considered a drought. The lower the index value, the more severe the drought. The lowest SPI value was -2.41 for Walhalla and -2.31 for Anderson Regional Airport, occurring in 2016 for both stations. This matches each station's driest year on record. In the last decade (2013 through 2022), both stations have had a mix of both dry and wet years. Annual SPI values do not show short-term conditions, such as monthly or seasonal conditions. During a year with a negative annual SPI value, there can be months or seasons with positive SPI values, and vice versa. While the annual SPI time series is provided here for reference, it is not the only method for looking at wet and dry periods over time. Furthermore, the SPI only accounts for precipitation accumulation and does not consider wetness or dryness in terms of evapotranspiration, soil moisture, streamflow, or groundwater.

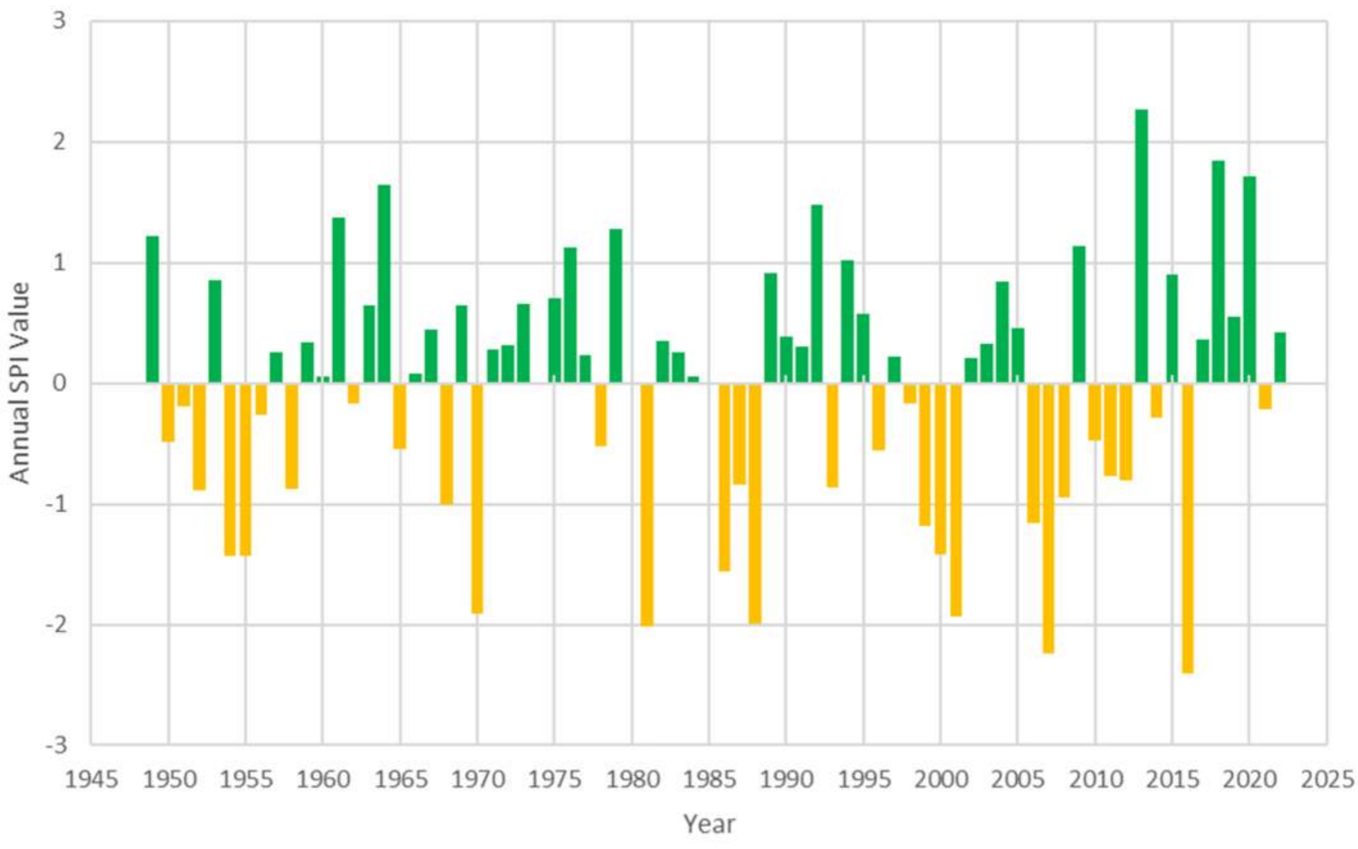

Figure 2-14. Annual Standard Precipitation Index values for Walhalla 1949 through 2022 (SCDNR SCO 2023f).

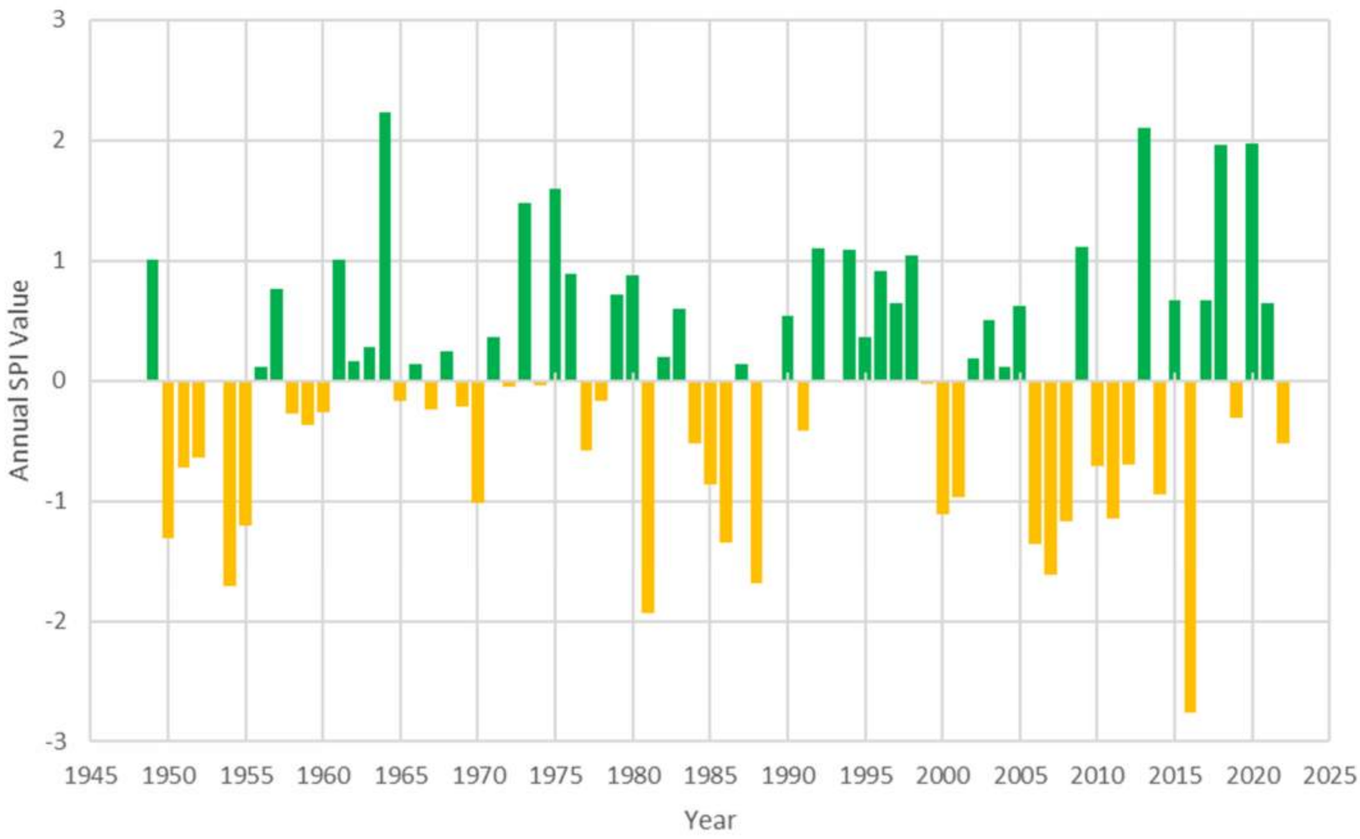

Figure 2-15. Annual Standard Precipitation Index values for Anderson Regional Airport 1949 through 2022 (SCDNR SCO 2023f).

The impact of drought on streamflow in the basin was analyzed using two USGS streamflow gaging stations at different locations in the basin. The gage at Chattooga River near Clayton, Georgia, is near the top of the basin, while the gage at Stevens Creek near Modoc is at the bottom of the basin. These two gages were selected for their long-term, continuous data records. Other gages in the basin have shorter periods of record and/or less continuous data than the locations selected. Table 2-7 provides the lowest monthly average flow, which year it occurred, and the long-term average monthly flow for each month at the two selected stream gages. Table 2-7 also shows the year with the lowest annual average flow and the long-term average annual flow.

Table 2-7. Year of lowest monthly and annual average flow compared to the long-term average for the Chattooga near Clayton, Georgia, and Stevens Creek near Modoc from 1941 through 2023.

Chattooga River near Clayton, Georgia (02177000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	1956	2017	2017	1986	2001	2008	2008	2007	1954	1954	2016	1955	2001
Lowest Average Flow (cfs)	155	198	252	349	261	202	143	152	118	99	133	183	323
Long-Term Average Flow (cfs)	794	868	911	865	717	593	518	473	460	454	514	689	657
Stevens Creek near Modoc (02196000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	1956	2012	2012	2012	2012	2008	2008	2011	1954	1954	2012	2001	2012
Lowest Average Flow (cfs)	25	88	48	23	9	5	2	3	1	0	0	8	308
Long-Term Average Flow (cfs)	665	803	924	545	262	182	161	133	82	168	192	385	4,483

Figures 2-14 and 2-15 and Table 2-7 show that the drought is a normal part of climate and hydrology in the Upper Savannah River basin. Because of the nature of drought, one type of indicator cannot fully encapsulate the intensity of drought impacts, regarding variation in impacts among sectors and location within a river basin. While 2016 was the driest years for both Walhalla and Anderson Regional Airport (Figures 2-14 and 2-15), Chattooga River near Clayton, Georgia, experienced its lowest annual average flow in 2001 while Stevens Creek near Modoc experienced its lowest annual average flow in 2012. Although dry climatological years do affect flows, there is not a perfect relationship between lack of rainfall and diminished stream flows. Furthermore, because the Upper Savannah River basin is a managed system with multiple reservoirs (Jocassee, Keowee, Hartwell, Russell, and Thurmond), reservoir levels need to be included in evaluating drought periods as well as climatological and streamflow data.

Although South Carolina typically receives adequate precipitation, droughts can occur at any time of the year and last for several months to several years. While precipitation is the main driver for water availability in the Upper Savannah River basin, multiple factors such as temperature, evapotranspiration, and water demands also need to be considered when evaluating how drought periods will impact stream and river flows in the basin. Severe drought conditions can contribute to diminished water and air quality, increased public health and safety risks, and reduced quality of life and social well-being. Because drought causes a lack of expected water across multiple sectors at different time frames, it is essential to plan for drought so water demands can be adequately met and managed before and during a severe drought period.

The following paragraphs describe notable drought events in the past 30 years that have impacted the Upper Savannah Basin. Some of these droughts were statewide events, while others were more impactful to the Upstate Region. More information on historical drought events across the state, some of which have affected the Upper Savannah River Basin, can be found in the following document produced by the SCO's *Keystone Drought Events in South Carolina* publication (SCDNR SCO 2023g).

1998 to 2002 Drought

The 1998 to 2002 drought was a statewide event, and it attributed to severe impacts across multiple sectors, including agriculture, recreation, forestry, and public water supply. Agricultural impacts included reduction of crop yields or yield loss, cost for digging new wells for irrigation, ponds going dry, as well as decreases in pasture ability to adequately feed livestock. Low flows exposed hazards to boats as well as negatively affected businesses that rely on river recreation for income. The potential for fire grew, leading to outdoor burn bans, while the reduced water availability stressed trees. This stress allowed for increased susceptibility to the southern pine beetle, which caused billions in losses to the timber industry.

The summer and early fall of 2002 were hydrologically the most intense portion of the 1998 to 2002 drought for the Upper Savannah River basin. From June 2002 to November 2002, the South Carolina DRC placed the entire basin in severe to extreme drought status, with the entire basin being in extreme drought from July 2002 to September 2002. Multiple water systems called for voluntary water use reductions, with some implementing mandatory water restrictions. Conditions improved by November 2002 and the entire state returned to normal drought status by spring 2003.

2007 to 2009 Drought

The 2007 to 2009 drought was a statewide event; however, the driest conditions were north of the Fall Line, particularly the Upper Savannah and Saluda River basins. Impacts spanned multiple sectors over two years, including agriculture, recreation, forestry, and public water supplies. Agricultural impacts included reduction of corn and soybean yields; however, hay production had the greatest losses, leading to decreased ability to adequately feed livestock (Carolinas Precipitation Patterns & Probabilities 2023).

The recreation industry experienced impacts from low flows that exposed hazards to boats and negatively affected businesses that rely on river recreation for income. Statewide, the forestry industry felt impacts because of increased fires from low soil moisture content and tree stress from reduced water availability. Early in the drought, in July and August 2007, wildfire numbers were above normal, with 518 fires and 2,730 acres burned. By April 2008, wildfire numbers were above normal, with 2,800 fires and 17,000 acres burned (SCDNR SCO 2008a). By September 2008, the state had a 66 percent increase in the number of acres burned compared to the five-year average (SCDNR SCO 2008b). It would not be until April 2009 that the risk of wildfires would start to wane from improved conditions.

The intensity and duration of the 2007 to 2009 drought also impacted public water supplies. By January 2008, 191 water systems across the state had implemented some level of water conservation, with 146 systems implementing voluntary restrictions and 45 systems implementing mandatory restrictions (SCDNR SCO 2008c). Of the water systems within the basin discussed later in this plan (Chapter 8), 10 reported voluntary restrictions and two reported mandatory restrictions. In July 2008, the Governor, along with the SCDNR, released a statement encouraging water conservation. Although this was targeted for counties in severe and extreme drought status, specifically in Upstate South Carolina, it was a message for everyone across the state on how to conserve water inside and outside the home (SCDNR SCO 2008d). While this message only encouraged water conservation, the Governor has seldom needed to use his executive authority in South Carolina to encourage water conservation, indicating how severe the situation had become in the Upstate area. It was not until June 2009 that conditions returned to normal.

2010 to 2013 Drought

Similarly to the 2007 to 2009 drought, the 2010 to 2013 drought was also a statewide event where the driest conditions impacted the Upper Savannah and Saluda River basins. All 46 counties in the state were placed into incipient drought status in summer 2010. However, conditions did not worsen until summer 2011, when most areas south of the Fall Line were placed in moderate drought status. It was not until fall 2011 when the Upper Savannah entered moderate drought status. By November 2011, the basin entered into severe drought status, because of the continued dry conditions from the summer into the fall that caused hydrologic conditions to decline (streamflows, reservoir levels, and groundwater). The basin remained in drought status until April 2014, spending 28 months in at least moderate drought status. While the dry conditions impacted agriculture production and increased fire potential, the largest impacts were to water systems and water recreation. The drop in lake levels limited boat ramp access and exposed water hazards. Several water systems that purchase water from the lakes enacted water conservation policies, to follow the water conservation practices from their suppliers.

2015 to 2016 Drought

Throughout 2015, dry conditions affected the entire state, with most of the state being in moderate drought status in July 2015. Below normal rainfall through the spring and early summer led to below normal streamflows and affected lake levels, particularly in the Catawba-Wateree basin. It also caused agricultural impacts. Dry conditions remained through early fall; however, in October 2015, the South Carolina DRC removed all drought conditions (statewide) because of the extreme rainfall event in early October (SCDNR SCO 2023h).

By July 2016, dry conditions had returned and the DRC had placed 28 counties in incipient drought conditions and four counties in moderate drought conditions (all in Oconee, Pickens, Anderson, and Abbeville Counties). These four counties went from normal to moderate drought status because of the lack of rainfall and high temperatures, leading to agricultural impacts, increased fire activity, and reduction in streamflows. By October 2016, dry conditions intensified in the Upstate region, and the DRC placed all counties in the Upstate region in moderate drought status, while putting Oconee, Pickens, and Anderson Counties in severe drought status. In the Upstate region, the severity and duration of the dry conditions reduced agricultural yields by 50 to 70 percent. Fires were harder to respond to because they required more resources and time for containment. Streamflows continued to stay below normal, causing reservoirs to fall below their target elevations. Water systems that purchased supplies from reservoirs followed their suppliers' plans for water conservation. It was not until June 2017 that the entire Upper Savannah River basin was not in moderate (or worse) drought conditions.

2.3 Natural Resources

2.3.1 Soils, Minerals, and Vegetation

The Natural Resources Conservation Service (NRCS) divides South Carolina into six land resource areas based on soil conditions, climate, and land use, as shown in Figure 2-16. These areas generally follow the boundaries of the state physiographic provinces (Section 2.1.3) but are defined based on soil characteristics and their supported land use types. The Upper Savannah River basin is primarily in the Southern Piedmont major land resource area, with additional portions extending into the Blue Ridge Mountains area. The extreme southern tip of the basin extends into the Carolina–Georgia Sandhills area. The following land resource area descriptions were originally presented in the South Carolina State Water Assessment (SCDNR 2009).

- The Blue Ridge Mountains land resource area consists of dissected, rugged mountains with narrow valleys. Most soils are moderately deep to deep on sloping-to-steep ridges and side slopes. The underlying material consists mainly of weathered schist, gneiss, and phyllite. The area is predominantly forested with a mixture of oak, hickory, and pine. Small farms within the area produce truck crops, hay, and corn.
- The Southern Piedmont land resource area is a region of gentle to moderately steep slopes with broad-to-narrow ridge tops and narrow stream valleys. The area is covered with strongly acidic, firm clayey soils formed mainly from gneiss, schist, phyllite, and Carolina slate. The area is forested with mixed hardwoods and various pines. Cotton, corn, and soybeans are the major crops grown in the area.
- The Carolina–Georgia Sandhills land resource area consists of strongly sloping, sandy soils underlain by sandy and loamy sediments. Approximately two-thirds of the region is covered by forest types dominated by mixed pine and scrub oaks. With well-drained to excessively drained soils, the region supports cotton, corn, and soybean growth.

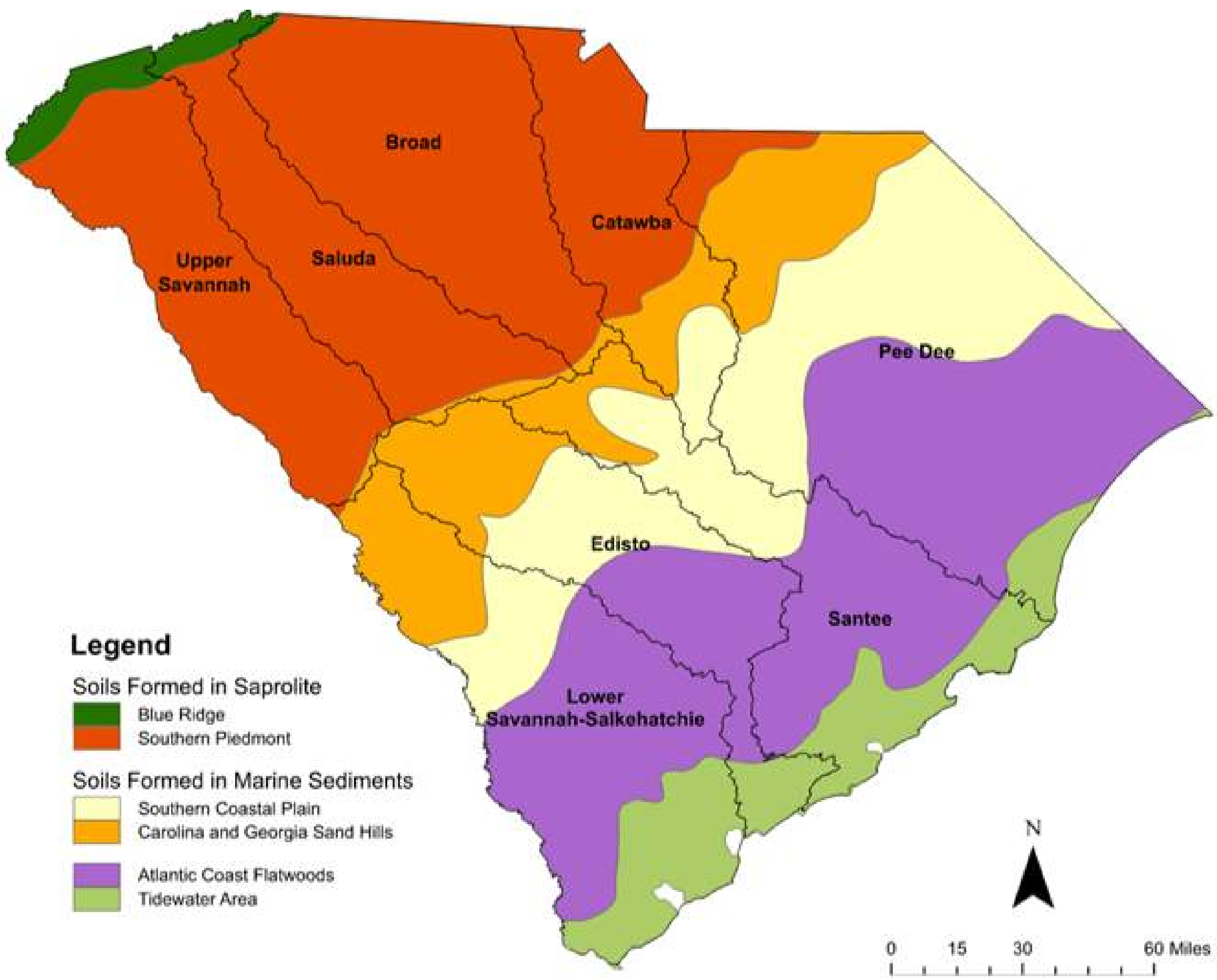

Figure 2-16. Generalized land resource and soils map of South Carolina.

There are currently 16 active mines within the Upper Savannah River basin: two in Oconee County, three in Pickens County, four in Anderson County, two in Abbeville County, one in McCormick County, and four in Edgefield County. The most common mined materials are sand (7) and granite (5). Two gold mines exist in the basin, one within the Blue Ridge Mountains of Oconee County and another within the Sumter National Forest of Abbeville County, as well as two shale mines (SCDHEC 2023a). According to the most recently published USGS Minerals Yearbook, South Carolina produced $1.15 billion in nonfuel minerals in 2019 (USGS 2022), consisting primarily of cement, gold, sand and gravel, and crushed stone. Because 16 of the state's 494 active mines, or approximately 3.2 percent, are in the Upper Savannah River basin, a rough percentage-based estimate of the annual value of minerals produced from the basin is $37.2 million.

2.3.2 Fish and Wildlife

The Upper Savannah River basin is home to an exceptionally diverse array of plants and animals. Across both the Upper and Lower Savannah River basins, there are 13 federally endangered and five federally threatened species. Fifty-five species in the combined basins are state-listed or of special concern (Georgia River Network 2018). The Upper and Lower basins are home to a total of 118 native fish species, which is more than the total richness of some states (Marcy et al. 2005). Many amphibians and reptiles also live within the Upper and Lower Savannah basins, including endangered salamanders and newts.

The Middle Savannah River subbasin is home to the robust redhorse (*Moxostoma robustum*), a fish once thought to be extinct but rediscovered in the 1980s (U.S. Fish and Wildlife Service [USFWS] 2011). In the Middle Savannah River subbasin, a further 15 fish species have been introduced. These include the yellow perch (*Perca flavescens*) and rainbow trout (*Oncorhynchus mykiss*), which were introduced for recreational fisheries purposes (Marcy et al. 2005).

The Walhalla State Fish Hatchery, one of five hatcheries within the state of South Carolina, is located within the upper reaches of the Upper Savannah River basin (SCDNR 2007a). The Walhalla hatchery was constructed in the 1930s and is the only cold-water hatchery operated by the SCDNR. This hatchery raises more than 500,000 brown, brook, and rainbow trout annually to stock South Carolina waters (SCDNR 2007b). These trout are stocked in various waters within the basin, including rivers and lakes within Oconee, Pickens, and Greenville Counties (SCDNR 2023c). The Georgia Department of Natural Resources (GDNR) also stocks more than 200,000 trout within 14 rivers in the basin (GDNR 2023). Figure 2-17 shows some representative species within the Upper Savannah River basin.

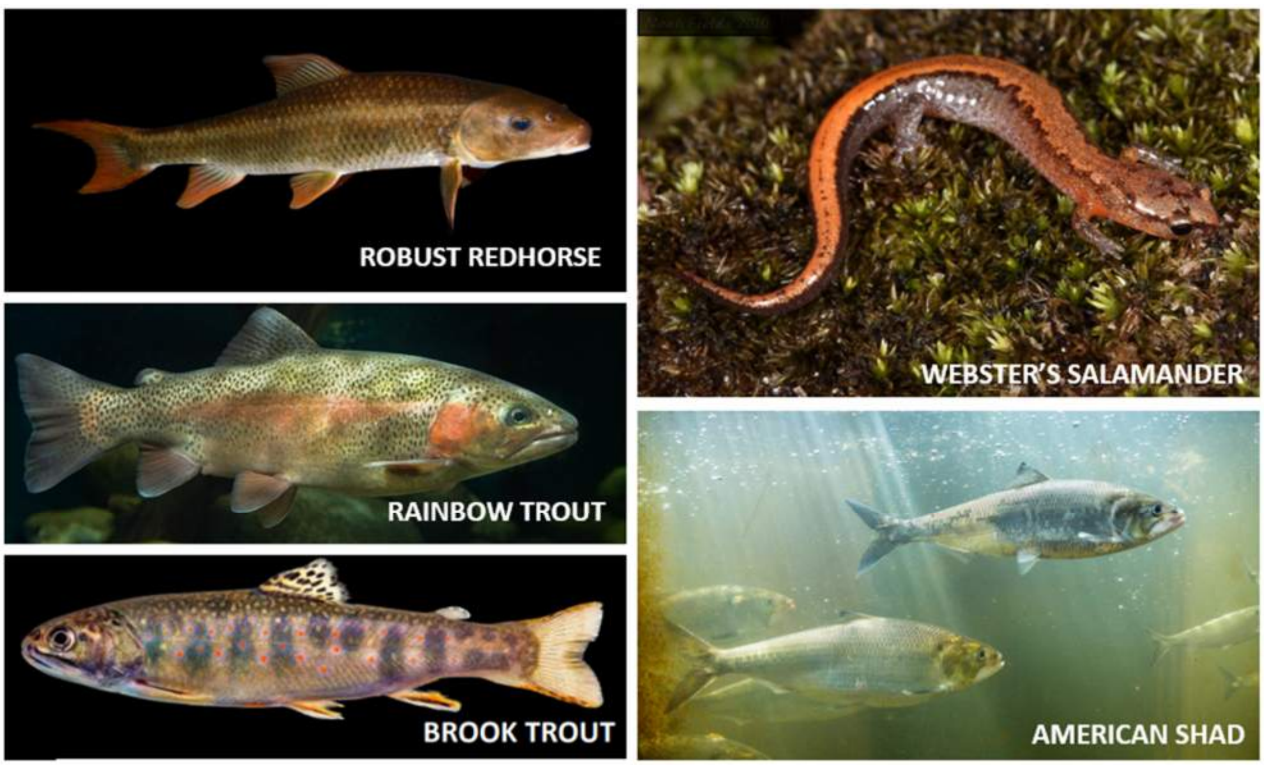

Figure 2-17. Representative species within the Upper Savannah River basin.

The Upper Savannah River basin provides habitat for numerous rare, threatened, and endangered species. Nine federally endangered and four federally threatened species are present, along with five state-listed endangered and five state-listed threatened species. The bald eagle, protected by the Bald and Golden Eagle Protection Act, has been noted in all eight Upper Savannah River basin counties. The tri-colored bat, which as of 2023 has been placed on the proposed federally endangered list, has likewise been noted in all eight counties. The Upper Savannah River basin is also one of only a handful of locations in the southeastern United States where populations of the shoals spider-lily (*Hymenocallis coronaria*) exist (Chattahoochee River Conservancy 2023). Table 2-8 provides a list of all threatened and endangered species within the eight Upper Savannah River basin counties.

Table 2-8. Federal- and state-listed endangered and threatened species in Upper Savannah River basin counties (SCDNR 2023d).

Federally Endangered	Federally Threatened	State Endangered	State Threatened
Carolina Heelsplitter	Black Rail	Bewick's Wren	American Peregrine Falcon
Gray Bat	Miccosukee Gooseberry	Indiana Bat	Bald Eagle
Harperella	Pool-Sprite, Snorkelwort	Red-Cockaded Woodpecker	Bog Turtle
Indiana Bat	Small Whorled Pogonia, Little Five-Leaves	Rafinesque's Big-Eared Bat	Coal Skink
Mountain Sweet Pitcherplant	Smooth Purple Coneflower	Webster's Salamander	Eastern Small-Footed Bat
Northern Long-Eared Bat			Southern Hog-Nosed Snake
Persistent Trillium			
Red-Cockaded Woodpecker			
Relict Trillium			
Rusty-Patched Bumble Bee			

Despite its high diversity and importance for species conservation in the American southeast, the Savannah River is listed as one of the most polluted rivers in the United States, with more than 90 303(d) impaired sites listed within the upper portion of the South Carolina side of the basin alone (SCDHEC 2022b). Several lakes, including Jocassee, Hartwell, Russell, and Thurmond, possess fish consumption advisories because of mercury and/or polychlorinated biphenyl (PCB) contamination (SCDHEC 2023b).

2.3.3 Natural and Cultural Preserves

The Upper Savannah River basin is well known for its natural and cultural resources. The South Carolina Heritage Trust program was founded in 1974 to protect critical natural habitats that monitored species depend on and significant cultural sites. There are seven natural preserves designated by the South Carolina Heritage Trust program within the Upper Savannah River basin (SCDNR 2019b):

- Laurel Fork Heritage Preserve/Wildlife Management Area – The Laurel Fork Heritage Preserve covers 1,361 acres in Pickens County and is on the northeastern edge of the Upper Savannah River basin. The area preserves the headwaters of Laurel Fork Creek, protects six species of regional or state concern, and features pristine upland pine and hardwood forest. The preserve lies within the Jocassee Gorges Wilderness Area and is bisected by the 72-mile Foothills Trail.
- Eastatoe Creek Heritage Preserve/Wildlife Management Area – The Eastatoe Creek Heritage Preserve covers 374 acres in Pickens County and is on the northeastern edge of the Upper Savannah River basin. The area preserves a steep mountain gorge, upland hardwood forests, and rare plant species supported by the fine spray emitted from the gorge. One species, the

Tunbridge fern (*Hymenophyllum tunbridgense*) exists nowhere else in North America. The preserve lies within the Jocassee Gorges Wilderness Area and is managed by the SCDNR.

- Wadakoe Mountain Heritage Preserve/Wildlife Management Area – The Wadakoe Mountain Heritage Preserve covers 37 acres in Pickens County and is on the northeastern edge of the Upper Savannah River basin. The area lies on the edge of the Jocassee Gorges Wilderness Area and protects various rare plant species including whorled horsebalm (*Collinsonia verticillata*), faded trillium (*Trillium discolor*), and plantain-leaved sedge (*Carex plantaginea*).
- Stumphouse Mountain Heritage Preserve/Wildlife Management Area – The Stumphouse Mountain Heritage Preserve covers 442 acres under an assortment of conservation easements and trusts and lies within the northern center of the Upper Savannah River basin. The preserve works in tandem with the City of Walhalla to protect Issaqueena Falls, historic railroad tunnels, and a pristine forested mountainside. The preserve contains the Stumphouse Tunnels, excavated in 1850 by the Blue Ridge Railroad as part of a plan to connect Charleston, South Carolina, with Knoxville, Tennessee, but never completed, and today are a popular tourist destination. The preserve protects an impressive array of bird, bat, and plant diversity.
- Buzzard Roost Heritage Preserve/Wildlife Management Area – The Buzzard Roost Heritage Preserve covers 501 acres of mountain habitat near the base of the Blue Ridge Mountains and within the northern center of the Upper Savannah River basin. The preserve protects numerous rare plant and animal species, including the federally endangered smooth coneflower (*Echinacea laevigata*).
- Brasstown Creek Heritage Preserve/Wildlife Management Area – The Brasstown Creek Heritage Preserve covers 3,170 acres and bounds the Sumter National Forest near the westernmost edge of Oconee County. The preserve protects a unique fire-dependent plant community called the pitch pine heath, as well as rare species such as Piedmont strawberry (*Waldsteinia lobata*), turkey beard (*Xerophyllum asphodeloides*), and purple sweet pinesap (*Monotropsis odorata*).
- Stevens Creek Heritage Preserve – The Stevens Creek Heritage Preserve covers 434 acres of a bluff along Stevens Creek in the southern extent of the Upper Savannah River basin and protects a “relict plant community” believed to have existed in the same spot since the last Ice Age. The preserve protects the endemic Miccosukee gooseberry (*Ribes echinellum*), Webster’s salamander (*Polydora websteri),* and other rare species.

Representative plant species protected by South Carolina Hertiage Trust preserves in the Upper Savannah basin are shown in Figure 2-18.

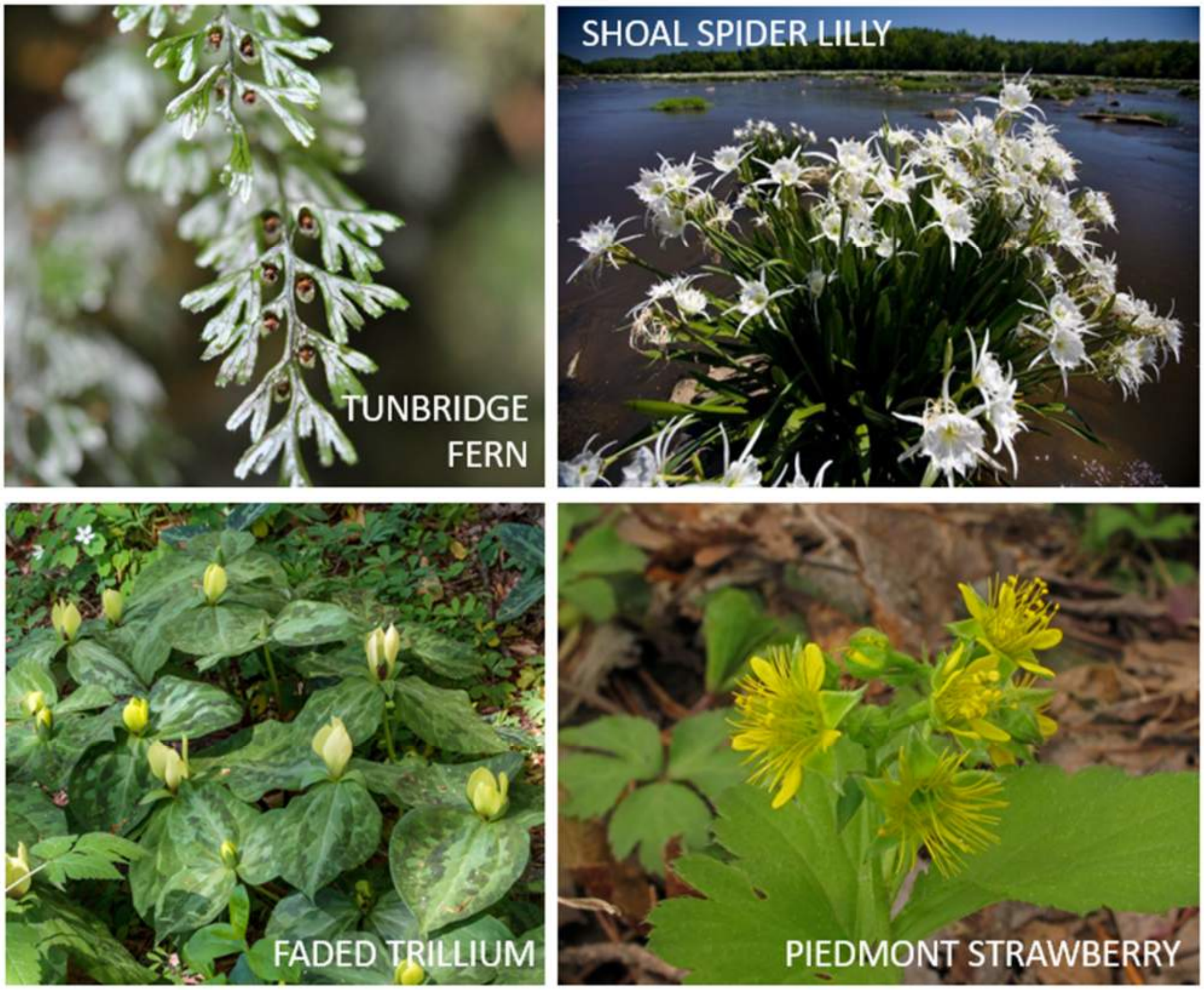

Figure 2-18. Representative species protected by South Carolina Heritage Trust preserves.

Additionally, there are 10 state parks within the Upper Savannah River basin: Devils Fork State Park, Keowee-Toxaway State Park, Oconee State Park, Oconee Station State Historic Site, Lake Hartwell State Park, Sadlers Creek State Park, Calhoun Falls State Park, Hickory Knob State Resort Park, Baker Creek State Park, and Hamilton Branch State Park (South Carolina State Parks 2023).

Approximately 24 percent, or approximately 780 sq mi, of the Upper Savannah River basin is conserved land (The Nature Conservancy 2024). Land within the basin is primarily conserved through federal and state government entities, as well as other agencies such as the USACE, as shown in Figure 2-19.

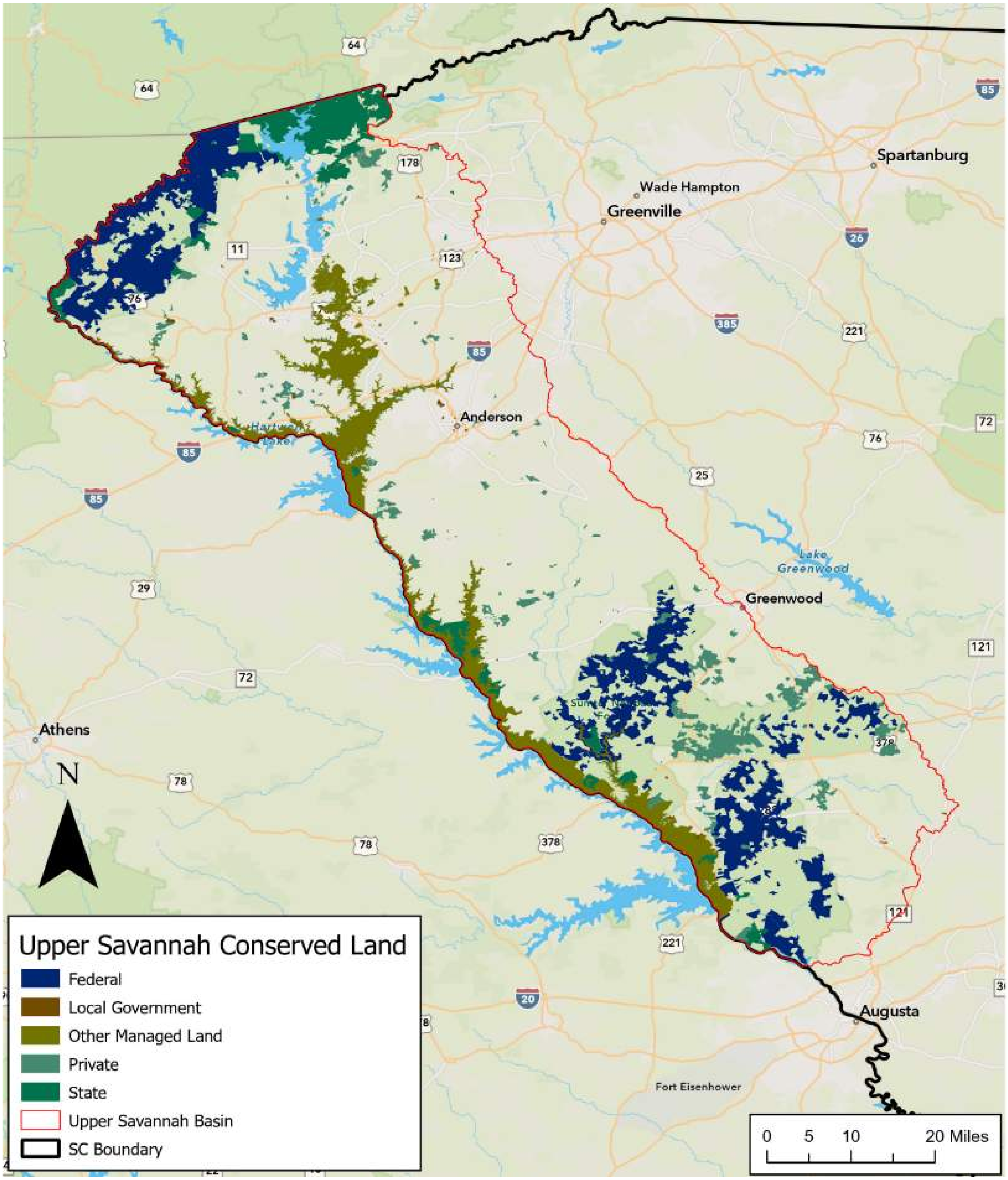

Figure 2-19. Conserved land within the Upper Savannah River basin.

2.4 Agricultural Resources

2.4.1 Agriculture and Livestock

Farming, including the production of both crops and livestock, is prevalent in the non-mountainous regions of the Upper Savannah River basin. While agricultural land has been gradually replaced with urban development outside cities such as Anderson and Seneca, crop and pasturelands cover approximately 16 percent of the basin (MRLC 2024a).

Total crop and livestock sales for the eight counties within the basin totaled $461 million according to the USDA Agricultural Census (USDA National Agricultural Statistics Service [NASS] 2017). Top agricultural products include hay, soybeans, and peaches. Peaches are a beloved crop in South Carolina, which produces the second most of any state, behind California. The peach industry contributes $80 million to South Carolina agriculture sales, and 60 percent of all peaches in the state are grown within the Upper Savannah River basin region, including Abbeville, Edgefield, Greenfield, and McCormick Counties. The largest peach farm in the state is located in Edgefield County (SC Peach Council 2023).

The USDA NRCS, which inventories land that can be used to produce the nation's food supply, has categorized 28 percent of the basin as prime farmland and 22 percent as farmland of statewide importance, as shown in Table 2-9 (USDA NRCS 2017). Prime farmland is land that contains the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. Prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, and a water supply that is dependable and of adequate quality. It is also not excessively erodible or saturated with water for long periods and has slopes ranging from 0 to 6 percent. Farmland of statewide importance is land that nearly meets the requirements of prime farmland and can economically produce high-yield crops when treated and managed with acceptable farming methods. Both farmland types can be found throughout the basin and their distribution is depicted in Figure 2-20.

Table 2-9. Area of NRCS-categorized farmland in the Upper Savannah River basin.

Farmland Type	Area (sq mi)	Percentage of Basin
Prime Farmland	1,293	28%
Farmland of Statewide Importance	1,037	22%
Farmland of Local Importance	<0.1	<0.01%
Not Prime Farmland	2,370	50%
Total	4,700	100%

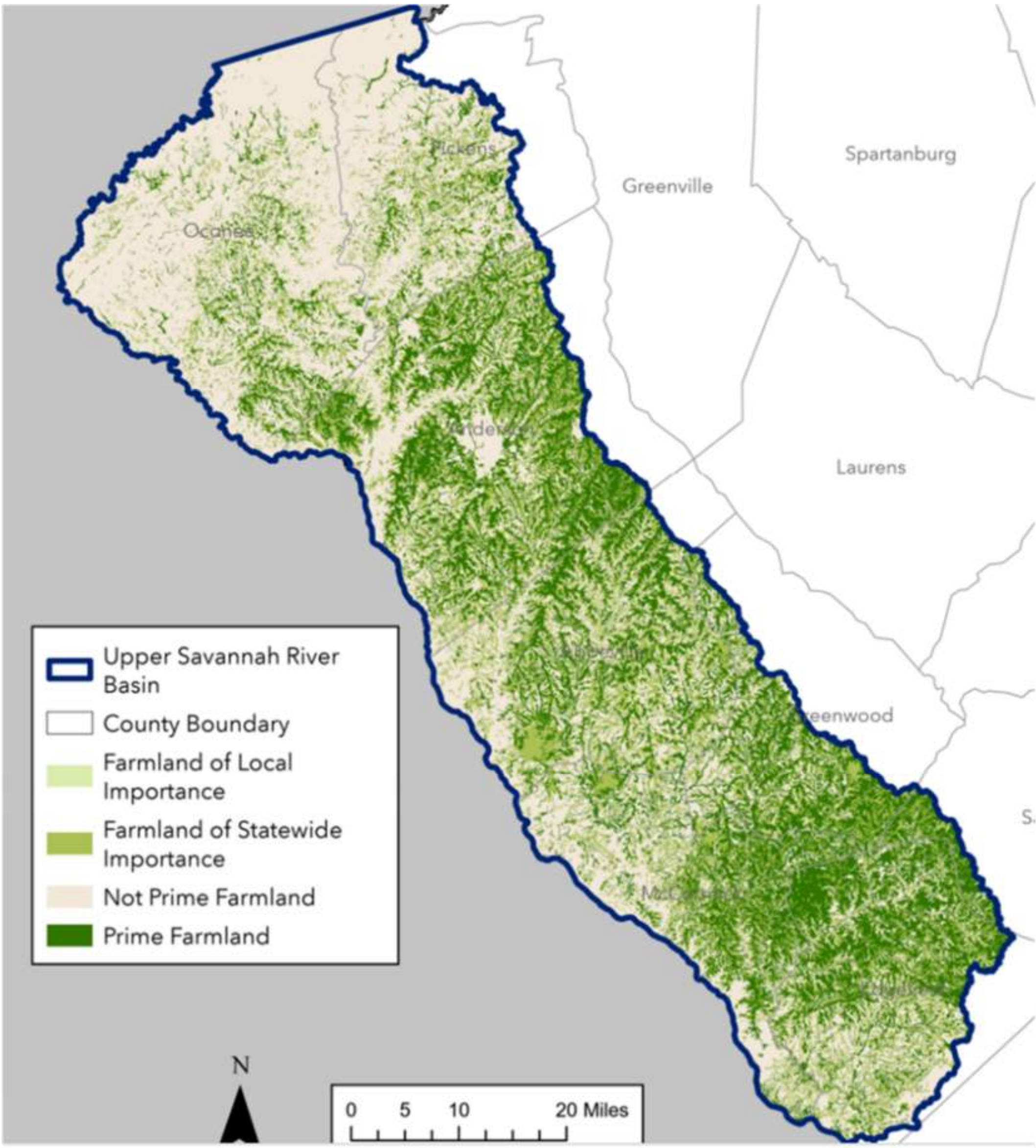

Figure 2-20. Location of NRCS-categorized farmland in the Upper Savannah River basin.

Most agricultural output in the Upper Savannah River basin is derived from the lower and eastern portions of the basin, centered around Anderson and Edgefield Counties. Based on the locations of prime farmland within the basin (Figure 2-20), these counties are among those with the greatest proportion of choice agricultural land. Counties in the north of the basin, such as Oconee and Pickens, are largely mountainous, steeply sloped, and possess less productive land. The extensive land area submerged under reservoirs within the basin, which would otherwise be fertile river valleys, also limits its overall amount of arable land.

As of October 2023, there were 1,648 livestock operations in the Upper Savannah River basin, and their locations are displayed in Figure 2-21 (SCDHEC 2023c). Raising poultry accounts for almost 90% of active operations and is followed by cattle, which makes up most of the remainder. Livestock operations dominate in the northern and western portions of the basin, where prime farmland, which could be used otherwise to grow crops, is scarce.

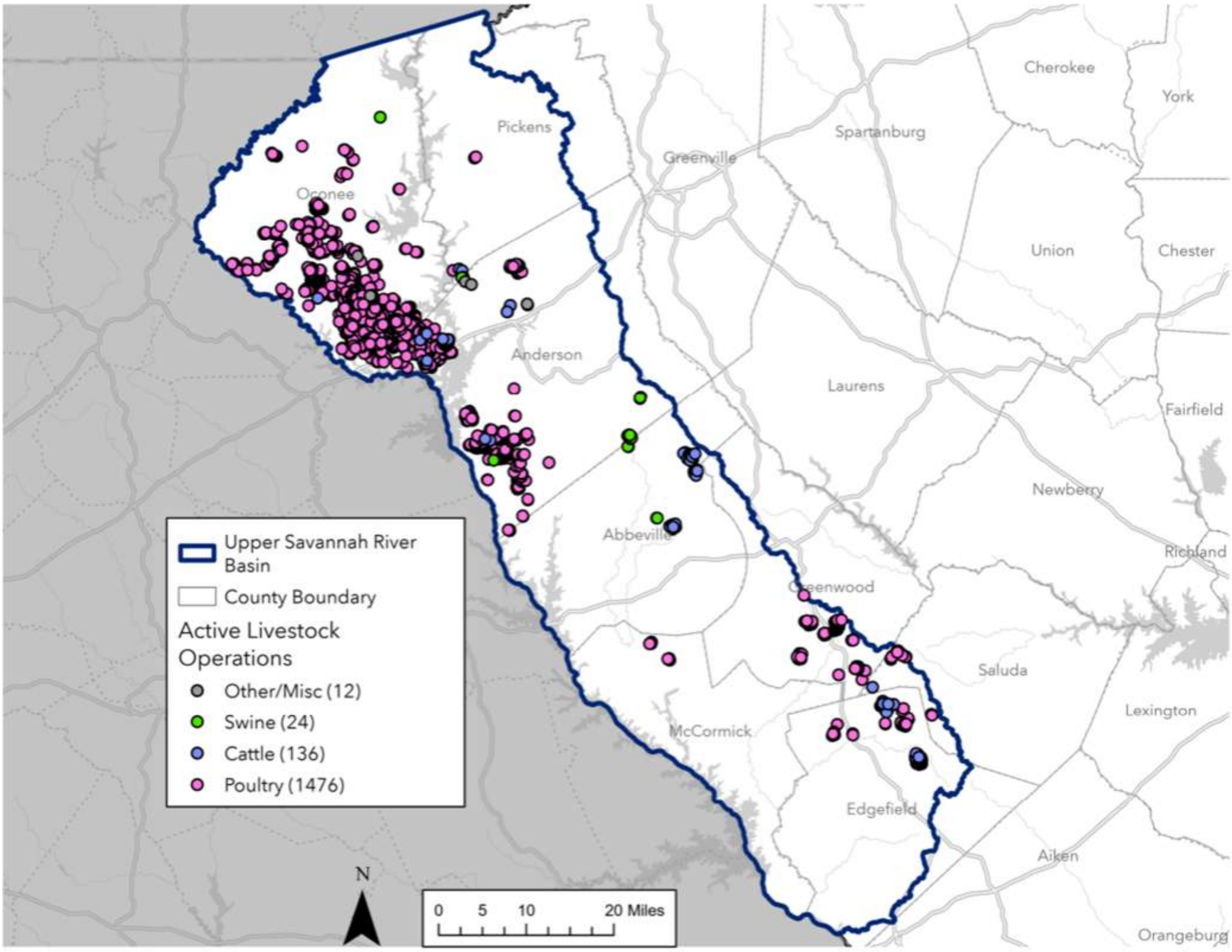

Figure 2-21. Active livestock operations in the Upper Savannah River basin.

Data from the Census of Agriculture, gathered by voluntary reporting, suggests that both the number of farm operations and irrigated acreage roughly doubled in the Upper Savannah River basin during the 25 years between 1992 and 2017, as seen in Figure 2-22. Most of this growth occurred at the turn of the 20th century, when reported irrigated acreage within the basin increased by 187 percent between the years of 1997 and 2002. Since 2002, increases in irrigated acreage have been more modest, with only a 25 percent increase since that time. Statewide, irrigated acreage has expanded more rapidly, and since 2002 has more than doubled. The more modest increase seen within the Upper Savannah River basin may reflect its low availability of groundwater because of the absence of large aquifers (Section 2.1.3, Geology). In 2017, the Upper Savannah River basin possessed a reported total of 338 farms using irrigation and 15,951 total irrigated acres, or 16 percent and 8 percent of the statewide totals, respectively (USDA NASS 2017).

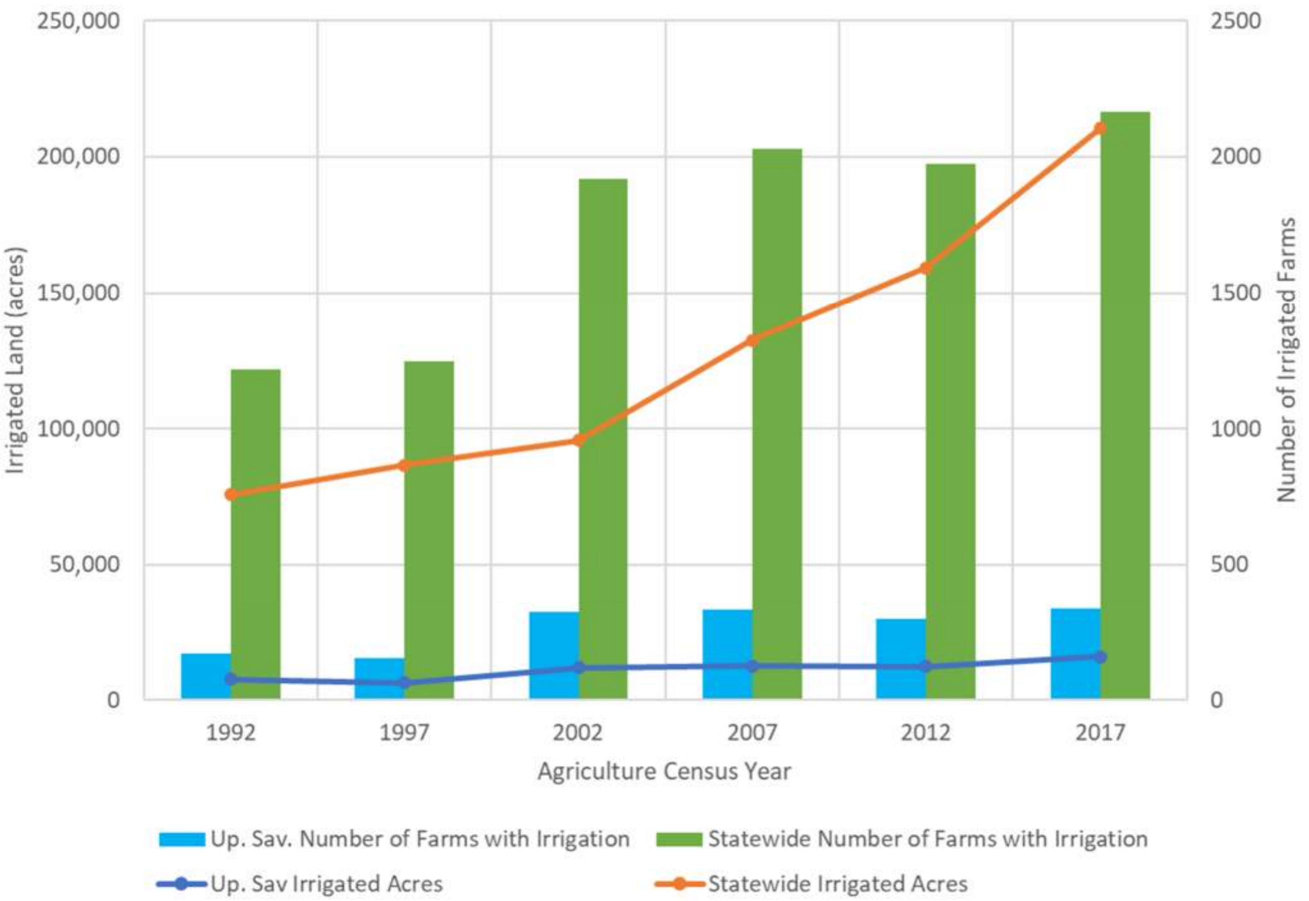

Figure 2-22. Number of farm operations and irrigated acreage for counties within the Upper Savannah River basin and statewide, 1992 to 2017 (USDA NASS 1997, 2007, 2017).

Additional 2017 Census of Agriculture data for the eight counties within the Upper Savannah River basin is provided in Table 2-10 and Table 2-11 (USDA NASS 2017). For the purposes of the census, a farm is any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year. Top commodities within the Upper Savannah basin include hay, soybeans, and peaches. A column with basinwide totals is also included.

Table 2-10. Summary of 2017 Census of Agriculture for counties in the Upper Savannah River basin, cropland (USDA NASS 2017).

All Values in Acres	Total All Counties	Abbeville	Anderson	Edgefield	Greenwood	McCormick	Oconee	Pickens	Saluda
Farm Operations	685,070	88,504	183,718	78,545	72,274	40,704	62,499	39,331	119,495
Cropland	195,302	18,796	69,888	23,223	15,078	3,857	18,908	12,245	33,307
Harvested Cropland	140,875	11,586	49,162	17,744	10,701	2,040	14,683	9,136	25,823
Irrigated Land	15,951	278	612	8,852	237	(D)	390	183	5,399
Hay and Haylage Harvested	98,334	10,773	37,860	5,513	10,304	1,440	11,240	7,477	13,727
Soybeans Harvested	11,279	254	7,228	1,058	–	(D)	1,892	253	594
Corn (Grain) Harvested	5,070	(D)	1,268	754	64	(D)	601	462	1,921
Cotton Harvested	0	(D)	(D)	(D)	–	–	–	–	–
Vegetables Harvested	620	81	346	(D)	33	5	85	70	(D)
Wheat Harvested	5,248	219	2,705	536	(D)	(D)	1,344	(D)	444
Corn (Silage) Harvested	1,429	–	(D)	(D)	(D)	–	–	(D)	1,429
Orchards Harvested	13,090	50	250	7,328	59	36	133	167	5,067
Peanuts Harvested	–	–	–	–	–	–	–	–	–
Oats Harvested	682	(D)	326	(D)	38	–	76	(D)	242

D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals

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Table 2-11. Summary of 2017 Census of Agriculture for counties in the Upper Savannah River basin, livestock (USDA NASS 2017).

	Total All Counties	Abbeville	Anderson	Edgefield	Greenwood	McCormick	Oconee	Pickens	Saluda
Cattle Operations	2,471	326	833	102	226	40	394	247	303
Cows/Beef Operations	2,206	306	711	90	205	37	354	218	285
Cows/Milk Operations	48	4	17	7	1	2	9	3	5
Hogs Operations	200	25	38	10	23	2	45	28	29
Sheep Operations	193	20	43	21	28	–	35	36	10
Chicken Layers (Egg) Operations	828	91	298	79	47	9	120	141	43
Chicken Broilers (Meat) Operations	151	9	27	3	3	2	58	6	43

The amount of water needed annually by the major row crops grown within the Upper Savannah River basin varies. Corn requires roughly one million gallons per acre over the course of a season, while mature peach trees may require as much as 35 to 45 gallons per day (Clemson Cooperative Extension 2021). This usage data, when combined with the Farm Service Agency (FSA)-reported irrigated acres of each crop type, provides a picture of how crop irrigation influences water usage within the basin. For instance, the approximately 5,000 acres of corn within the basin use an estimated 5 billion gallons in a season. If the 13,000 acres of reported orchards are assumed to be peach trees at a density of 120 trees per acre, they would consume upward of 60 million gallons per day. Although these numbers appear quite large, this amounts to less than 0.5 percent of the total volume of the Lake Hartwell reservoir, which is comparable to the entire water withdrawn from the basin in a day (SCDNR 2023b).

An agricultural water use survey conducted by Clemson University in 2018 found that surface drip irrigation is the most used irrigation technique in counties within the Upper Savannah River basin, followed by hand watering (Sawyer et al. 2018). The water use survey represented a limited sample of statewide irrigation practices and was based on responses from 167 participants representing practices used on 75,000 acres of irrigated land in South Carolina. Statewide, most respondents noted groundwater as their main source of irrigation water (141), with other sources being lake/pond (29), river/stream (14), municipal (7), and recycled (2). Table 2-12 lists the irrigation techniques used by survey respondents who own farming operations in the Upper Savannah River basin.

Table 2-12. Irrigation techniques used in the Upper Savannah River basin (Sawyer 2018).[1]

General	High Efficiency	Precision
Traveling Gun	Drip – Surface	Hand Watering
Solid Set	Micro-irrigation	Hydroponics

[1] Center Pivot – Fixed Rate with best nozzle technology (a high-efficiency type) may also be used; however, this category was not included in the survey.

2.4.2 Silviculture

While not as prominent as other industries, silviculture plays a significant role in the Upper Savannah River basin. South Carolina Forestry Commission (SCFC) timber production values for 2021 are summarized in Table 2-13 (SCFC 2022). Harvested timber values are categorized as both "stumpage," which is the value of standing trees "on the stump," and "delivered," which is the value of the logs when they are delivered to the mill. The latter considers all costs associated with cutting, preparing, and hauling timber to the plant.

While the Upper Savannah is among the most forested river basins in South Carolina, possessing an average land cover of 79 percent forested land, it is one of the lowest in terms of timber value. Three of its eight counties rank in the bottom five statewide in delivered value, and only two counties (Edgefield and Greenwood) rank in the top half. In total, just over $100 million in timber value was generated in 2021 within the Upper Savannah River basin, or roughly 9 percent of the statewide total. The low value of timber within the basin is largely because of its mountainous nature and the costs associated with harvest in such conditions. In general, the timber harvest grows in value as one moves from the north to the south of the basin, as shown in Figure 2-23.

Table 2-13. Value of timber for counties in the Upper Savannah River basin and state total.

County	Acres of Forestland	Percent Forest	Harvest Timber Value (in millions)		Delivered Value Rank
			Stumpage	Delivered	
Abbeville	262,549	76%	7.1	14.9	32
Anderson	195,015	44%	2.4	5.4	43
Edgefield	228,527	75%	11.5	23.4	19
Greenwood	212,656	70%	11.0	23.2	21
McCormick	212,442	91%	5.0	11.5	37
Oconee	247,728	65%	1.3	3.1	45
Pickens	227,860	68%	1.0	2.3	46
Saluda	208,498	74%	10.0	20.6	26
Statewide	12,849,182	66%	573.7	1,162.3	–

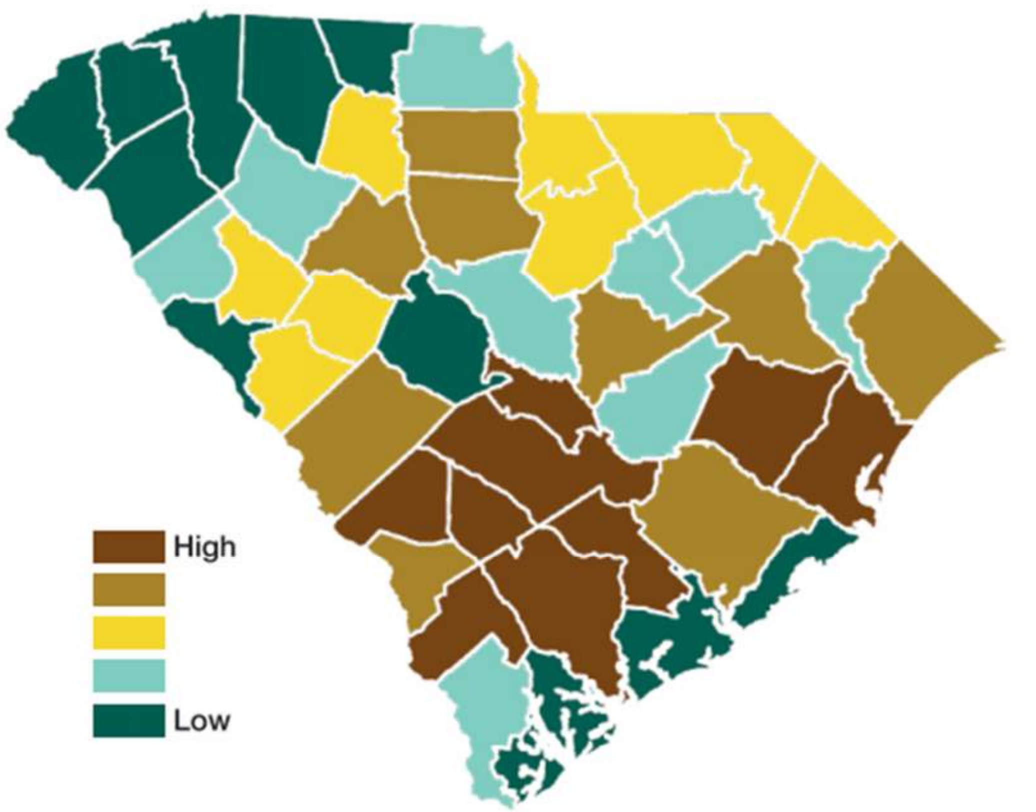

Figure 2-23. South Carolina delivered timber value rating by county (SCFC 2022).

2.4.3 Aquaculture

Limited data are available on aquaculture in the basin. However, the 2017 Census of Agriculture lists a handful of farms in the Upper Savannah River basin that possess reported aquaculture sales, shown in Table 2-14. Reported commercial aquaculture is concentrated in Anderson, Edgefield, Oconee, and Pickens Counties, with Pickens representing the greatest number and diversity of commodities. For the most part, sales data have not been disclosed for these farms (USDA NASS 2017).

Table 2-14. Number of aquaculture farms in counties of the Upper Savannah River basin (USDA NASS 2017).

Aquaculture Type	Abbeville	Anderson	Edgefield	Greenwood	McCormick	Oconee	Pickens	Saluda
Catfish	–	–	–	–	–	–	2	–
Trout	–	–	–	–	–	1	–	–
Other Food Fish	–	–	–	–	–	2	–	–
Crustaceans	–	2	–	–	–	–	–	–
Ornamental Fish	–	–	–	–	–	–	2	–
Sport or Game Fish	–	–	1	–	–	–	2	–
Other Aquaculture Products	–	–	1	–	–	–	–	–

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2.5 Socioeconomic Environment

2.5.1 Population and Demographics

The Upper Savannah River basin is overall the seventh most populous basin in South Carolina, possessing approximately 8 percent of the state's population in 10 percent of its area. The estimated Upper Savannah River basin population as of the 2020 census was approximately 404,000, which increased by approximately 9 percent since 2010. Figure 2-24 displays a population density map using data from the 2020 census (U.S. Census Bureau 2020). This map also contains parts of the North Carolina and Georgia portions of the basin.

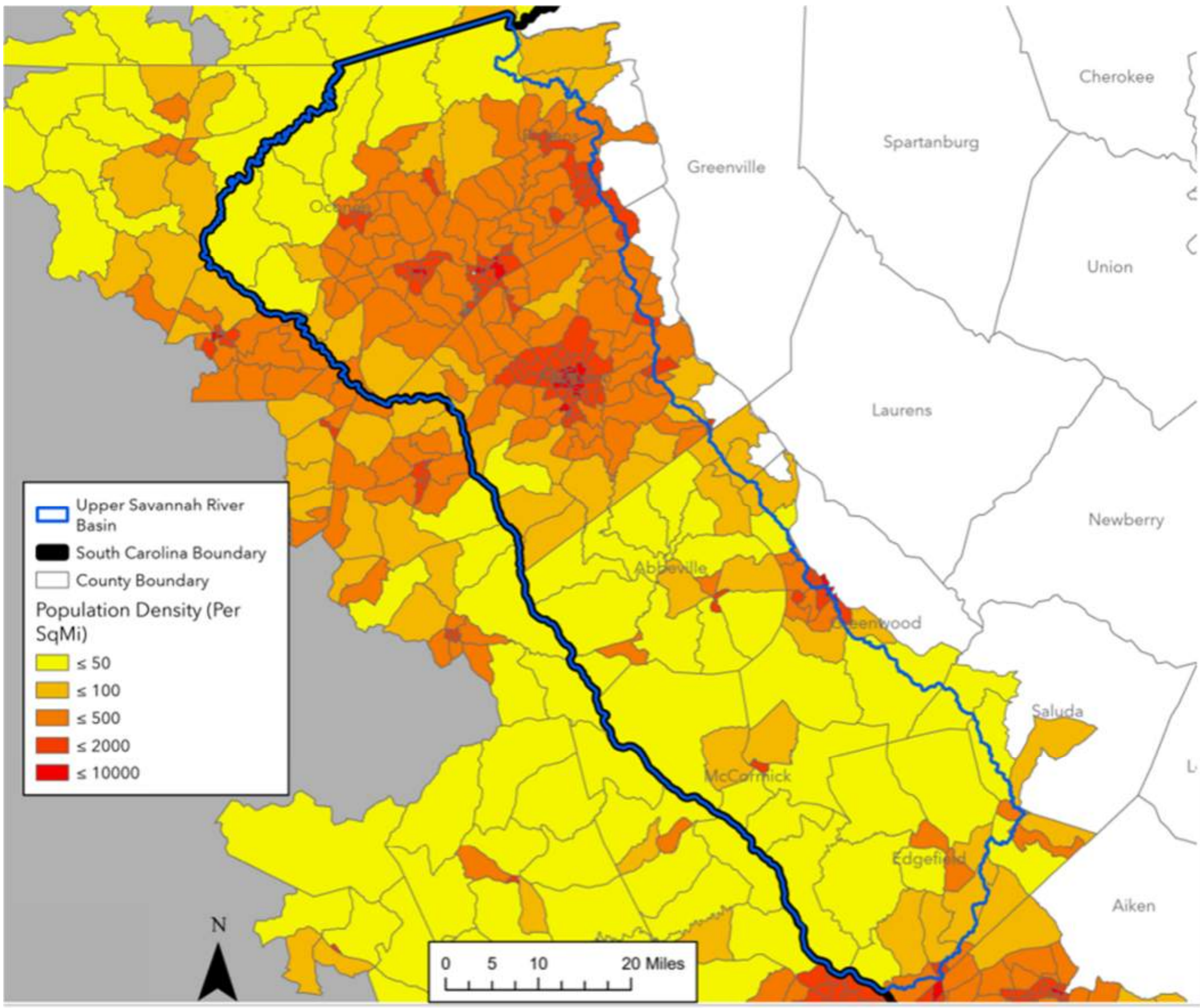

Figure 2-24. Population density of the Upper Savannah River basin by census block group (U.S. Census Bureau 2020).

The Upper Savannah River basin is predominantly rural but also contains a diverse mix of urban areas. Most major urban areas are found along the I-85 corridor, which runs east to west along the northern third of the basin. The City of Anderson, with 28,000 residents, is the largest urban area within the basin. It, along with smaller municipalities such as Seneca (about 9,000 residents) and Pendleton (about 4,000 residents), make up some of the largest population centers in the north. Many of the smaller towns, cities, and suburban areas in the north of the basin are also included in the large, over 900,000-person metropolitan area of Greenville. The smaller urban and suburban portions of Greenwood (about 22,000 residents) and Abbeville (about 5,000 residents) make up the most significant population centers in the middle of the basin. In the extreme south of the basin, a small portion of the suburban areas outside of Augusta, Georgia (about 615,000 residents) and North Augusta, South Carolina (about 24,000 residents) are present. Patterns of high and low population density within the South Carolina portion of the basin are also reflected in its North Carolina and Georgia portions. Along the North Carolina border, the rural Blue Ridge Mountains dominate on either side. In Georgia, the population is likewise highest in the basin's northern and southern swathes and least in its rural center (U.S. Census Bureau 2020).

Population changes within the Upper Savannah River basin from 2010 to 2020 are displayed in Figure 2-25 (U.S. Census Bureau 2020). In general, the population is growing or stagnant in most of the basin, with the exception of some, mostly rural, census blocks. The most rapidly growing areas are concentrated in places where population density is already high, such as the I-85 corridor in the north of the basin and the suburban areas surrounding Augusta, Georgia, in the south. Most of the mountainous areas along the North Carolina and South Carolina borders are also rapidly growing.

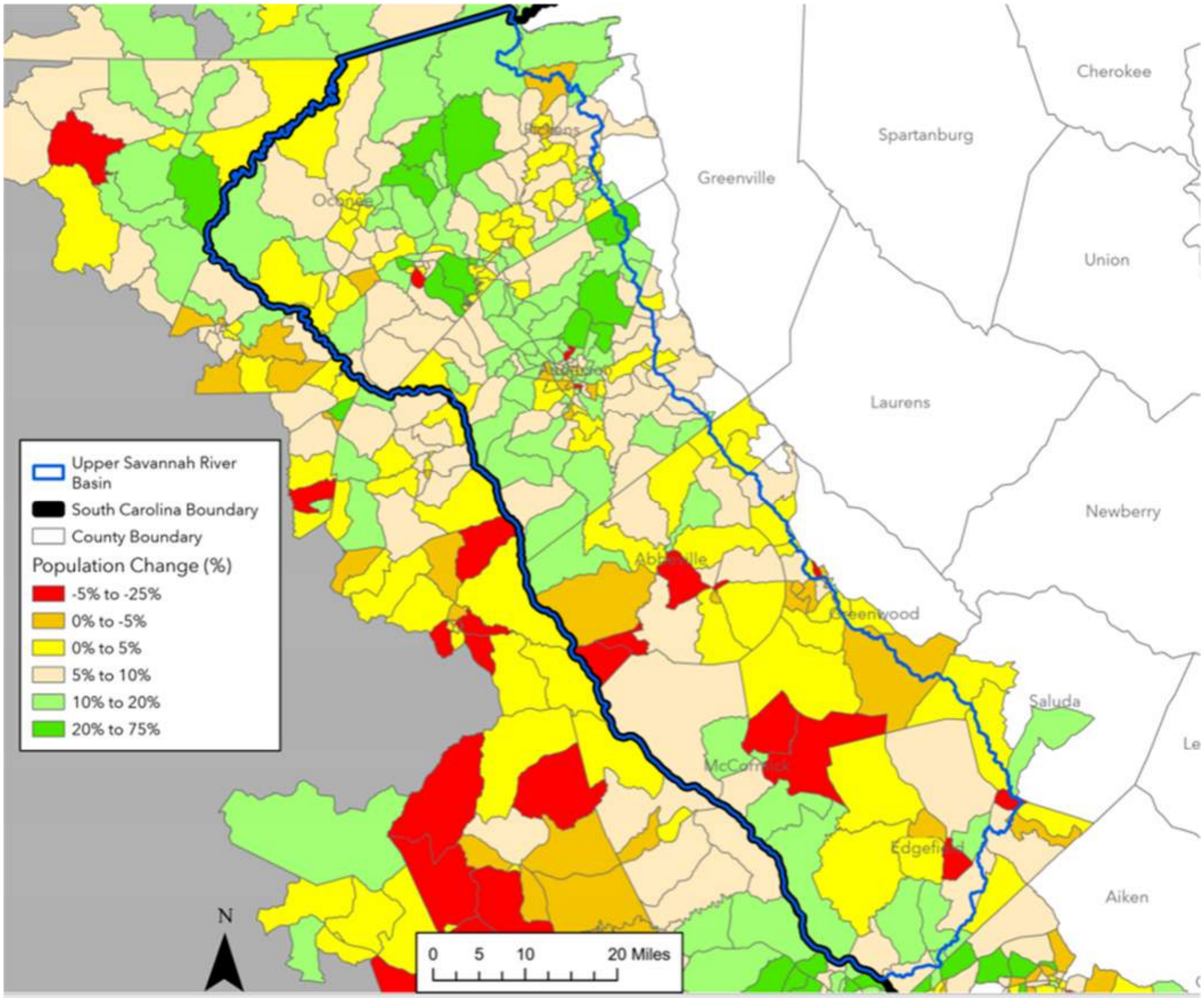

Figure 2-25. Change in Upper Savannah River basin population from 2010 to 2020 by census block group (U.S. Census Bureau 2020).

When the population projections of each major county within the basin are averaged, the Upper Savannah River basin population as a whole is projected to grow by just 0.8 percent by 2035 (South Carolina Revenue and Fiscal Affairs Office 2019). This slow growth is because of the significant estimated population decreases in Abbeville and McCormick Counties, which continue long trends of decline, and slow growth in Edgefield, Greenwood, and Saluda Counties. Most of the growth is centered in the basin's north, within Anderson, Oconee, and Pickens Counties. The estimated change in population through 2035 for counties in the Upper Savannah basin is provided in Table 2-15.

Table 2-15. Estimated change in population from 2020 to 2035 by county (SC Revenue and Fiscal Affairs Office 2019).

County	Estimated 2020 Population	Estimated 2035 Population	Percentage Change
Abbeville	24,300	22,195	-8.7
Anderson	204,570	234,420	14.6
Edgefield	27,150	27,425	1.0
Greenwood	70,960	71,430	0.7
McCormick	9,180	7,135	-22.3
Oconee	79,595	86,380	8.5
Pickens	126,595	139,525	10.2
Saluda	20,680	21,220	2.1

The 2021 per capita income of counties within the basin is provided from the U.S. Bureau of Labor Statistics and presented in Table 2-16. The 2021 per capita income for the eight counties within the basin ranges from $40,596 (Abbeville County) to $52,336 (Oconee County). The average income across the basin is $45,323, which is below the statewide average of $52,467. The counties of the Upper Savannah River basin predominantly fall within the middle percentiles of per capita income rankings when compared to all 46 counties statewide. Six out of eight counties fall within 20th to 28th place. Abbeville and Oconee Counties are outliers, falling within the lowest and highest quartiles of rankings, respectively. The percentage of the population below the poverty line for the counties of the basin ranges from 15.9 percent (Anderson and Greenwood Counties) to 19.5 percent (McCormick County), with a basinwide average of 16.7 percent. In total, an estimated 90,000 people in the basin live below the poverty line (SC Revenue and Fiscal Affairs Office 2021).

Table 2-16. Per capita income for counties within the Upper Savannah River basin (U.S. Bureau of Labor Statistics 2021).

County	2021 Per Capita Personal Income	Rank in State	Percentage Change from 2020
Abbeville	$40,596	42	6.60%
Anderson	$46,894	20	6.70%
Edgefield	$45,299	23	5.40%
Greenwood	$44,723	25	7.10%
McCormick	$44,391	27	5.20%
Oconee	$52,336	9	6.90%
Pickens	$43,842	28	6.60%
Saluda	$44,503	26	10.10%
Basin Average	$45,323	-	-
Statewide Average	$52,467	-	-

2.5.2 Economic Activity

The U.S. Bureau of Economic Analysis (USBEA) tracks real gross domestic product (GDP) by county. Table 2-17 presents the 2021 GDP from the eight counties of the Upper Savannah River basin (USBEA 2021a). Data from the top three counties within the basin are included individually. Several industries, including agriculture and manufacturing, rely heavily on the water resources of the basin. Table 2-18 provides the distribution of employment by industry sector for these counties (USBEA 2021b).

Table 2-17. 2021 GDP of select counties in the Upper Savannah River basin (in thousands of dollars).

Industry Type	Combined Counties	Anderson	Oconee	Pickens
All industry total	22,579,672	8,171,537	4,174,810	4,638,169
Private industries	18,703,043	6,935,640	3,789,284	3,431,502
Agriculture, forestry, fishing, and hunting	157,025	5,041	24,786	2,149
Mining, quarrying, and oil and gas extraction	51,656	43,771	(D)	(D)
Utilities	1,716,679	516,467	1,151,926	(D)
Construction	904,153	339,433	160,204	203,308
Manufacturing	5,501,402	1,989,418	899,509	1,027,551
Durable goods manufacturing	3,350,325	1,247,774	783,793	646,785
Nondurable goods manufacturing	2,151,077	741,645	115,716	380,765
Wholesale trade	1,002,671	483,358	124,518	71,587
Retail trade	1,642,554	641,906	267,599	391,623
Transportation and warehousing	279,434	203,489	(D)	22,980
Information	278,495	87,433	70,374	64,191
Finance, insurance, real estate, rental, and leasing	3,416,353	1,182,279	587,967	776,048
Finance and insurance	389,744	142,238	76,358	96,792
Real estate and rental and leasing	2,826,486	1,040,041	511,610	679,256
Professional and business services	972,431	422,775	164,088	193,615
Professional, scientific, and technical services	487,117	214,682	80,352	125,954
Management of companies and enterprises	58,002	30,533	1,818	3,700
Administrative and support and waste management and remediation services	443,682	177,560	81,918	63,961
Educational services, health care, and social assistance	1,242,892	497,079	152,155	269,488
Educational services	120,732	76,177	12,554	25,134
Health care and social assistance	1,096,222	420,902	139,600	244,354
Arts, entertainment, recreation, accommodation, and food services	776,503	310,065	88,044	255,526
Arts, entertainment, and recreation	103,852	34,456	19,945	37,915
Accommodation and food services	660,186	275,608	68,099	217,611
Other services (except government and government enterprises)	540,756	213,125	85,913	115,835
Government and government enterprises	3,876,630	1,235,898	385,526	1,206,667

Table 2-18. Percentage of employment by sector for all counties in the Upper Savannah River basin combined, 2021.

Industry Sector	Upper Savannah River Basin Average Percentage of Employment
Farm employment	4.1%
Forestry, fishing, and related activities	1.2%
Mining, quarrying, and oil and gas extraction	<1.0%
Utilities	<1.0%
Construction	6.4%
Manufacturing	16.5%
Wholesale trade	2.1%
Retail trade	10.3%
Transportation and warehousing	2.3%
Information	<1.0%
Finance and insurance	3.0%
Real estate and rental and leasing	4.1%
Professional, scientific, and technical services	3.7%
Management of companies and enterprises	<1.0%
Administrative and support and waste management and remediation services	6.4%
Educational services	1.3%
Health care and social assistance	8.4%
Arts, entertainment, and recreation	1.9%
Accommodation and food services	7.8%
Other services (except government and government enterprises)	8.1%
Government and government enterprises	18.4%

2.6 Conclusion

The Upper Savannah River basin is an important piece of South Carolina's heritage. Located within this basin, from the high Blue Ridge Mountains of the north to the rolling sandhills of the south, are many of the great natural and human-made wonders of South Carolina. The basin boasts seven Heritage Preserves, 10 state parks, and remarkable biodiversity. With more than 14 percent of the basin utilized for agriculture and more than 28 percent classified as prime farmland, the Upper Savannah River basin also constitutes an important agricultural center. This wealth of land and resources has attracted thousands to live within the basin's borders. Featuring many of the largest water reservoirs in the state, with a river system that feeds directly into the Lower Savannah–Salkehatchie River basin to the south, proper management of the water resources within the Upper Savannah River basin has never been more critical.

Chapter 3
Water Resources of the Upper Savannah River Basin

3.1 Surface Water Resources

3.1.1 Major Rivers and Lakes

The Upper Savannah River basin, as defined for South Carolina's river basin planning process, extends from the North Carolina state line down to the Savannah River confluence with Stevens Creek in Edgefield County. The Savannah River headwaters originate in the Blue Ridge physiographic provinces of North Carolina and Georgia, including the Tugaloo and the Seneca Rivers. Major tributaries of the Savannah River include the Chattooga River, Twelvemile Creek, Rocky River, Little River, and Stevens Creek. The Broad River tributary in Georgia also drains to the Savannah River and is used to modify flows from Lake Thurmond during drought conditions. The Upper Savannah River basin has a drainage area of approximately 3,200 sq mi in South Carolina (SCDNR 2009).

Five large reservoirs have been built on the Savannah River and its tributaries: Lake Thurmond, Lake Hartwell, and Lake Russell on the Savannah River mainstem, and Lake Keowee and Lake Jocassee on the Keowee River. Controlled releases from hydroelectric power facilities on these and additional smaller reservoirs greatly impact streamflow in the mainstem of the river. Development has eliminated most of the free-flowing streams in the basin (SCDNR 2009). Section 3.1.3 details the surface water development in the subbasin. Unregulated streams depend on direct precipitation, surface runoff, and groundwater discharge to maintain flows. Tributary flows in the upper Blue Ridge region of the basin are more reliable, as compared to the flashier tributaries in the lower portion of the basin, because of the higher rainfall and groundwater storage capabilities (SCDNR 2009).

Figure 3-1 shows the location of the five major subbasins, the major riverine wetland types, reservoirs, and small lakes and ponds within the Upper Savannah River basin. Freshwater forested/shrub wetlands lie along tributary streams throughout the basin.

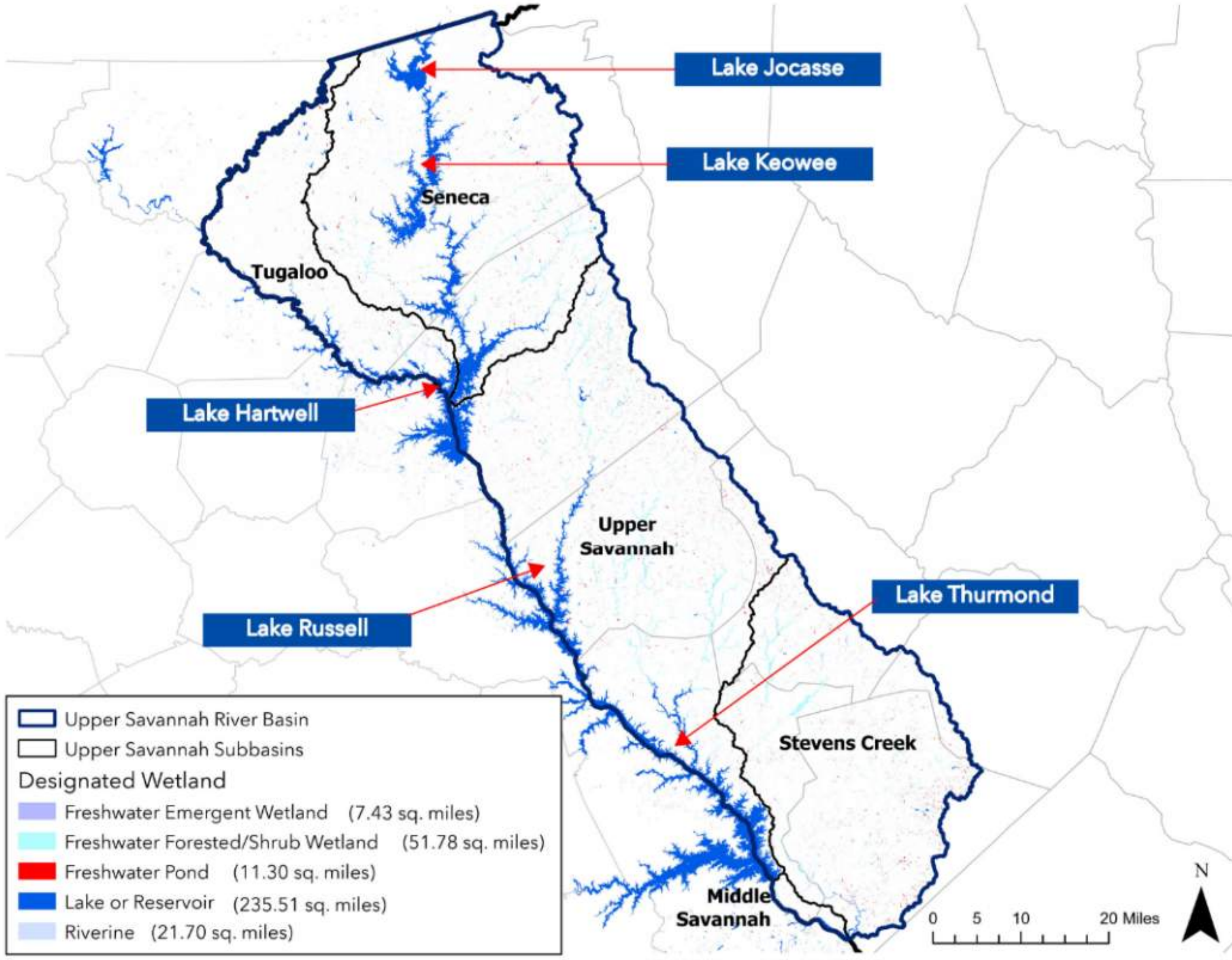

Figure 3-1. Wetland types of the Upper Savannah River basin (USFWS 2023).

3.1.2 Surface Water Monitoring

At the end of the 2023 water year (September 30, 2023), there were 16 active gaging stations operated by the USGS in the Upper Savannah River basin in South Carolina or on water bodies that run along state boundaries which report daily streamflow, stage, or lake elevation data (USGS 2024). Nine of the active stations' datasets include daily mean discharge (flow) data, while the remaining seven active stations report daily mean stage or reservoir elevation data.

An additional 24 gaging stations are no longer active but previously collected streamflow, stage, or reservoir elevation data. Table 3-1 lists all gaging stations in the basin and provides the first and last years in their periods of record, drainage areas, and select daily streamflow statistics through September 30, 2023 (where available and with USGS provisional data included) (USGS 2024). Stations are grouped by subbasin, as defined by the 8-digit hydrologic unit code (HUC). Gaging stations that do not record daily mean discharge data are included in Table 3-1, but streamflow statistics are not available (NA) for these sites. Figure 3-2 shows the locations of all the active and inactive gaging stations. The lowest recorded daily mean streamflow in the Savannah River in the Upper Savannah basin was 10 cfs, which was observed in 1996 below Hartwell Lake near Hartwell, Georgia. This low flow is likely due to a period of non-generation at the dam upstream and not caused by natural conditions. The highest streamflow in the Upper Savannah River was 185,000 cfs, recorded near Clarks Hill in 1940.

Table 3-1. Streamflow characteristics at USGS gaging stations in the Upper Savannah River basin.

Map Identifier	Gaging Station Name	Station Number	Period of Record[1]	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[2] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Seneca River Subbasin – HUC 03060101								
1	Howard Creek near Jocassee	02184475	1988–1996	2.2	7.9	2.8	1.4 (1988, 1993)	135 (1989)
2	Whitewater River at Jocassee	02184500	1951–1968	50	176	56	24 (1954)	3,140 (1964)
3	Keowee River near Jocassee	02185000	1950–1968	148	494	162	57 (1954)	10,600 (1964)
4	Eastatoee Creek on Cleo Chapman Hwy near Sunset	02185010	2020–present	22	61	29	19 (2023)	628 (2023)
5	Lake Keowee near Six Mile[3]	02185145	1988–2000	272	NA	NA	NA	NA
6	Little River near Walhalla	02185200	1967–2003	72	174	61	8.0 (2002)	10,000 (1967)
7	Keowee River near Newry	02185500	1939–1961	455	1,151	382	152 (1954)	19,600 (1940)
8	Twelvemile Creek near Liberty	02186000	1954–present	106	183	59	12 (2008)	5,410 (2020)
9	Golden Creek near Easley	02186090	1998–2000	1.5	2.0	0.97	0.42 (2000)	18 (2000)
10	Coneross Creek near Seneca	02186645	1989–present	65	114	38	3.1 (2002)	2,800 (1990, 1994)
11	Eighteenmile Creek above Pendleton	02186699	1998–2008	47	55	18	3.3 (2002)	2,980 (2003)
12	Eighteenmile Creek below Pendleton	02186702	2012–present	49	74	25	10.2 (2017)	1,670 (2013)
13	Seneca River near Anderson	02187000	1928–1959	1,026	2,034	737	170 (1931)	76,000 (1928)
Tugaloo River Subbasin – HUC 03060102								
14	Chattooga River at Burrells Ford, near Pine Mtn, Georgia	02176930	2009–present	47	197	54	24 (2016)	3,200 (2015)
15	Chattooga River near Clayton, Georgia	02177000	1939–present	207	651	216	68 (2008)	18,500 (2004)

Table 3-1 (continued). Streamflow characteristics at USGS gaging stations in the Upper Savannah River basin.

Map Identifier	Gaging Station Name	Station Number	Period of Record[1]	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[2] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Tugaloo River Subbasin – HUC 03060102 (continued)								
16	Chattooga River near Tallulah Falls, Georgia	02178000	1917–1929	256	854	355	96 (1925)	12,400 (1918)
17	Tugaloo River near Hartwell, Georgia	02184000	1925–1960	909	1,919	550	188 (1954)	23,700 (1940)
18	Chauga River above Westminster	34410808 3090600	2020–present	67	NA	NA	NA	NA
Upper Savannah River Subbasin – HUC 03060103								
19	Hartwell Lake near Anderson	02187010	2005–present	2,088	NA	NA	NA	NA
20	Hartwell Lake near Hartwell, Georgia	02187250	1976–2001	2,088	NA	NA	NA	NA
21	Hartwell Lake Tailrace near Hartwell, Georgia	02187251	1984–2000	2,088	NA	NA	NA	NA
22	Savannah River below Hartwell Lake near Hartwell, Georgia	02187252	1984–1999	2,090	3,445	102	10 (1996)	21,000 (1998)
23	Savannah River near Iva	02187500	1950–1981	2,231	4,469	574	78 (1961)	47,200 (1952)
24	Rocky River near Starr	02187910	1989–present	111	125	28	4.9 (2008)	5,340 (2020)
25	Rocky River near Calhoun Falls	02188000	1950–1966	267	303	104	9 (1954)	8,440 (1964)
26	Russell Lake above Calhoun Falls	02188100	2004–present	2,900	NA	NA	NA	NA
27	Savannah River near Calhoun Falls	02189000	1896–1979	2,876	5,272	1,720	300 (1961)	75,200 (1900)
28	RB Russell Lake near Calhoun Falls, South Carolina	02189004	1984–2001	2,900	NA	NA	NA	NA
29	RB Russell Tailrace near Calhoun Falls	02189005	1996–2000	2,900	NA	NA	NA	NA
30	Little River near Mt. Carmel	02192500	1940–present	217	192	24	0 (2011)	15,200 (1940)
31	Blue Hill Creek at Abbeville	02192830	1998–2008	3.2	3.0	0.47	0 (2007)	111 (2003)

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Table 3-1 (continued). Streamflow characteristics at USGS gaging stations in the Upper Savannah River basin.

Map Identifier	Gaging Station Name	Station Number	Period of Record[1]	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[2] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Upper Savannah River Subbasin – HUC 03060103 (continued)								
32	Thurmond Lake near Plum Branch[3]	02193900	2005–present	0.5	NA	NA	NA	NA
33	Lake Thurmond near Clarks Hill	02194500	1983–2001	6,150	NA	NA	NA	NA
34	Lake Thurmond Tailrace near Clarks Hill	02194501	1988–2000	6,150	NA	NA	NA	NA
35	Savannah River near Clarks Hill, South Carolina	02195000	1940–1954	6,150	8,427	3,130	1,120 (1941)	185,000 (1940)
Stevens Creek Subbasin – HUC 03060107								
36	Turkey Creek below Johnston	02195665	June 2023–present	113	NA	NA	NA	NA
37	Stevens Creek near Modoc	02196000	1929–present	545	378	11	0 (1954, 2014)	31,700 (1940)
38	Horn Creek near Colliers (Edgefield)	02196250	1980–1994	14	14	3.4	0.77 (1982)	530 (1981)
39	Stevens Creek at Woodlawn Road near Murphy Village[3]	021963601	2019–present	721	NA	NA	NA	NA
Middle Savannah River Subbasin – HUC 03060106								
40	Savannah River near Evans, Georgia	02195520	2005–present	6,360	NA	NA	NA	NA

[1] "Present" indicates that the gage was active at the end of water year 2023 (September 30, 2023).
[2] "90% exceeds flow" is the flow for which 90% of daily flows are higher and 10% are lower.
[3] The drainage area for this gage was not reported by USGS, and the value in the table is estimated.
NA = not available.

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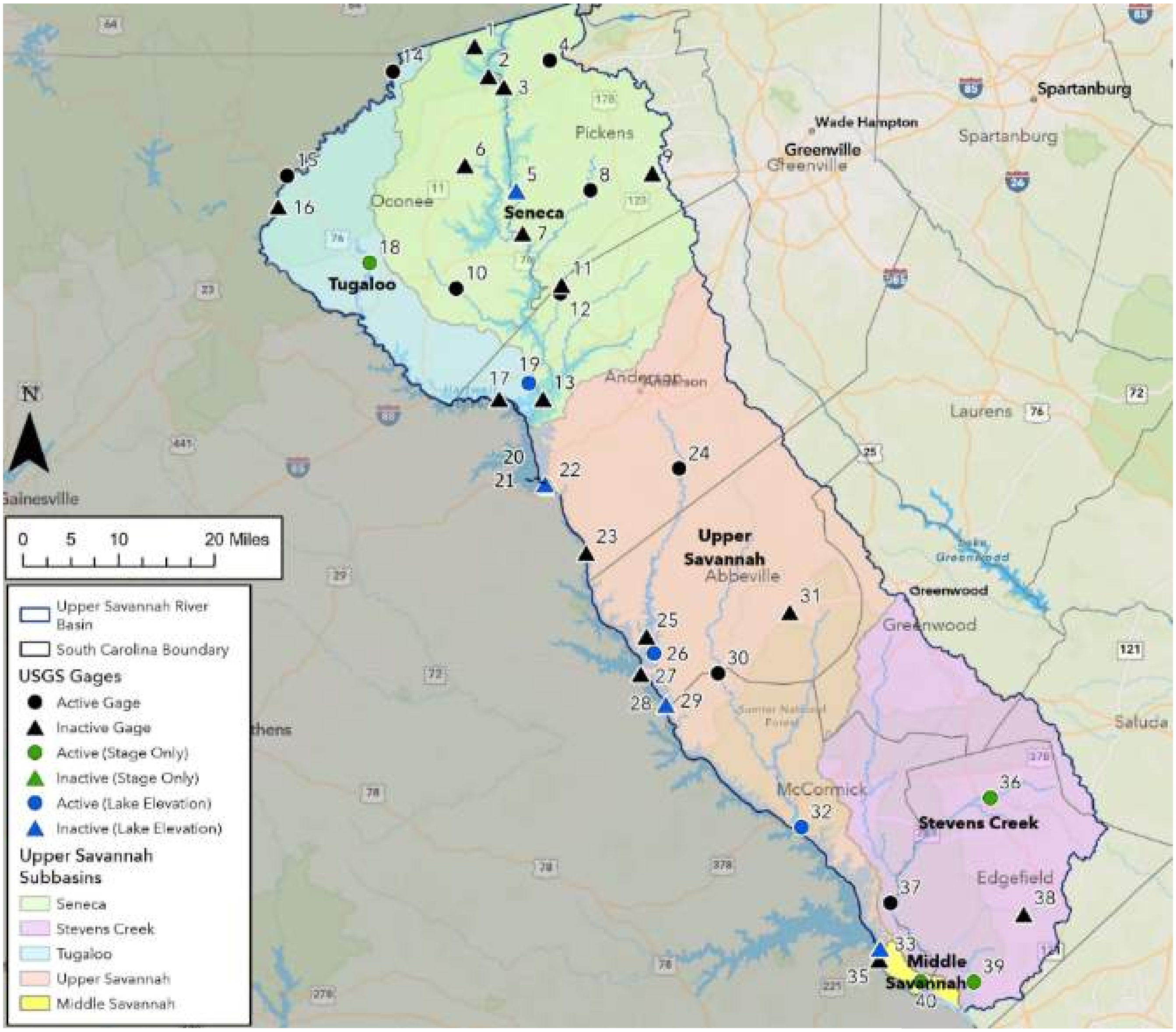
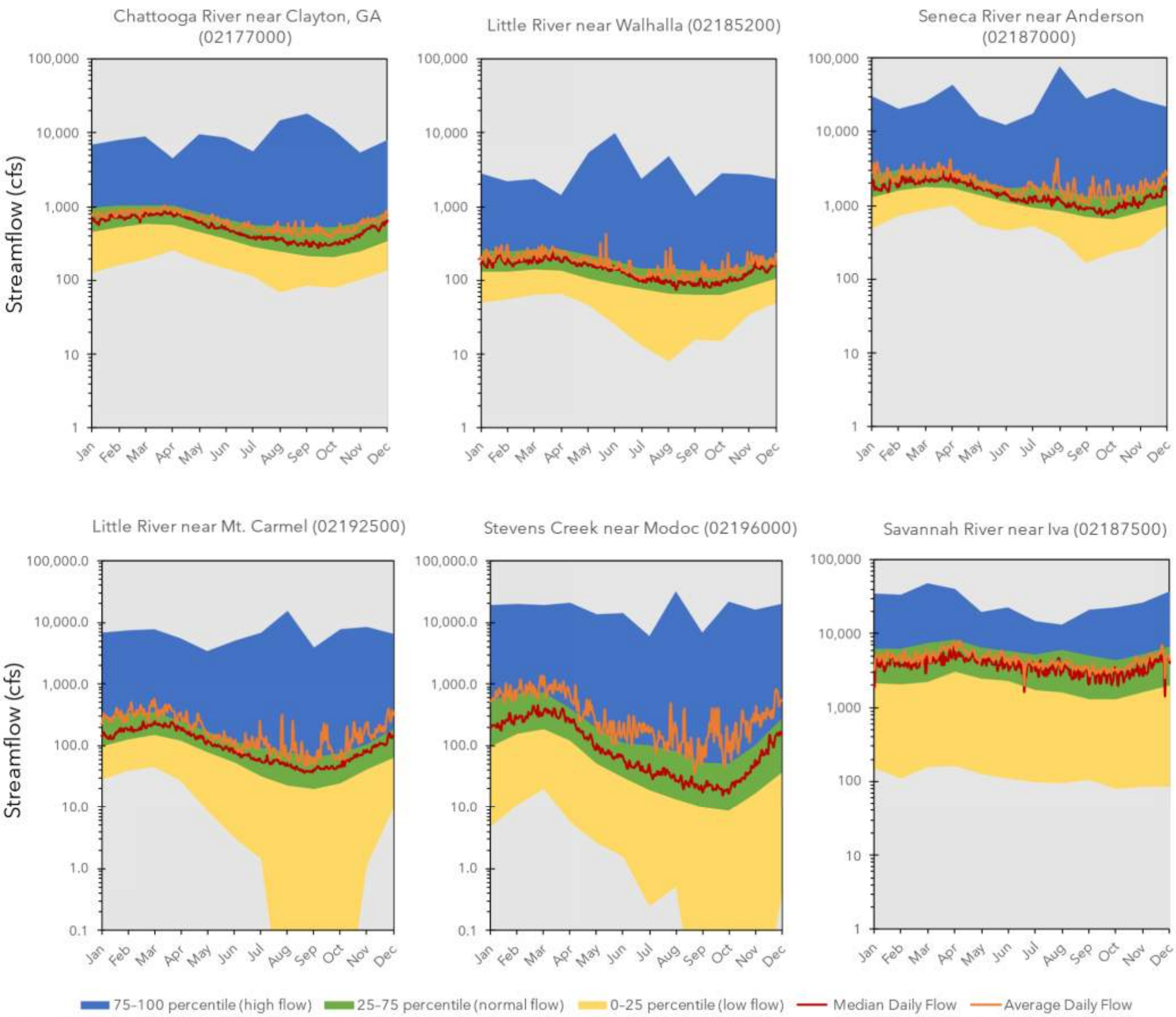


Figure 3-2. USGS gaging stations.

Figure 3-3 presents duration hydrographs showing average daily streamflow throughout the year at select gaging stations on the Savannah River and its tributaries in the Upper Savannah basin. The tributary gaging stations shown are on unregulated streams and depend upon precipitation, groundwater discharge, and surface runoff to maintain flows. In the northwestern-most Blue Ridge region of the basin, flows are generally uniform year-round because of the well-sustained base flows resulting from high rainfall and groundwater storage (SCDNR 2009). Streamflow becomes more variable with distance from the mountains; for example, Little River near Mt. Carmel and Stevens Creek exhibit highly variable flow, including recorded periods of zero flow. The Savannah River mainstem at the now-discontinued gaging station near Iva (below Lake Hartwell) has well-sustained flows because of reservoir releases. At all stations selected, median flows are lower than mean flows, with the greatest differences occurring at tributary stream gaging stations lower in the basin.



Note: The Little River near Walhalla and Little River near Mt. Carmel gaging stations are on different waterbodies. Little River near Walhalla is located on the Little River that drains into Lake Keowee, while Little River near Mt. Carmel is on the Little River that drains into Lake Hartwell.

Figure 3-3. Duration hydrographs for select gaging stations on the Upper Savannah River and its tributaries.

Aggregated monthly flows provide a smoother, larger timescale depiction of flow variability over the recorded period, which is useful for identifying low and high flow periods of the recent past. As examples, Figure 3-4 shows plots of mean monthly flows at the Chattooga River near Clayton, Georgia, and the Little River near Mt. Carmel gaging stations, averaged over the previous 30 water years (October 1993 through September 2023). The fifth percentile of the mean monthly flows over the nearly 84-year period beginning in 1939 is 204 cfs at the Chattooga River near Clayton, Georgia station. The fifth percentile of the mean monthly flows over the nearly 67-year period of record (January 1940 to September 1970, August 1986 to October 2003, and October 2004 to present) is 18 cfs at the Little River near Mt. Carmel station. Mean monthly flows at both stations exhibit similar patterns, with higher sustained flow at the Chattooga River station and more variable flows at the Little River station. The fifth percentile flows at the Little River station are used in the graph to distinguish the periods of drought, most of which occurred during the periods of 2007 to 2008 and 2010 to 2012. The historical minimum flow at the Little River station occurred from August 2011 to October 2011, when zero flow was observed; this appears as a gap in the data in Figure 3-4.

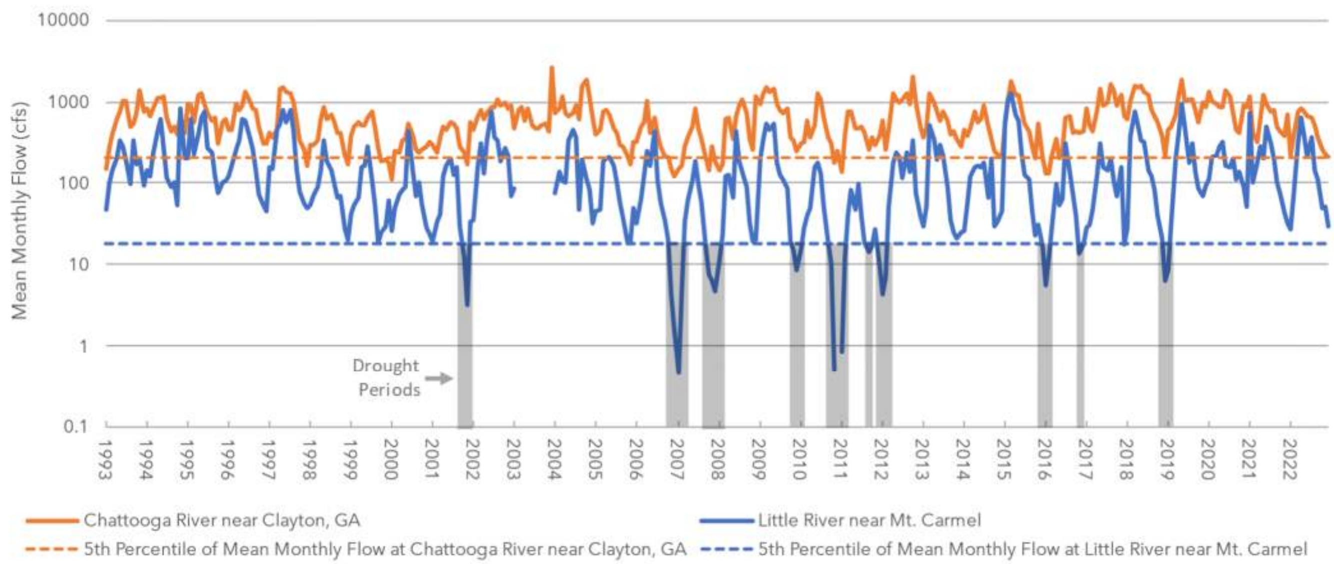


Figure 3-4. Mean monthly flows at gaging stations on the Chattooga River near Clayton and the Little River near Mt. Carmel.

Several of the USGS gages in the Upper Savannah basin monitor reservoir elevations. Figure 3-5 presents the historical water levels in the USACE reservoirs (Lake Thurmond, Lake Russell, and Lake Hartwell) since 2005 (including the drought period of 2007 to 2008). These lakes are controlled by complex operating rules, which aim to balance filling and drawdowns. Lake Hartwell and Lake Thurmond operate on seasonal guide curves, with higher water levels in the summer months and lower water levels in the winter months. Several times during the last 20 years, including during the historic drought of 2007 to 2008, water levels dropped below guide curve elevations (Figure 3-5). Lake Russell reached its maximum drawdown level of 5 feet during the 2007-2008 drought event.

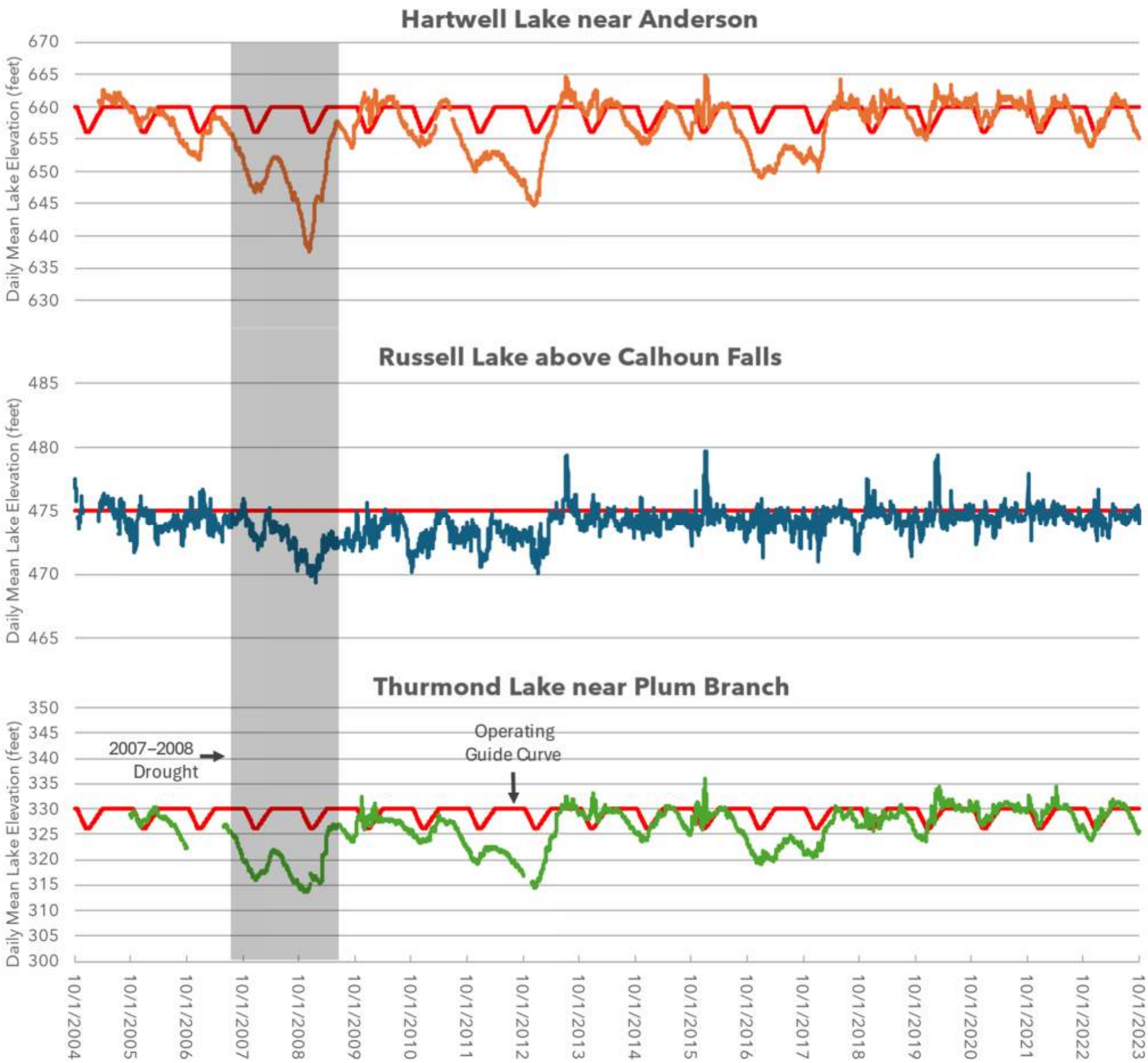


Figure 3-5. Historical water levels in Lake Hartwell, Lake Russell, and Lake Thurmond.

In addition to the USGS gaging stations that measure stage and flow, there are numerous sites throughout the basin where SCDES collects water quality data as part of their ongoing Ambient Surface Water Physical and Chemical Monitoring program to assess the water's suitability for aquatic life and recreational use. The program includes ongoing fixed-location monitoring and statewide statistical survey monitoring. The fixed-location monitoring includes monthly collection and analysis of water from Base Sites in a uniform manner to provide solid baseline water quality data. The Statistical Survey Sites are sampled once per month for one year and moved from year to year (SCDHEC 2022c).

3.1.3 Surface Water Development

The Upper Savannah River basin has been developed with numerous flood-control and hydroelectric power projects, many of which also serve as water supply sources. Five of South Carolina's largest reservoirs are located in the basin. Table 3-2 shows the lakes in the Upper Savannah River subbasin and along its borders that are larger than 200 acres. Figure 3-1 shows the reservoirs with storage capacities above 1 million acre-feet. All of the hydroelectric generating facilities in the Upper Savannah basin are peaking power systems and are not relied upon for base electrical demands.

The USACE constructed Lake Hartwell, Lake Russell, and Lake Thurmond on the Savannah River (SCDNR 2009). Previously named Clarks Hill Lake, J. Strom Thurmond Lake is the largest reservoir in the basin in terms of surface area and it is the second largest in both surface area and volume of all lakes in South Carolina. Lake Thurmond was completed in 1954 and was the first USACE reservoir on the Savannah River. The lake was initially built to provide hydropower, flood control, and navigation. Water supply and recreation became important uses in later years. Lake Thurmond's releases control the flow regime in the lower Savannah River. Lake Russell and Lake Hartwell are located above Lake Thurmond. Lake Hartwell, completed in 1963, is the largest lake in South Carolina by volume and extends up the Savannah, Tugaloo, and Seneca Rivers. Lake Hartwell provides both flood control and hydroelectric power, and has a greater drawdown potential than the other reservoirs in this system. Lake Russell was constructed in 1985 for hydroelectric power production and flood control and later became an important recreation and water supply resource.

On the Keowee River, Lake Jocassee is the site of the Jocassee Pumped Storage Facility, which is a pumped-storage hydroelectric facility owned and operated by Duke Energy (SCDNR 2009). The lake is also a popular recreation area. Just downstream, Lake Keowee was created in 1971 by damming the Keowee and Little Rivers. It serves several purposes, its primary purpose being to supply cooling water for the adjacent Oconee Nuclear Station. Lake Keowee also provides water for Duke Energy's Keowee Hydro Facility, serves as a reservoir for the Jocassee Pumped Storage Facility, and is a source of water supply for the city of Greenville. During periods of low electricity demand, energy is spent to pump water from Lake Keowee to the higher-elevation Lake Jocassee, where it may be released again to generate potential energy from gravity as it flows back into Lake Keowee. The Keowee Hydro Facility and the Jocassee Pumped Storage Facility, known together as the Keowee-Toxaway Hydroelectric Project, generates 868 megawatts of power (Duke Energy 2023). Lake Keowee is also a popular recreation site.

Table 3-2. Characteristics of lakes 200 acres or larger in the Upper Savannah River subbasin.

Name	Stream	Surface area[1] (acres)	Storage capacity[1] (acre-feet)	Purpose
Lake Thurmond	Savannah River	70,250	2,460,000	Power, navigation, flood control, water supply, water quality, recreation, and fish and wildlife management
Lake Hartwell	Savannah River	55,950	2,190,000	Power, navigation, flood control, water supply, water quality, recreation, and fish and wildlife management
Lake Russell	Savannah River	25,653	910,000	Power, flood control, water supply, water quality, recreation, and fish and wildlife management
Lake Keowee	Keowee-Little River	17,660	1,000,000	Power, recreation, and water supply
Lake Jocassee	Whitewater-Toxaway	7,980	1,185,000	Power and recreation
Stevens Creek	Savannah River and Stevens Creek	2,400	23,600	Power
Lake Secession	Rocky River	1,362	31,200	Power, recreation, and water supply
Lake Tugaloo	Chattooga River	597	43,000	Power and recreation
Bad Creek Reservoir	Bad Creek	363	35,513	Power
Broadway Lake	Rocky River	300	1,800	Recreation
Lake Yonah	Tugaloo River	293	10,200	Power and recreation

Source: Adapted from Table 8-2 in SCDNR (2009), and SCDNR (2023b) and USACE (2024).

[1] Storage capacities and surface areas listed for Lake Thurmond, Lake Hartwell, and Lake Russell are at the top of the designated summer conservation pool (330 feet for Lake Thurmond, 660 feet for Lake Hartwell, and 475 feet for Lake Russell). These storage capacities are based on surveys conducted by USACE between 2015 and 2023.

Additionally, numerous regulated and unregulated small dams create small impoundments on many of the Upper Savannah River tributaries. Dams that are less than 25 feet in height or that impound less than 50 acre-feet are generally exempt from regulation in South Carolina. There are 230 SCDES-regulated dams in the Upper Savannah River basin, most of which are classified as Low Hazard, Class 3 dams as shown in Table 3-3. Most of the regulated dams, particularly those designated as High Hazard dams, are on the upper reaches of the basin, as shown in Figure 3-6. Primarily Low Hazard regulated dams are also clustered at the southeastern end of the basin, north of Augusta, Georgia.

Table 3-3. Regulated dams in the Upper Savannah River basin.

Dam Type	Number of Dams	Description
High Hazard, Class 1	83	Structure where failure will likely cause loss of life and/or serious damage to infrastructure
Significant Hazard, Class 2	20	Structure where failure will not likely cause loss of life but infrastructure may be damaged
Low Hazard, Class 3	127	Structure where failure may cause limited property damage
Total	**230**	

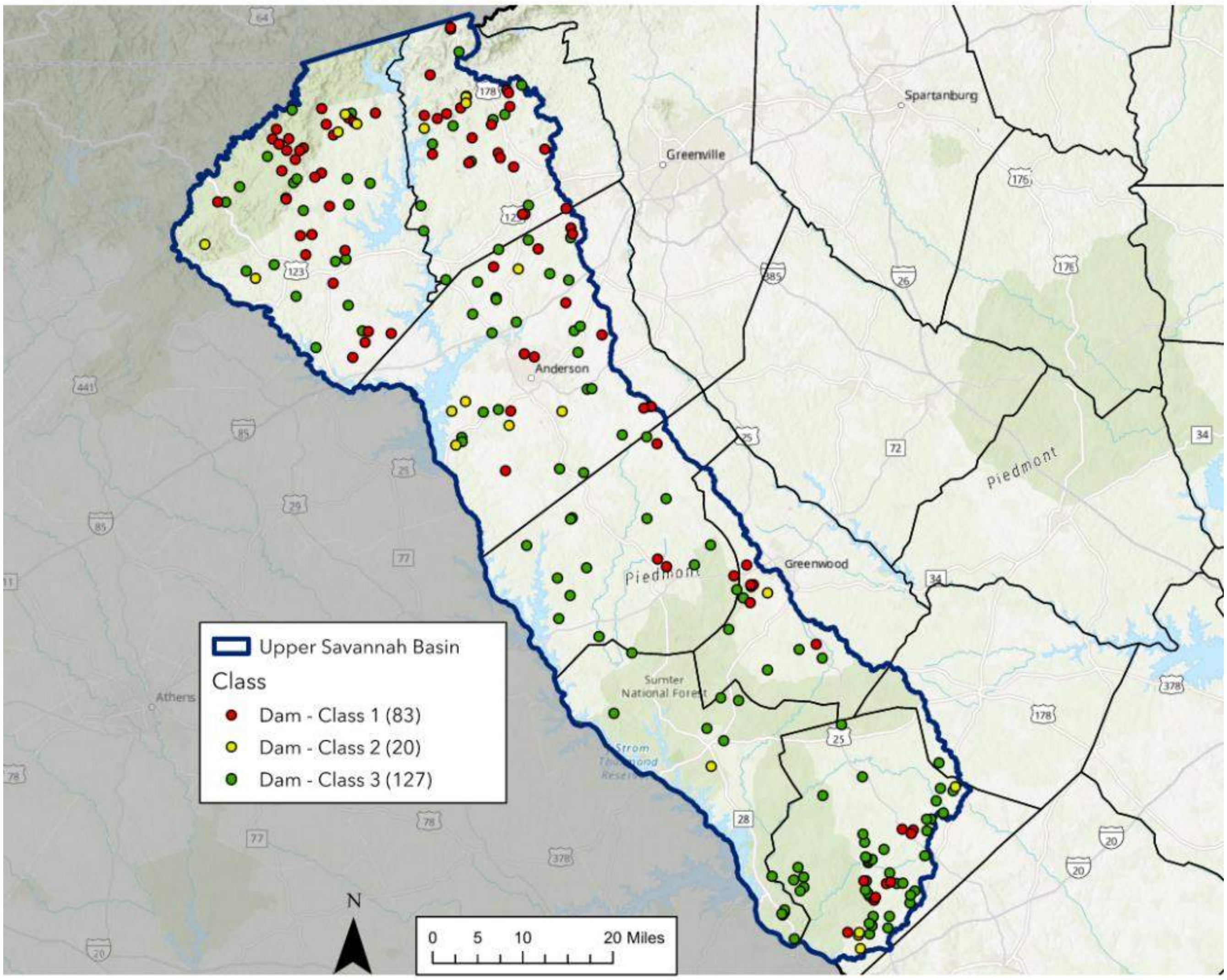


Figure 3-6. Regulated dams in the Upper Savannah River basin.

Table 3-4 details the major hydroelectric power–generating facilities in the Upper Savannah River basin. The facility with the largest generating capacity is Duke Energy's Bad Creek pump-storage project above Lake Jocassee. The smaller Stevens Creek project helps mitigate the downstream impacts of variable releases from Lake Thurmond (SCDNR 2009).

Table 3-4. Major hydroelectric power–generating facilities in the Upper Savannah River basin.

Facility Name and Owner	Impounded Stream	Reservoir	Generating Capacity (megawatts)
Bad Creek Pumped Storage Duke Energy	Bad Creek	Bad Creek Reservoir	1,400
Jocassee Pumped Storage Duke Energy	Whitewater-Toxaway	Lake Jocassee	710
Keowee Hydro Facility Duke Energy	Keowee-Little River	Lake Keowee	157.5
Tugalo Georgia Power	Tallulah River	Lake Tugaloo	68.2
Yonah Georgia Power	Tugaloo River	Lake Yonah	22.5
Hartwell USACE	Savannah River	Lake Hartwell	428
Richard B. Russell USACE	Savannah River	Lake Russell	644
J. Strom Thurmond USACE	Savannah River	Lake Thurmond	402.5
Stevens Creek Dominion Energy	Savannah River-Stevens Creek	Stevens Creek Reservoir	17.3

Source: Adapted from Table 8-3 in SCDNR (2009) and SCDNR (2023b).

There are no navigation projects in the Upper Savannah River basin (SCDNR 2009). The USACE reservoirs provide flood control because of their large storage capacities. The NRCS has constructed other smaller flood-control projects, mainly in the upper reaches of the basin. The first flood-retarding project in South Carolina, on Twelvemile Creek, was completed in 1954 as a pilot program and prompted other projects to follow (SCDNR 2009).

More than 99.9% of the total water withdrawals in the Upper Savannah basin in 2022 were surface water withdrawals (SCDNR 2023b). By far, the greatest user of surface water that year was the thermoelectric power industry, which reported withdrawals totaling 97.4 percent of surface water withdrawals that year. The majority of that water is returned to the system after being used as cooling water. Public water suppliers made up 2.3 percent of the surface water withdrawals, and agricultural irrigation, golf courses, mining, and industrial use each accounted for less than 1 percent of surface water usage.

3.1.4 Surface Water Concerns

The headwaters of the Savannah River and several of its tributaries drain North Carolina, South Carolina, and Georgia watersheds. Stretches of the Savannah River and its tributaries, the Chattooga and Tugaloo Rivers, run along the South Carolina and Georgia state line. Known surface water users in the Georgia portion of the Upper Savannah River planning basin include at least 24 public water suppliers, 12 industrial water users, four hydroelectric power facilities, and one thermoelectric power facility (SCDNR 2023b; CDM Smith 2017).

Most lakes and streams in the Upper Savannah River basin are designated as "Freshwater" (Class FW) water bodies, meaning they are suitable for aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses. Eastatoe Creek, Rocky Bottom Creek, and parts of the Chauga and Chattooga Rivers are designated as "Outstanding Resource Waters" (Class ORW) (SCDES 2024a). This designation indicates an outstanding recreational or ecological resource that is suitable as a drinking-water source with minimal treatment. Lake Jocassee is designated as a "Trout Put, Grow, and Take Water" (Class TPGT), meaning it is a freshwater body that specifically supports the growth of stocked-trout populations. Lake Jocassee is also listed as one of the least eutrophic lakes in South Carolina, along with Lake Keowee and Lake Yonah (SCDNR 2009). Table 3-5 provides a summary of stream classifications in the Upper Savannah basin.

Table 3-5. Stream classifications in the Upper Savannah River basin.

Stream Classification	Length (miles)	Percentage of Upper Savannah Streams
Freshwater (FW)	5,240	89.5%
Outstanding Resource Waters (ORW)	302	5.2%
Trout Natural (TN) & Trout Put, Grow, and Take (TPGT)	310	5.3%

Water quality concerns have been associated with stream and river reaches in the basin that do not meet water quality standards and do not support designated uses. Water quality monitoring conducted by SCDHEC (now named SCDES) from 2002 to 2006 demonstrated that aquatic life uses were fully supported at 83 percent of sites (133 out of 161) (SCDHEC 2010). Approximately 46 percent (13 out of 28) of sites that were not fully supportive of aquatic life uses were biologically impaired with respect to macroinvertebrate community assessments. Recreational use was fully supported at 56 percent (77 out of 138) of sampled sites. Sites not supportive of recreational use were all impaired by high levels of fecal coliform bacteria.

More recently, the 2022 Section §303(d) Clean Water Act list of impaired waters documented impairments at 91 sampling stations located on 59 different streams and lakes in the basin, including portions of Twelvemile Creek, the Rocky River, the Little River, Stevens Creek, Lake Hartwell, Lake Russell, and Lake Thurmond (SCDHEC 2022b). Table 3-6 provides a summary of the impairments and the associated non-supported designated uses.

Table 3-6. 2022 §303(d) Upper Savannah River basin impairment summary.

Designated Use	Number of Stations with Impairments	Nature of Impairments (number of impairments)
Aquatic Life	55	Macroinvertebrate (19) Cadmium (4) Chlorophyll-a (2) Copper (1) Dissolved Oxygen (3) Lead (1) pH (15) Total Nitrogen (6) Total Phosphorus (2) Turbidity (9) Zinc (2)
Fish Consumption	19	Mercury (17) Polychlorinated biphenyls (5)
Recreational Use	20	*Escherichia coli (E. coli)*[1] (20)

[1] Fecal coliform bacteria was the indicator for bacterial impairments until 2013, when the indicator was changed to *E. coli*.

As of fall 2023, fish-consumption advisories for mercury have been issued for Lake Thurmond, Lake Russell, Lake Keowee, Lake Jocassee, Lake Yonah, and Lake Tugaloo (SCDHEC 2023b). Fish-consumption advisories for PCBs have been issued for Lake Hartwell and its Seneca River and Twelvemile Creek arms.

The RBC members raised other surface water–related concerns during the planning process. At the first RBC meeting held on July 26, 2023, RBC members identified their initial concerns and priorities, which included the following:

- Various demands on water resources in the basin, including protection of natural resources and economic growth, must be balanced. Resource use should be fair and equitable.
- Infrastructure vulnerabilities and potential catastrophic failures related to water resources in the basin need to be identified and planned for.
- The Upper Savannah River basin is shared between North Carolina, Georgia, and South Carolina. Water supply planning should be a collaborative process, especially regarding water use from Georgia.
- Impact of droughts on low flows in streams should be minimized.
- Recreational fishing opportunities need to be protected and preserved for future generations.

3.2 Surface Water Assessment Tools

3.2.1 Surface Water Assessment Model

Surface water allocation and supply planning models were previously constructed for each of the eight major river basins in South Carolina, including the Savannah River basin (CDM Smith 2017). The models were constructed using the SWAM software. For this study, the Savannah River basin SWAM model was used to assess current and future surface water availability and to evaluate the effectiveness of proposed water management strategies within the Upper Savannah River planning basin. Note that the Savannah basin SWAM model was updated in 2023 and 2024. Updates included extending the period of record to 2021, adding new permits and registrations, removing inactive users, and updating reservoir characteristics including stage-storage curves based on available data. Both the Upper and Lower Savannah planning basins are included in the SWAM model, but modeling efforts and results presented here represent only the Upper Savannah portion of the basin.

SWAM simulates a network of river reaches, impoundments, withdrawals, and returns, in which water is routed hydrologically between nodes. The model focuses principally on mainstem rivers, along with primary and secondary tributaries. The model simulates basin hydrology, water use, and complex reservoir operations at a daily or monthly timestep, including calculations of physically and legally available water, withdrawals, storage, consumption, and return flows at each spatial node.

Key inputs to the model include:

- Calculated and estimated unimpaired "boundary" flows for the headwaters of the mainstem and tributaries included in the model. Boundary flows were calculated using standard statistical techniques to transpose downstream USGS stream gage data to upstream locations, unimpaired by storage, withdrawals, or return flows. CDM Smith (2017) details these calculations.
- Reach Gain/Loss Factors. These factors are used to augment, or deplete, streamflows, with distance downstream, to account for local drainage and/or groundwater interactions. These factors are assigned in the model based on either site-specific calibration (using USGS-observed data) or mapped drainage area changes.
- Reservoir characteristics, such as capacity, bathymetry, constraints, and flexible operating rules, are often conditioned on specific calculated hydrologic conditions.

Model variables, which users can modify to explore future conditions, include:

- Water demands (municipal, industrial, thermoelectric, agricultural, golf courses, and fish hatcheries)
- Water user withdrawal permits (new or changes to existing)
- Interbasin transfers
- Reservoir operating rules and storage characteristics
- Environmental flow targets
- Patterns of underlying unimpaired hydrologic and climate variability (global changes to headwater flow magnitudes and/or sequences)

Using this information, the SWAM model calculates available water (physically available based on full simulated flows and legally available based on permit conditions and other uses), withdrawals, storage, consumption, and return flows at user-defined nodes. Figure 3-7 shows the Savannah River basin SWAM model framework. The model was calibrated using extended periods of USGS-gaged flow data, as described in CDM Smith (2017). Figure 3-8 provides example calibration plots. As noted, the primary calibration (adjusted) parameters for this exercise were the reach flow factors. The model can be used to simulate current and future demands based on defined scenarios and to identify potential shortages in water availability when compared to demands for withdrawals or instream flow targets. The scenarios that were evaluated specifically for the Upper Savannah River basin are discussed in further detail in Section 4 (Current and Projected Water Demand) and Chapter 5 (Comparison of Water Resource Availability and Water Demand).

The model, as well as its Users Guide and the full report on the Savannah Basin Model development and calibration, are publicly available for download at SCDES's website. The models and associated documentation can be found at https://des.sc.gov/programs/bureau-water/hydrology/surface-water-program/surface-water-models.

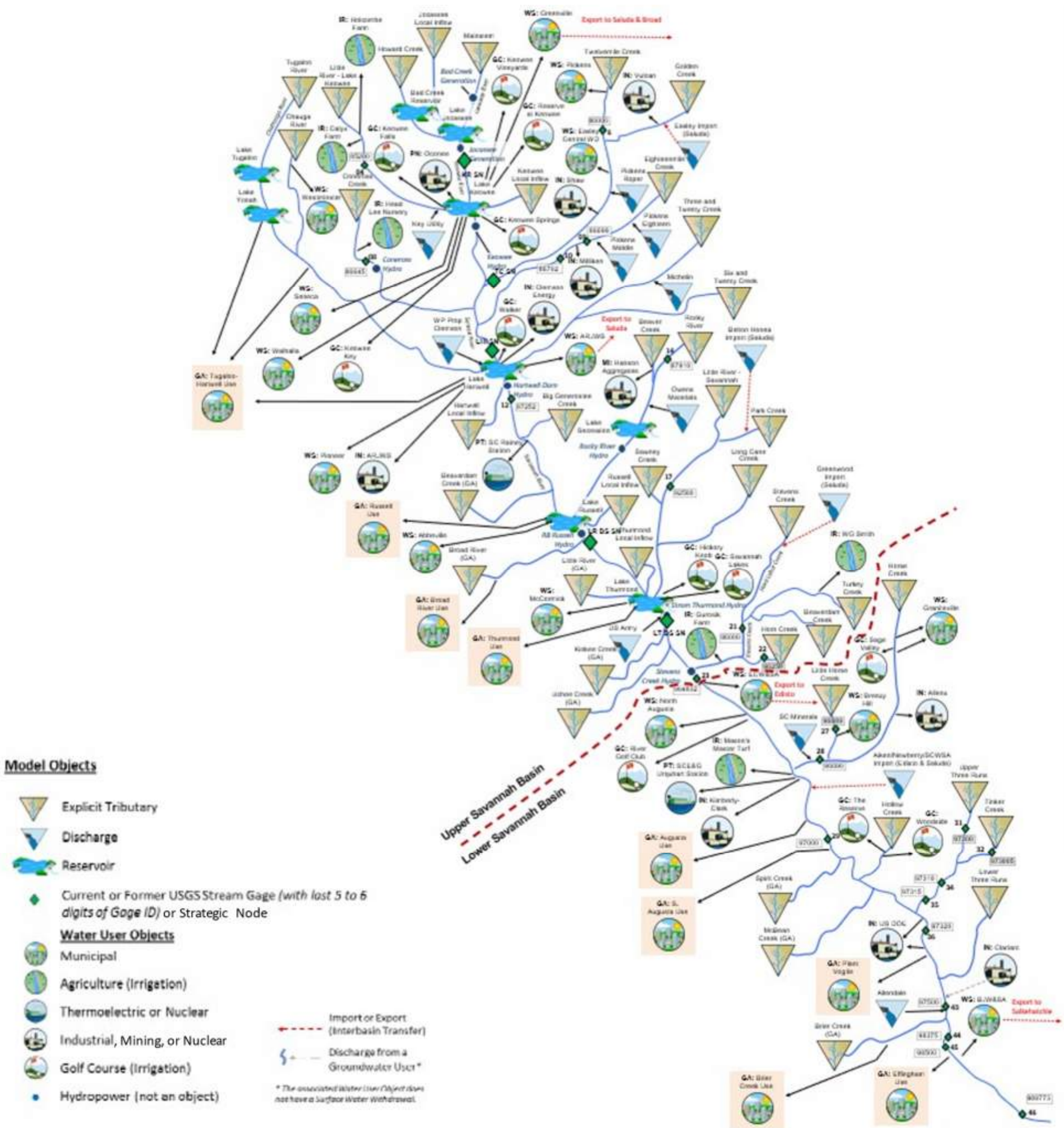


Figure 3-7. SWAM Model interface for the Savannah River basin.

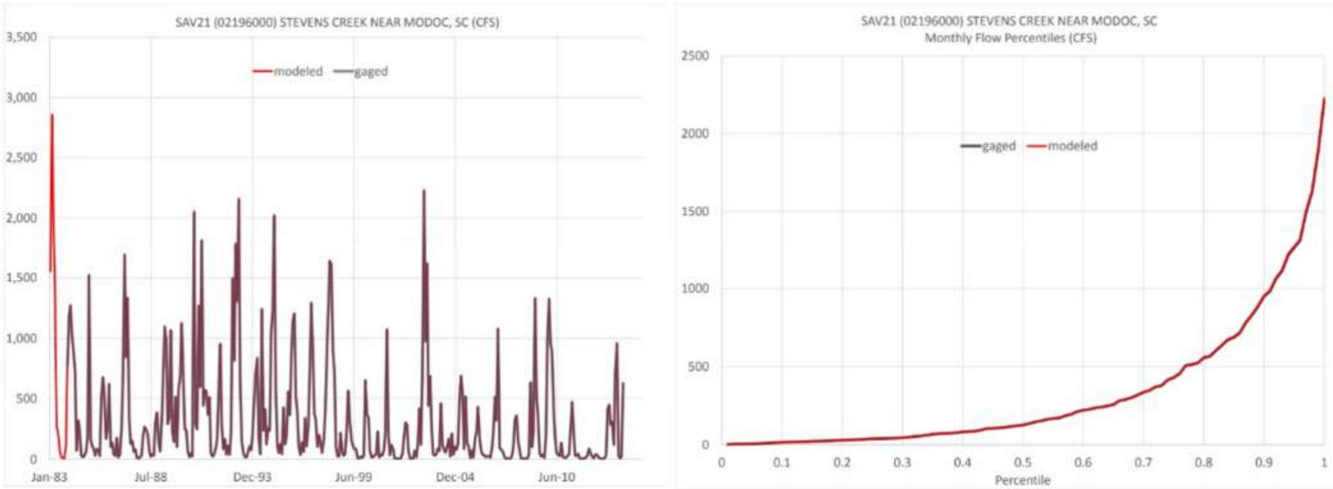


Figure 3-8. Example Savannah River basin SWAM model calibration plots (CDM Smith 2017).

3.2.2 Other Surface Water Analyses

While the SWAM models focus on the hydrology of larger mainstem rivers and primary tributaries in the Savannah River basin and other South Carolina basins, other work has focused on the hydrology and flow characteristics in smaller headwater streams, specifically those that are classified as "wadeable." To formulate relationships between hydrologic metrics (such as flow patterns, statistics, and variability in these streams) with ecological suitability metrics, daily rainfall-runoff modeling of small headwater streams throughout the state was performed using the WaterFALL® model (Watershed Flow ALLocation model), as described in Eddy et al. (2022) and Bower et al. (2022). Separately, as discussed in Bower et al. (2022), biological response metrics were developed and combined with the hydrologic metrics from WaterFALL® to identify statistically significant correlations between flow characteristics and ecological suitability for fish and macroinvertebrates. The results are intended to help guide scientific decisions on maintaining natural hydrologic variations while also supporting consumptive water withdrawals. As a component in the analysis, the WaterFALL® hydrologic modeling results augment the SWAM modeling results by providing similar hydrologic understanding of the smaller headwater streams not simulated explicitly or individually in SWAM. Chapter 5 further discusses the use of the ecological flow metrics as performance measures in the Upper Savannah RBC planning process.

3.3 Groundwater Resources

3.3.1 Groundwater Aquifers

Groundwater in the Upper Savannah River basin is primarily stored in saprolite rock, which stores rainfall and recharges water to underlying rock fractures (SCDNR 2009). The Upper Savannah River lies in both the Blue Ridge and Piedmont physiographic provinces. Within the Blue Ridge provinces, the following geologic units exist, from northwest to southeast: the Toxaway Gneiss, the Tallulah Falls Formation, and the Brevard zone, which separates the Blue Ridge and Piedmont. To the southeast in the Piedmont province lie the Chauga belt, the Walhalla thrust sheet, the Sixmile thrust sheet, the Laurens thrust stack, the Lowndesville shear zone, the Charlotte terrane, the Carolina terrane, the Modoc shear zone, the

Savannah River terrane, and the Augusta terrane. Gabbro and granite rock intrusions are also present in the basin.

The saprolite layer is as thick as 150 feet within the basin (SCDNR 2009). Roughly a quarter of the wells within the basin serve domestic purposes and are bored into the saprolite. The quantity and size of the bedrock fractures beneath the saprolite diminish with depth. Most wells in the basin are less than 300 feet deep, and the maximum well is 1,100 feet deep. Well yields from fractured rock are reliable but are typically limited to less than 50 gpm. Wells located in valleys tend to have larger yields than those in topographically high areas because of low areas, providing larger areas for recharge and being areas of weak, more fractured rock. Groundwater supply potential is not known in much of the basin, and aquifer or hydrogeologic units have not been delineated.

3.3.2 Groundwater Monitoring

The USGS and SCDES perform groundwater monitoring. Groundwater monitoring wells are used to identify short- and long-term trends in groundwater levels and aquifer storage, and to monitor drought conditions. Statewide, the groundwater monitoring network operated by SCDES has more than 180 wells (SCDES 2024b). Most wells have hourly data automatically recorded while some are measured manually four to six times per year. Most wells have water-level records dating to the 1990s, with the earliest well dating back to 1955. Only 15 SCDES wells are located in the Piedmont and Blue Ridge physiographic provinces, with the majority of the monitoring wells in the Coastal Plain province. None of the SCDES monitoring wells are in the Upper Savannah River basin (SCDES 2024b).

USGS maintains a groundwater-level monitoring network of an additional 21 wells in South Carolina (USGS 2023b). Two active USGS wells are located in the Upper Savannah basin: MCK-52 in McCormick County and OC-233 in Oconee County. Figure 3-9 shows the USGS groundwater monitoring wells in the Upper Savannah River basin.

Groundwater use in the basin is limited, and no areas are known to experience groundwater-level declines due to overpumping. The OC-233 USGS monitoring well, located in Oconee County and toward the northern end in the basin, has limited influence from area pumping, making it suitable for use in examining the relationship between precipitation, recharge, and groundwater levels. Figure 3-10 shows groundwater levels in this well with precipitation trends recorded at the nearby Walhalla, South Carolina, weather station (NOAA 2023a). The bottom graph compares precipitation trends to the average annual precipitation from 1999 through 2022. The figure illustrates how the lower-than-average precipitation from 2010 through 2012 correlates to declining water levels over this same period. Levels increased sharply in response to greater-than-average rainfall in both 2009 and 2013. Precipitation trends have been gradually increasing since 2008, with groundwater levels following the same general trend over this time period.

Potentiometric maps, which illustrate the levels to which groundwater will rise in wells and indicate general directions of flow, have not been drawn for areas northwest of the Fall Line, including the Upper Savannah River basin. Unlike the Coastal Plain region where water levels slope toward the coast, groundwater levels in the Upper Savannah basin are expected to generally follow topographic patterns.

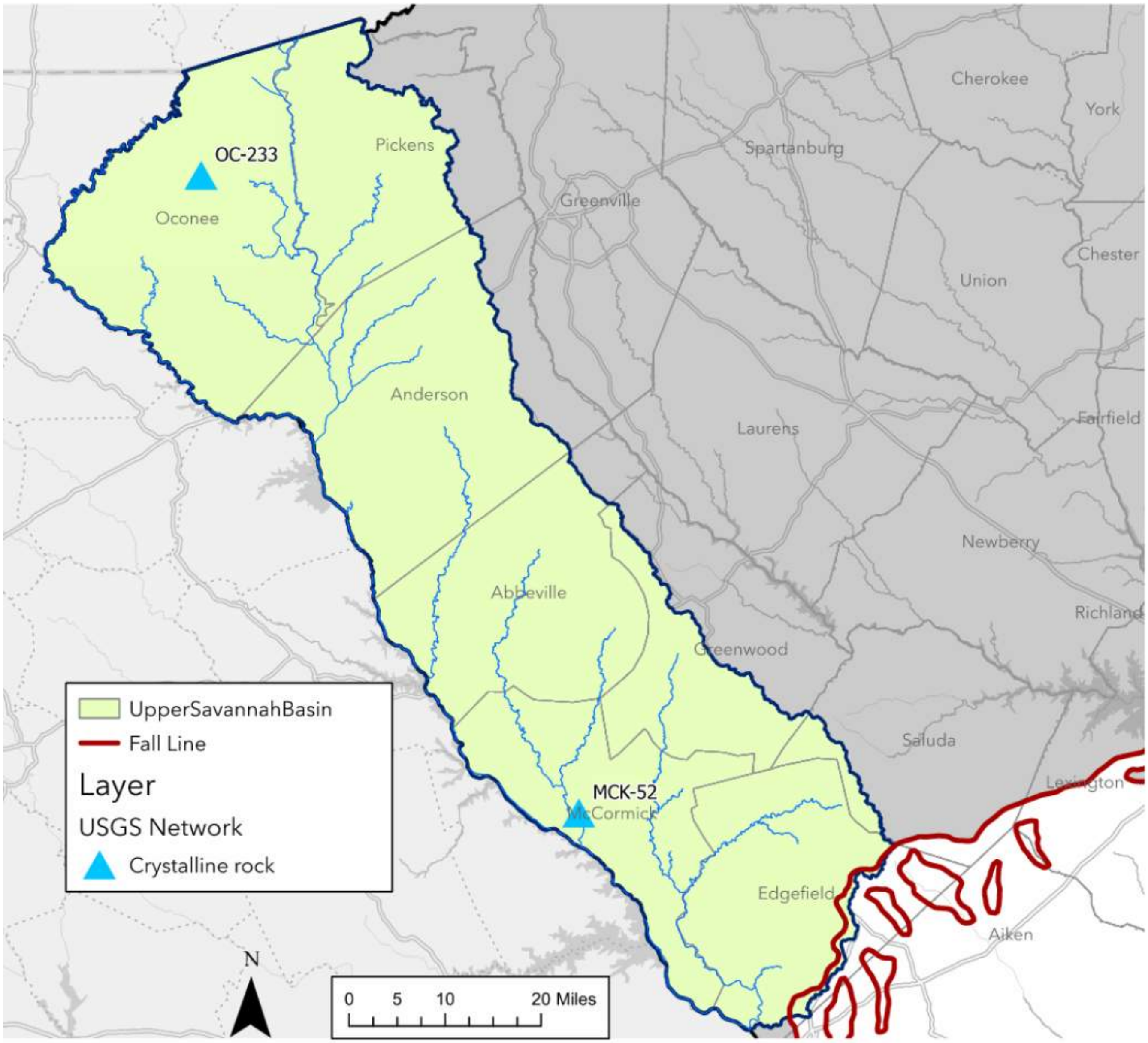
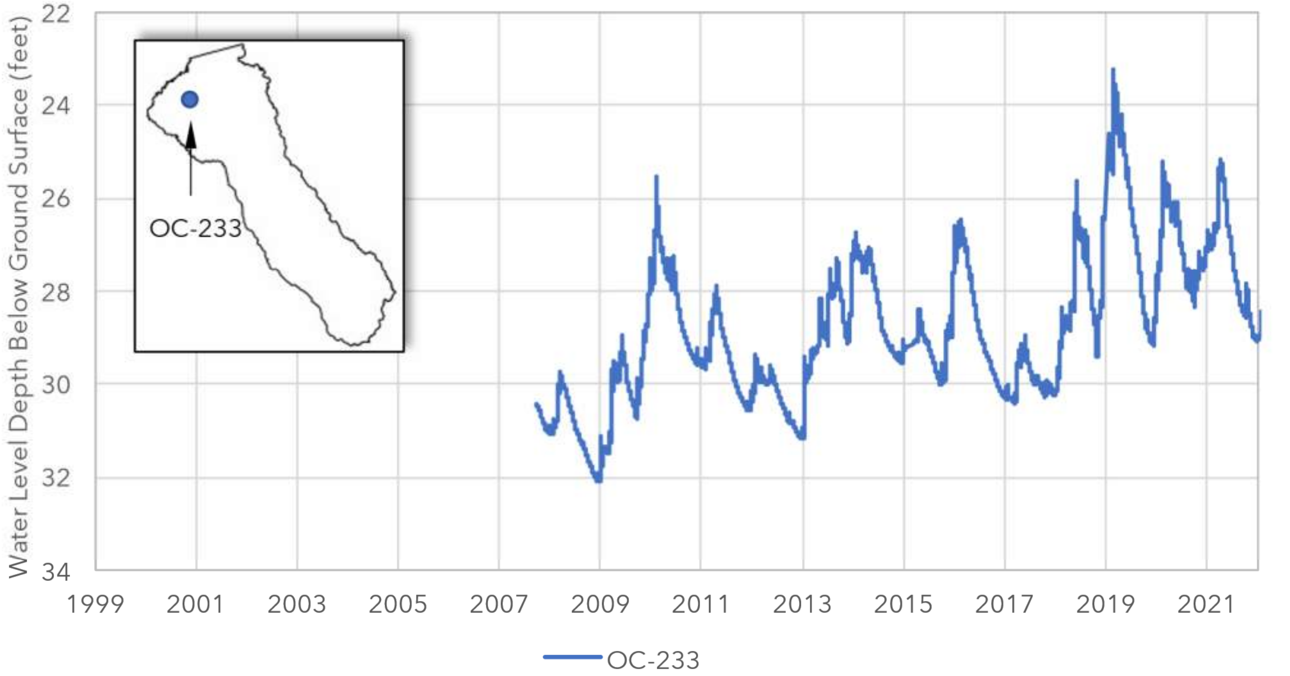


Figure 3-9. USGS groundwater monitoring wells.



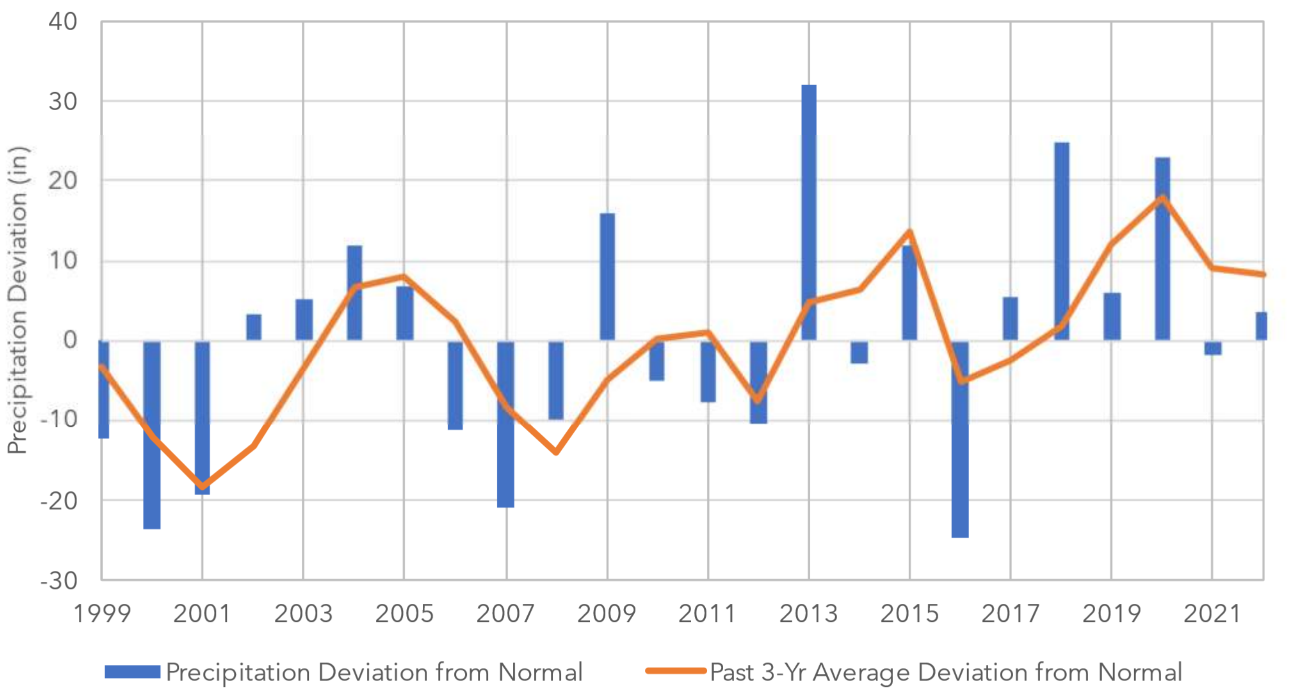


Figure 3-10. Groundwater levels in crystalline rock aquifer in Oconee County and precipitation deviation from normal (bottom graph) in nearby Walhalla, South Carolina.

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3.3.3 Groundwater Development

In 2022, the Upper Savannah River basin had the second lowest volume of groundwater withdrawals of the eight basins in the state, with only the Saluda reporting less groundwater usage (SCDNR 2023e). Reported groundwater withdrawals in the Upper Savannah River basin are typically less than 0.5 million gallons per day (MGD), and withdrawals were reported to total 0.4 MGD in 2022 (SCDNR 2023e). That year, 24 percent of the reported withdrawals were for water supply, 28 percent of withdrawals were for agricultural irrigation, and 48 percent of withdrawals were for golf courses (SCDNR 2023e).

The largest user of groundwater in the basin in 2022 was Mt. Vintage Gold Club, which withdrew 0.2 MGD from eight wells (SCDNR 2023e). The next largest user was Layman Wholesale Nursery, an agricultural user that withdrew 0.1 MGD from two wells. All other permitted groundwater withdrawers in the basin reported uses of less than 0.1 MGD in 2022. An industrial facility, Michelin, has a groundwater well in the basin but did not report any groundwater use in 2022.

The overall average well depth in the basin is 277 feet and the average well yield is 24 gpm, which is low but high enough to support most domestic uses as well as small irrigation and agricultural use. Groundwater is the water source for rural homes in the Upper Savannah River basin (SCDNR 2023e).

3.3.4 Capacity Use Areas

SCDES regulates groundwater use in South Carolina in areas designated as Capacity Use Areas (CUAs). Under South Carolina's Groundwater Use and Reporting Act (Chapter 5, Section 49-5-60), a CUA is designated where excessive groundwater withdrawals present potential adverse effects to natural resources, public health, safety, or economic welfare. SCDES then coordinates with affected governing bodies and groundwater withdrawers to develop a groundwater management plan for the CUA.

Groundwater withdrawals in the Upper Savannah River basin are minimal, and none of the Upper Savannah basin lies within a CUA.

3.3.5 Groundwater Concerns

Groundwater use within the basin is limited; consequently, there are no areas experiencing significant water level declines because of over-pumping (SCDNR 2009). Several wells with higher total dissolved solids levels are in the Carolina terrane, especially in McCormick County (SCDNR 2009). Alkalinity concentrations are also greater in the Carolina terrane. Lower pH values (less than 6.0) have been observed in the northernmost areas of the basin, in the Blue Ridge belt, and in the Walhalla and Sixmile thrust sheets.

Chapter 4
Current and Projected Water Demand

This chapter summarizes current and projected water demands over the 50-year planning horizon from 2020 to 2070 in the Upper Savannah River basin. Demand projections are based on historical demands and published projection datasets for variables that influence water demand including population, economic development, and irrigated acreage. A statistical model was built to project demands for each major water use category using the current demands and driver variables. Two demand projections were developed: a Moderate Demand Scenario using median rates of water use and moderate growth, and a High Demand Scenario using high rates of water use and high growth. The demand projections were used in the surface water model to assess future water availability as summarized in Chapters 5 and 6.

4.1 Current Water Demand

Current water demands reflect the most recent withdrawal data, as reported to SCDES, that were available at the time of the analysis. Current surface water demands are based on data available through 2019 and were developed to reflect average withdrawals over the last 10 years (in most cases). Current groundwater demands are based on withdrawals reported for 2014 to 2021 and were developed to reflect average withdrawals over that 8-year period.

The withdrawals used for this demand characterization were reported to SCDES by permitted and registered water users in the Upper Savannah River basin as required by state regulation. All users withdrawing more than 3 million gallons of surface water or groundwater in any month must either obtain a permit or register their use and report withdrawals to SCDES annually. Users withdrawing less than this threshold are not required to report their withdrawals; however, they may choose to report voluntarily. For surface water withdrawals over the threshold, agricultural water users must register their use while all other users must permit their use in accordance with SCDES's Regulation 61-119, Surface Water Withdrawal, Permitting, Use and Reporting. For groundwater withdrawals over the threshold, users withdrawing within a CUA must permit their use, while those withdrawing outside of a CUA must only register their use. All groundwater users in the Upper Savannah River basin are outside of CUAs and therefore register their use.

Current withdrawals from permitted and registered users in the Upper Savannah River basin total approximately 2,917.4 MGD on average, with 2,917.0 MGD from surface water and 0.4 MGD from groundwater. Of this total withdrawal, only an estimated 2 percent (62 MGD) of the water is consumptively used and 98 percent (2,855 MGD) is returned to streams and rivers after use.

Current water use is summarized in Table 4-1. Withdrawals are dominated by the thermoelectric water use category. One user, Oconee Nuclear Station, alone withdraws 2,847 MGD from Lake Keowee; however, only 1 percent of total withdrawal is consumed, and 99 percent is returned downstream. The next largest use categories are public supply, with 59.3 MGD of withdrawals (2 percent of basin withdrawals), then manufacturing, with 8.0 MGD of withdrawals (0.3 percent). Minimal water withdrawals are associated with agriculture (0.01 percent), golf course irrigation (0.04 percent), and mining (0.01

percent). Figure 4-1 illustrates the distribution by sector for all sectors and Figure 4-2 illustrates the distribution by sector excluding thermoelectric use to better illustrate the remaining use categories. Appendix A includes a table of all water users along with the user's source (surface water or groundwater), withdrawals, and discharges. For surface water modeling purposes, consumptive use percentages (i.e., the amount of water withdrawn that is not returned to surface water or groundwater) for each water user were calculated by comparing withdrawal and discharge amounts as reported to SCDES. It is assumed that all groundwater is used consumptively or returned to the groundwater system through septic tanks.

Table 4-1. Current water demand in the Upper Savannah River basin.

Water Use Category	Groundwater (MGD)	Surface Water (MGD)	Total (MGD)
Thermoelectric	-	2,848.5[1]	2,848.5
Public Supply	0.1	59.2	59.3
Manufacturing	-	8.0	8.0
Golf Course	0.2	0.8	1.1
Agriculture	0.1	0.2	0.3
Mining	-	0.3	0.3
Total	**0.4**	**2,917.0**	**2,917.4**

[1] Only about 1 percent is consumed and 99 percent is returned to surface water downstream

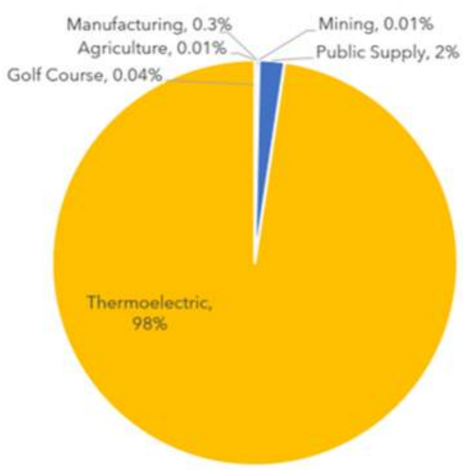

Figure 4-1. Current water use category percentages of total demand.

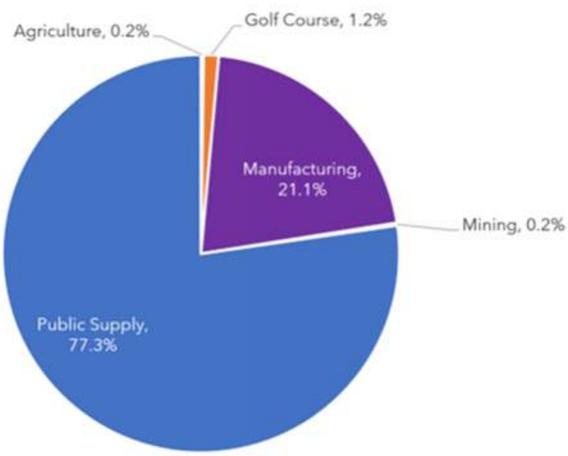

Figure 4-2. Current water use categories percentages of total demand without thermoelectric.

To evaluate surface water availability in the Upper Savannah basin in South Carolina, it was necessary to include withdrawals and discharges in the Upper Savannah River basin for Georgia users. The withdrawal and return data used for the demands calculations were obtained from Georgia Environmental Protection Division's (GAEPD) Consumptive Use Database. Facilities that withdraw or discharge in Georgia are required to report relevant data to GAEPD on a monthly basis. Current demands and consumptive use amounts for Georgia surface water users in the Upper Savannah River basin are summarized in Table 4-2, aggregated by location into four water user groups. The total surface water demand in the Upper Savannah River basin is 2,938.8 MGD with 2,917.0 MGD withdrawal for South Carolina users and 21.8 MGD withdrawal for Georgia users.

Table 4-2. Georgia surface water demands in the Upper Savannah River basin.

Water User Group[1]	Withdrawal (MGD)	Consumptive Use (MGD)	Return (MGD)
Tugaloo-Hartwell	11.4	9.7	1.7
Russell	1.5	0.3	1.2
Broad River	3.1	1.5	1.6
Thurmond	5.8	4.7	1.1
Total	**21.8**	**16.2**	**5.6**

[1] Georgia-side water users were aggregated into groups based on their general location within the basin.

4.2 Permitted and Registered Water Use

As of September 2024, 3,491.7 MGD has been permitted or registered by South Carolina users in the Upper Savannah River basin. Of this total, 3,491.0 MGD has been permitted and 0.7 MGD has been registered. Currently, 83.6 percent (2,917.4 MGD) of the total permitted and registered surface water amount is withdrawn and only 2 percent (62.0 MGD) is used consumptively within the basin.

For groundwater, there are no permitted users. Use by registered groundwater users in the basin is 0.4 MGD. Groundwater users are required to register and report their use to SCDES if they exceed 3 million gallons per month (MGM), but the registrations do not include a withdrawal limit.

Figure 4-3 shows the location of all permitted and registered surface water intakes and groundwater wells in the South Carolina portion of the basin. Table 4-3 summarizes permitted and registered surface water and groundwater withdrawals by water use category. Appendix A includes a table of all permitted or registered withdrawals for each user.

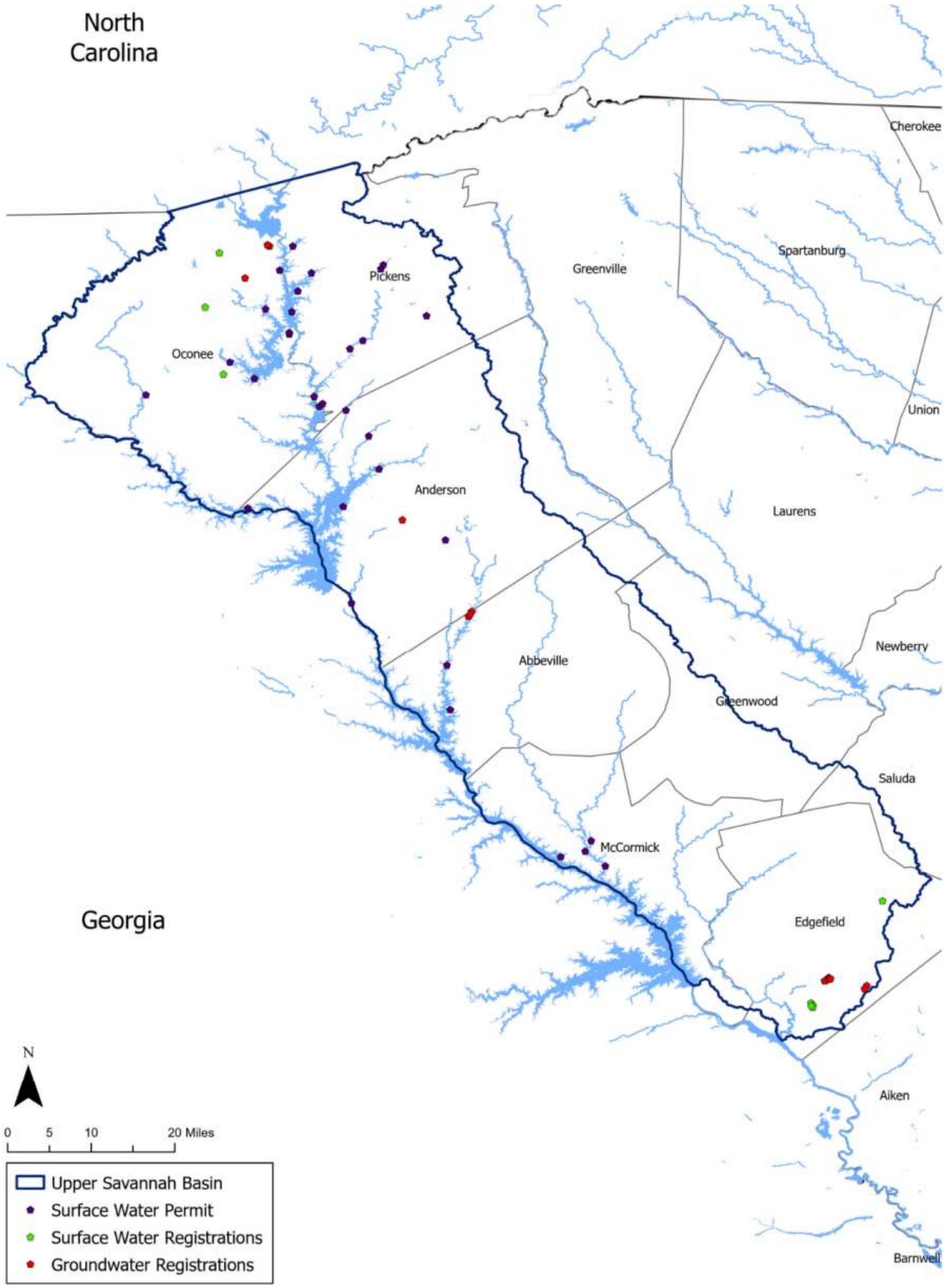

Figure 4-3. Locations of permitted and registered water intakes and groundwater wells with registrations in the Upper Savannah River basin.

Table 4-3. Permitted and registered surface water totals by category in the Upper Savannah River basin.

Water Use Category	Surface Water (MGD)			Groundwater (MGD)			Total (MGD)		
	Permitted	Registered	Total	Permitted	Registered[1]	Total	Permitted	Registered	Total
Thermoelectric	3,138.0	-	3,138.0	-	-	-	3,138.0	-	3,138.0
Public Supply	286.7	-	286.7	-	0.1	0.1	286.7	0.1	286.8
Manufacturing	53.7	-	53.7	-	-	-	53.7	-	53.7
Golf Course	11.6	-	11.6	-	0.23	0.23	11.6	0.23	11.8
Agriculture	-	0.3	0.3	-	0.1	0.1	-	0.4	0.4
Mining	1.0	-	1.0	-	-	-	1.0	-	1.0
Total	**3,491.0**	**0.3**	**3,491.3**	**-**	**0.4**	**0.4**	**1,341.0**	**0.7**	**3,491.7**

Water Use Category	Percentage of Total Permitted and Registered Surface Water Currently in Use	Percentage of Total Permitted and Registered Groundwater Currently in Use	Percentage of Total Permitted and Registered Water Currently in Use
Thermoelectric	90.8%	-	90.8%
Public Supply	20.7%	100%	16.0%
Manufacturing	14.8%	-	14.8%
Golf Course	7.1%	100%	8.9%
Agriculture	66.3%	100%	73.0%
Mining	28.5%	-	28.5%
Total	**83.6%**	**100%**	**83.6%**

[1] Groundwater registrations do not include limits and were assumed to be equal to current use.

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4.3 Projection Methodology

The methodology to calculate demand projections followed the guidance in *Projection Methods for Off-Stream Water Demand in South Carolina* (SCDNR 2019c). SCDNR developed this document over several years in collaboration with the South Carolina Water Resources Center at Clemson University and the U.S. Army Corps of Engineers, with additional input from stakeholders including:

- South Carolina Water Works Association Water Utility Council
- South Carolina Farm Bureau Water Committee
- South Carolina Chamber of Commerce Environmental Committee
- South Carolina Water Quality Association
- PPAC

Following the guidance in the statewide projections report, SCDNR developed demands for the Upper Savannah River basin with only minor deviations from the framework, as presented in this section. In the Upper Savannah River basin, demands were projected to increase for the public water supply, manufacturing, and agriculture sectors. Nearly all water used for hydroelectric power generation is returned directly to the river and was assumed to remain constant. Water use for mining accounts for less than 0.1 percent of total withdrawals and was projected to remain stable over the planning horizon. All groundwater withdrawals, which also account for less than 1 percent of total withdrawals, were also assumed to remain at current levels over the planning horizon.

For the three water use categories with projected increases in demands, the projection methodology varies by water use category. Each water use category has an associated driver variable that influences demand growth, as shown in Table 4-4. Projections for these driver variables come from a variety of published sources. Published values were extrapolated to 2070 to match the planning horizon of the River Basin Plan.

Two demand projections were developed: (1) the Moderate Water Demand Scenario (Moderate Demand Scenario) and (2) the High Water Demand Scenario (High Demand Scenario). The Moderate Demand Scenario was originally referred to as the Business-as-Usual Scenario in the Planning Framework. The Moderate Demand Scenario is based on median rates of water use and moderate growth projections, while the High Demand Scenario is based on the maximum monthly rates of water use in recent reporting and high-growth projections. While it is unlikely that the conditions of the High Demand Scenario would occur for an extended time or universally across the basin, the scenario is useful for establishing an upper bound for the projected demand. The subchapters present additional details on the calculation of demand for each water use category.

Table 4-4. Driver variables for each water use category.

Water Use Category	Driver Variable	Driver Variable Data Source	Moderate Demand Scenario	High Demand Scenario
Public Supply	Population	South Carolina Office of Revenue and Fiscal Affairs (SC ORFA)	SC ORFA projection to 2035; extend straight-line growth or assume constant population if the population projection is negative	Project using statewide or countywide growth rate, increased by 10%
Manufacturing	Economic production	Subsector growth rates from the U.S. Energy Information Agency (EIA)	Manufacturing subsector growth with the minimum adjusted to 0%	Manufacturing subsector growth with the minimum adjusted to 2.1%[1]
Thermoelectric	NA	NA	Assumed constant	Assumed constant
Agriculture	Irrigated acreage	National-scale studies: ▪ Brown et al. (2013) ▪ Crane-Droesch et al. (2019)	Assume irrigated acreage increases with an annual growth rate of 0.65%	Assume irrigated acreage increases with an annual growth rate of 0.73%
Golf Course	NA	NA	Assumed constant	Assumed constant
Mining	NA	NA	Assumed constant	Assumed constant

NA – not applicable
[1] 2.1% is the total overall EIA economic growth projection increased by 10% (1.9% + 10% x 1.9% = 2.1%)

4.3.1 Public Supply Demand Projections Methodology

Public supply is the second largest water use sector in the Upper Savannah River basin. Demand projections for public supply were developed based on county-level populations and water use projections. Population projections for the Moderate Demand Scenario were obtained from SC ORFA. These projections, which end in 2035, were extended to 2070. For the Moderate Demand Scenario, projections are extended linearly. If SC ORFA projections indicate a decline in population, then the extension to 2070 is flatlined at 2035 levels. For the High Demand Scenario, populations are projected to grow exponentially. If SC ORFA projected growth, then the exponential growth rate was increased by 10 percent. If the SC ORFA projection for a county was less than the state average, then the high-scenario population projection is set at the state average plus 10 percent. As shown in Figure 4-4, some counties are projected to experience population declines while others may experience substantial growth in both the Moderate and High Demand Scenarios. Nearly all public supply water use in the Upper Savannah River basin is from surface water, with only the Town of Salem withdrawing 0.09 MGD from groundwater. This minimal groundwater use for public supply was assumed to remain constant.

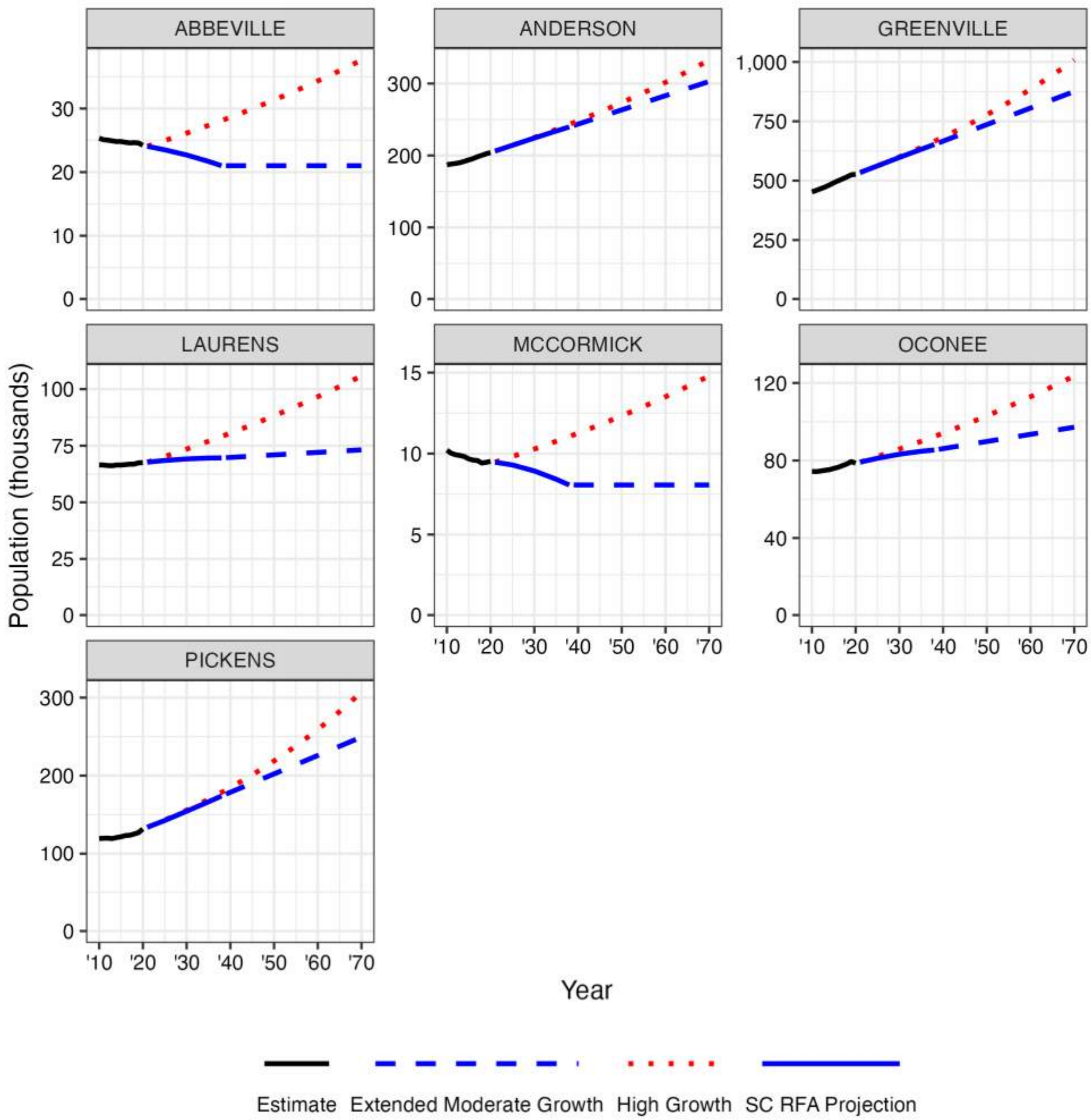

Figure 4-4. Population projections for counties withdrawing water from the Upper Savannah River basin (Pellett 2023). **(Note: The y-axis is scaled differently for each county.)**

4.3.2 Manufacturing Demand Projections Methodology

Water is used for manufacturing in the Upper Savannah River basin for producing products such as flooring, textiles, construction materials, and chemicals. Manufacturing demand projections were based on projected subsector growth rates from EIA, which ranged from 0.3 to 2.1 percent for the sectors present in the Upper Savannah River basin (EIA 2023). The Moderate Demand Scenario used EIA projected growth rates, while the High Demand Scenario adjusted the growth rates to a minimum of 2.1 percent, representing the overall EIA economic growth projection increased by 10 percent. All manufacturing water use in the Upper Savannah River basin is from surface water.

4.3.3 Agriculture Demand Projections Methodology

Water demand projections for agriculture were developed using existing unit use rates and projections of increases in irrigated area. Moderate Demand Scenario projections were based on regional projections of irrigation in the southeast growing 0.65 percent per year (Brown et al. 2013). For the High Demand Scenario, the growth rate was increased to 0.73 percent per year, based on projections of climate change impacts on agricultural irrigation (Crane-Droesch et al. 2019).

For input to the SWAM model, projected growth of irrigation water use was assigned to subbasin outlets in the model. This method represents a relatively robust assumption that irrigation will expand somewhere in each subbasin where irrigation currently occurs but might underrepresent expansion of irrigation withdrawals on small tributaries within each subbasin.

4.3.4 Other Demand Projections Methodology

Other water withdrawals in the Upper Savannah River basin support thermoelectric energy production, golf course irrigation, and mining. Water use for golf courses and mining operations is low, and was held constant into the future. Water use for thermoelectric energy production was held constant as there are not public plans for expansion in the future. While there are plans for expansion of a hydro facility, there are not currently plans for new energy-producing facilities with consumptive water demands in the Upper Savannah River basin over the planning horizon. For the Moderate Demand Scenario, demands were held constant based on median rates of recent historic use. For the High Demand Scenario, demands were held constant based on maximum rates of recent historic use.

4.3.5 Georgia Demand Projections Methodology

Future withdrawals from Georgia-side of the Upper Savannah River basin were also considered. Growth projections over the planning horizon of 2020 to 2060 for Georgia water users were used to estimate the percent demand growth between 2021 and 2070 (CDM Smith 2024a; CDM Smith 2024b, CDM Smith 2024c). To support surface water modeling for this river basin planning effort, Georgia-side water demands were grouped into nine consolidated users based on geography and/or source water. Growth factors were calculated for each consolidated water user group based on the percent growth and the current withdrawal amounts reported for individual water users within that group. Future 2070 demands for the nine consolidated Georgia water users were calculated by multiplying the monthly current demands by the growth factors, which were assumed to be the same through the 2070 planning horizon, as for the 2060 planning horizon used by Georgia.

4.4 Projected Water Demand

From 2025 to 2070, total withdrawals by South Carolina permitted and registered users are projected to increase by 2 percent from 2,676 MGD to 2,740 MGD under the Moderate Demand Scenario and by 4 percent from 2,927 MGD to 3,041.7 MGD under the High Demand Scenario. Included in these projections is 0.4 MGD of groundwater withdrawals, which are projected to remain constant over the planning horizon. The Moderate and High Demand Scenarios have different starting points from one another and differ from the current use because the Moderate Demand Scenario is based on each user’s median recent use, the High Demand Scenario is based on each user’s maximum recent use, and the Current Use Scenario is based on each user’s average recent use. Surface water demand is expected to reach 78 to 87 percent of currently permitted and registered surface water withdrawals by 2070 for the Moderate and High Demand Scenarios, respectively. Surface water demands in the Upper Savannah River Basin for Georgia users are projected to increase from 22.3 MGD in 2025 to 29.9 MGD in 2070. Total Upper Savannah River Basin demands from both South Carolina and Georgia users are projected to reach 2,769.9 MGD under the Moderate Demand Scenario and 3,071.6 MGD under the High Demand Scenario by 2070.

Table 4-5 shows and Figure 4-5 summarizes projected surface water and groundwater demands over the planning horizon. The figure includes stacked area graphs, with total demand shown as thick black lines and shaded areas showing which portion of total demand comes from groundwater or surface water. For example, in 2025, the Moderate Demand Scenario total demand is 2,740 MGD. Of that, 0.4 MGD is from groundwater and 2,739.6 MGD is from surface water. Groundwater demands are too small to be visible on the figure. Figure 4-6 shows projected demands by water use category, which are further described in the subchapters that follow.

Table 4-5. Projected surface water and groundwater demands.

Year	Moderate Demand Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	2,675.3	0.4	2,675.5	2,927.0	0.4	2,927.1
2030	2,682.3	0.4	2,682.5	2,938.9	0.4	2,938.9
2035	2,689.2	0.4	2,689.4	2,950.9	0.4	2,950.9
2040	2,690.8	0.4	2,690.9	2,956.2	0.4	2,956.1
2050	2,710.7	0.4	2,710.7	2,988.3	0.4	2,988.1
2060	2,719.7	0.4	2,719.5	3,006.5	0.4	3,007.7
2070	2,739.6	0.4	2,740.0	3,040.4	0.4	3,041.7
% Increase 2025-2070	**2%**	**-**	**2%**	**4%**	**-**	**4%**

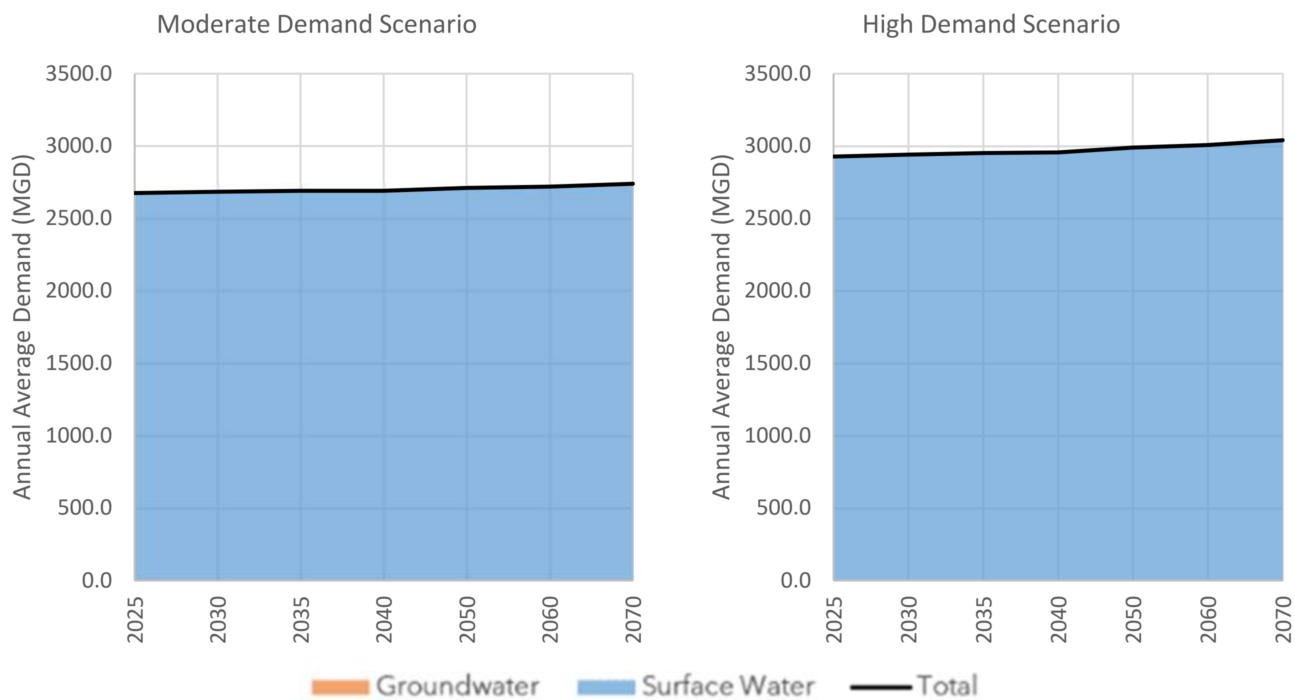

Figure 4-5. Demand projections by water source. (Note: Groundwater demands projected at a constant average annual demand of 0.4 MGD are too small to be seen on this chart.)

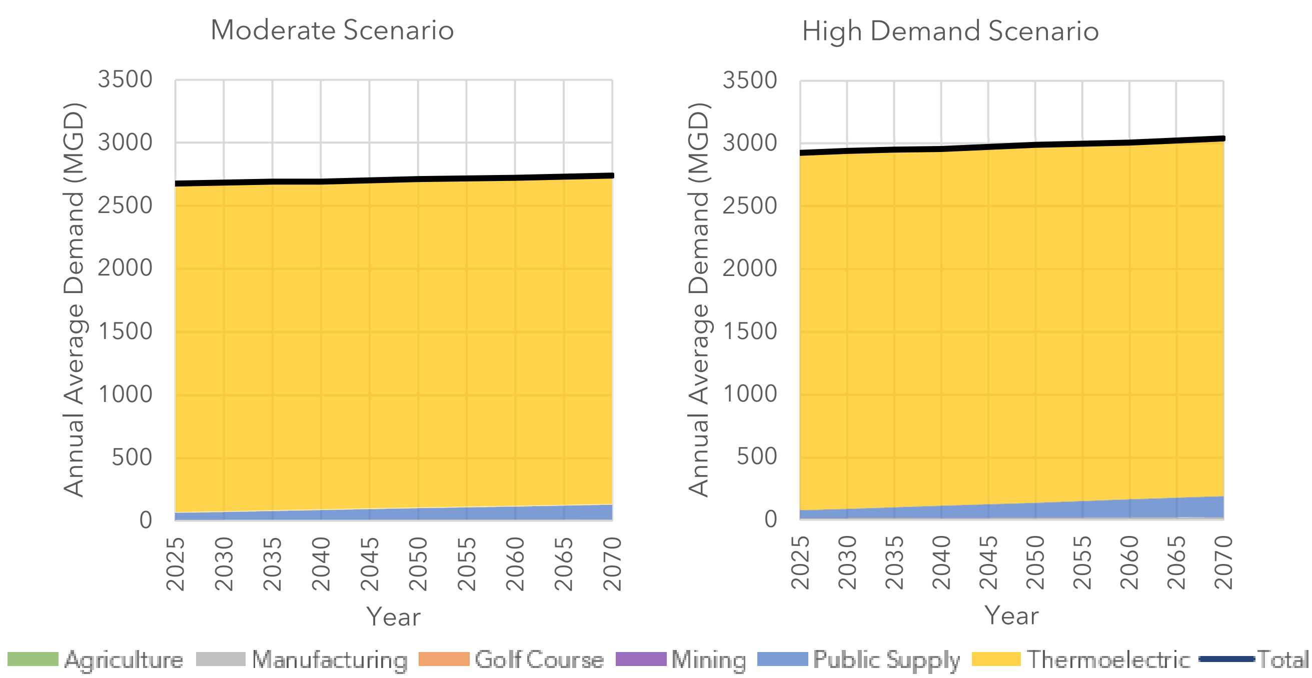

Figure 4-6. Demand projections by water use category. (Note: Agriculture, golf course, manufacturing, and mining demands make up less than 1 percent of the total 2070 demands and are too small to be seen on this chart.)

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4.4.1 Public Supply Demand Projections

Most of the water demand growth in the Upper Savannah River basin is expected to come from increasing demand for public water supply. Table 4-6 presents projected population increases. In the Moderate Demand Scenario, public supply demands are projected to increase 105 percent between 2025 and 2070 (57.7 to 118.4 MGD). In the High Demand Scenario, public supply demands are projected to increase by 169 percent (63.0 to 169.5 MGD). Most of the public supply demand increase will be met by surface water, which will serve over 99 percent of demand. The minimal groundwater use for the Town of Salem was assumed to remain constant at 0.09 MGD. Projected 2070 public supply surface water withdrawals for the Moderate and High Demand Scenarios are approximately 41 and 59 percent of the total permitted amount for public supplies from surface water, respectively. Figure 4-7 shows and Table 4-7 summarizes public supply demand projections by water source.

Table 4-6. Projected population increases (in thousands) (provided by SCDES).

Scenario	County	2025	2030	2035	2040	2050	2060	2070
Moderate Demand Scenario	Abbeville	23.5	22.7	21.7	21.0	21.0	21.0	21.0
	Anderson	214.2	224.3	234.0	243.6	263.4	283.1	302.9
	Greenville	562.5	597.8	632.2	666.5	736.2	805.9	875.6
	Laurens	68.5	69.2	69.6	69.8	70.9	72.1	73.2
	McCormick	9.3	8.9	8.4	8.1	8.1	8.1	8.1
	Oconee	81.1	83.2	84.8	86.1	89.8	93.5	97.2
	Pickens	142.5	154.4	166.4	178.6	202.2	225.9	249.5
High Demand Scenario	Abbeville	25.0	26.1	27.3	28.6	31.3	34.3	37.6
	Anderson	214.3	225.0	236.3	248.1	273.5	301.6	332.6
	Greenville	562.5	600.1	640.3	683.2	777.7	885.3	1,007.7
	Laurens	70.2	73.5	76.9	80.5	88.2	96.6	105.8
	McCormick	9.8	10.3	10.8	11.3	12.3	13.5	14.8
	Oconee	82.1	85.9	89.9	94.1	103.1	112.9	123.6
	Pickens	143.2	155.8	169.6	184.7	218.8	259.3	307.2

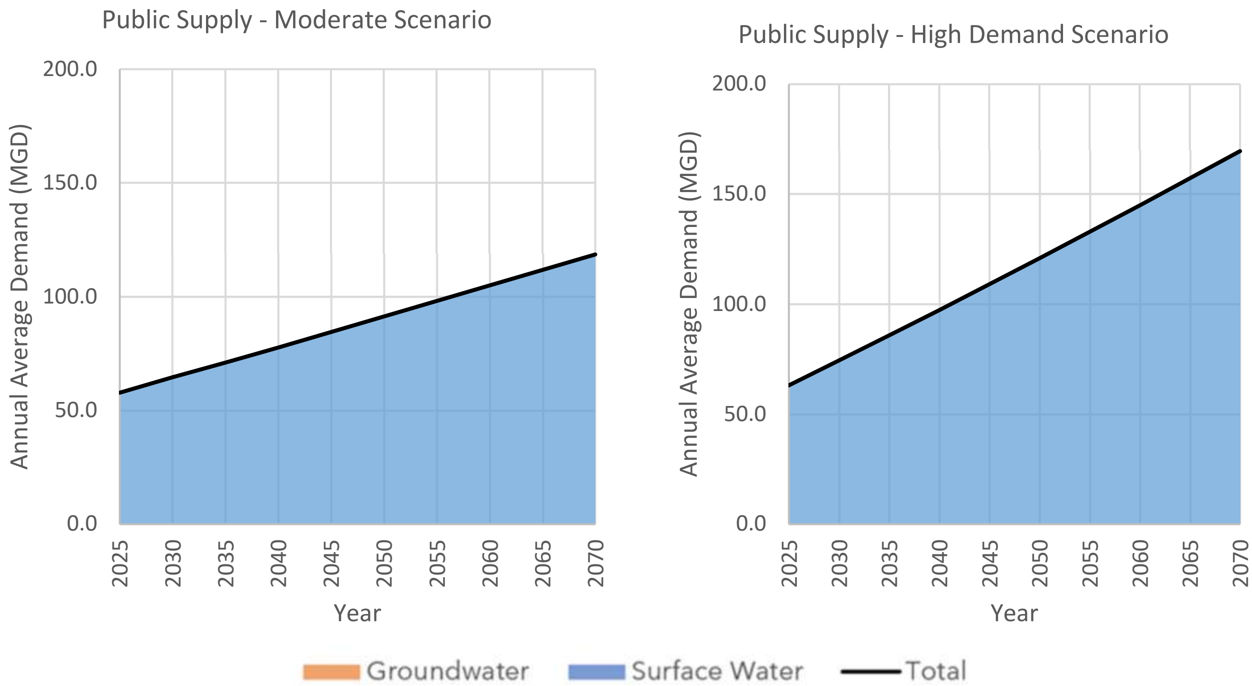

Figure 4-7. Projected public supply water demands. (Note: Groundwater demands projected at a constant average annual demand of less than 1 MGD are too small to be seen on this chart.)

Table 4-7. Projected public supply water demands.

Year	Moderate Demand Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	57.7	0.1	57.8	63.0	0.1	63.1
2030	64.3	0.1	64.4	74.2	0.1	74.3
2035	70.9	0.1	71.0	85.6	0.1	85.7
2040	77.5	0.1	77.6	97.2	0.1	97.3
2050	91.1	0.1	91.2	120.6	0.1	120.7
2060	104.8	0.1	104.9	144.7	0.1	144.8
2070	118.4	0.1	118.5	169.5	0.1	169.6
Percent Increase 2025-2070	**105%**	-	**105%**	**169%**	-	**169%**

4.4.2 Manufacturing Demand Projections

Manufacturing demands are projected to increase 48 percent between 2025 and 2070 (7.3 to 10.8 MGD) in the Moderate Demand Scenario. In the High Demand Scenario, manufacturing demands are projected to increase 61 percent between 2025 and 2070 (12.7 to 20.4 MGD). Projected 2070 manufacturing surface water withdrawals for the Moderate and High Demand Scenarios are approximately 20 and 38 percent of currently permitted manufacturing surface water withdrawals, respectively. Figure 4-8 shows and Table 4-8 summarizes manufacturing demand projections.

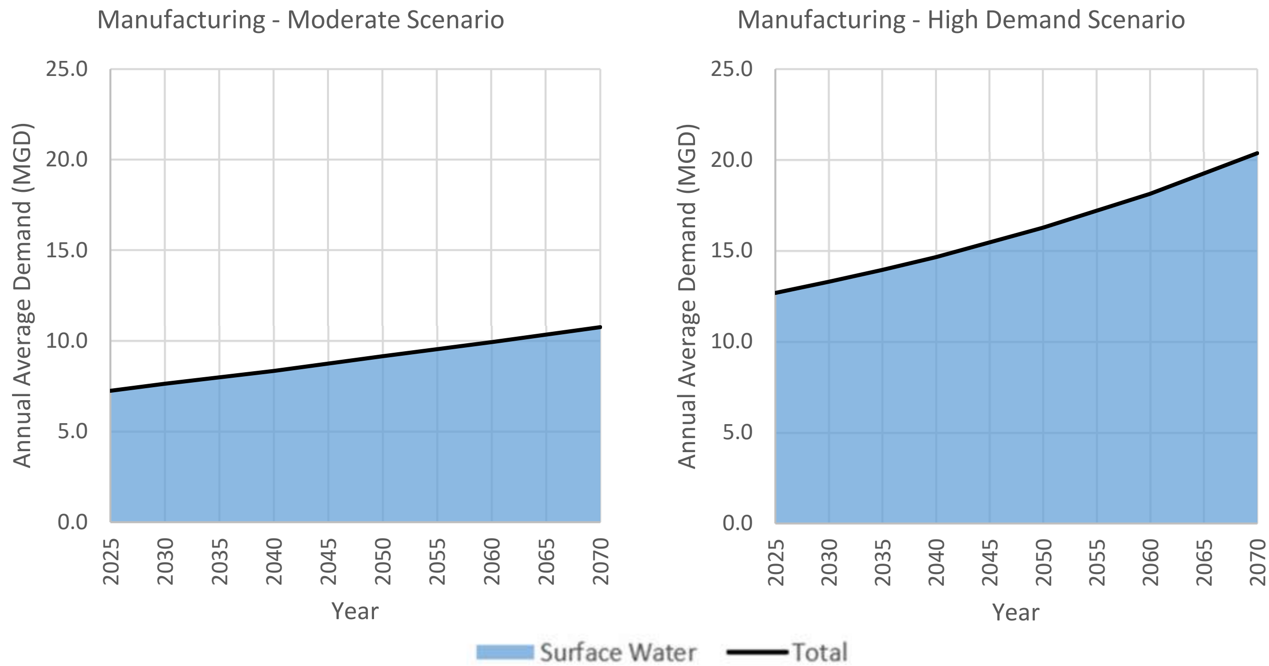

Figure 4-8. Projected manufacturing water demands.

Table 4-8. Projected manufacturing water demands.

Year	Moderate Demand Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	7.3	0.0	7.3	12.7	0.0	12.7
2030	7.6	0.0	7.6	13.3	0.0	13.3
2035	8.0	0.0	8.0	14.0	0.0	14.0
2040	8.3	0.0	8.3	14.6	0.0	14.6
2050	9.1	0.0	9.1	16.3	0.0	16.3
2060	9.9	0.0	9.9	18.1	0.0	18.1
2070	10.8	0.0	10.8	20.4	0.0	20.4
Percent Increase 2025-2070	**48%**	-	**48%**	**61%**	-	**61%**

4.4.3 Agriculture Demand Projections

Agriculture demands are projected to increase 23 percent between 2025 and 2070 (0.26 to 0.32 MGD) in the Moderate Demand Scenario. In the High Demand Scenario, agriculture demands are projected to increase 31 percent between 2025 and 2070 (0.41 to 0.53 MGD). Projected 2070 agriculture surface water withdrawals for the Moderate and High Demand Scenarios are approximately 75 and 143 percent of currently permitted agriculture surface water withdrawals, respectively. Figure 4-9 shows and Table 4-9 summarizes agriculture demand projections.

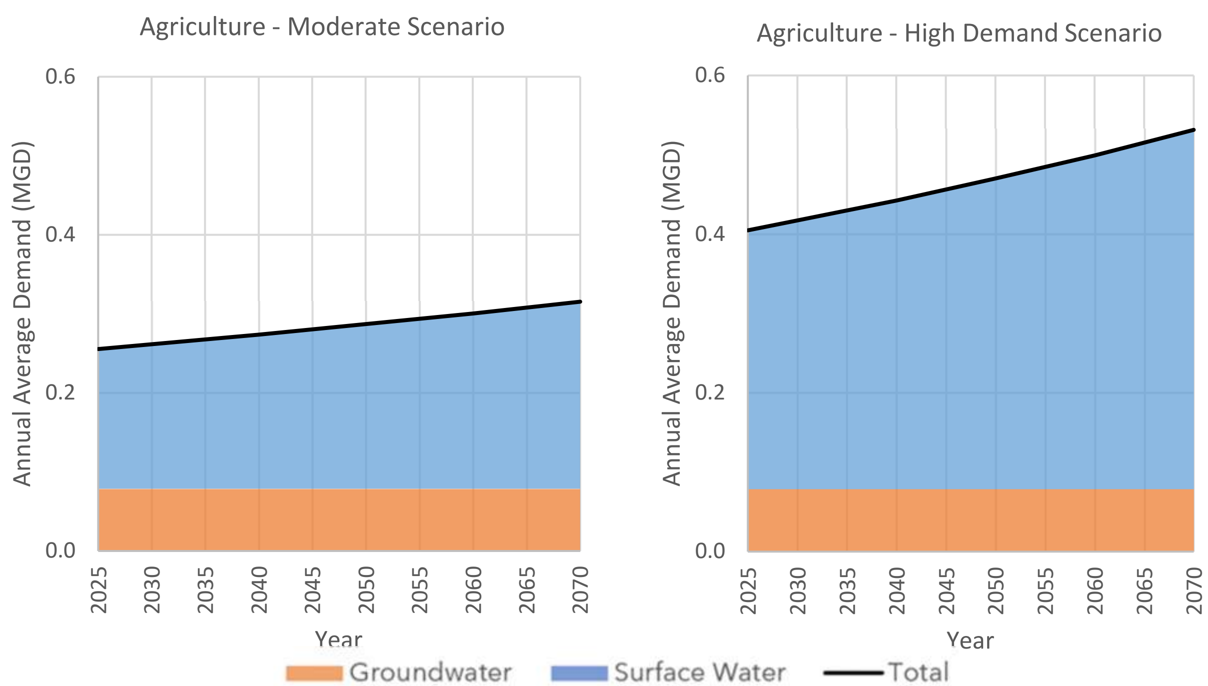

Figure 4-9. Projected agriculture water demands.

Table 4-9. Projected agriculture water demands.

Year	Moderate Demand Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	0.18	0.08	0.26	0.33	0.08	0.41
2030	0.18	0.08	0.26	0.34	0.08	0.42
2035	0.19	0.08	0.27	0.35	0.08	0.43
2040	0.19	0.08	0.27	0.36	0.08	0.44
2050	0.21	0.08	0.29	0.39	0.08	0.47
2060	0.22	0.08	0.30	0.42	0.08	0.50
2070	0.24	0.08	0.32	0.45	0.08	0.53
Percent Increase 2025-2070	**34%**	**-**	**23%**	**39%**	**-**	**31%**

4.4.4 Georgia Demands

Projected water demands for Georgia water users from the portion of the Upper Savannah River basin are expected to increase 34 percent by 2070. The same demand growth was assumed for both the Moderate and High Demand Scenarios. Figure 4-10 shows and Table 4-10 summarizes Georgia demand projections.

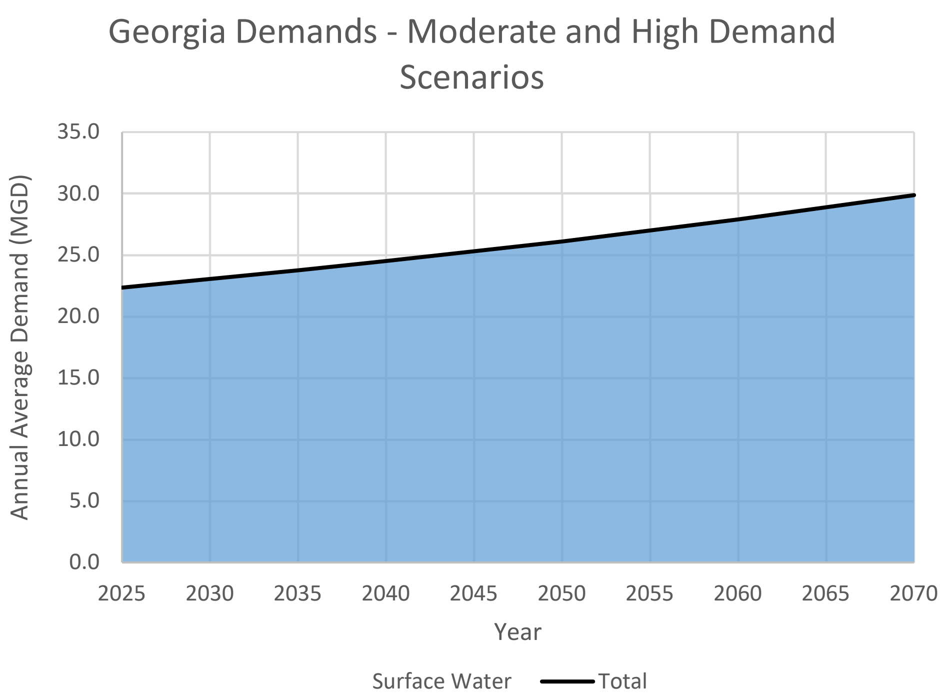

Figure 4-10. Projected Georgia water demands.

Table 4-10. Projected Georgia water demands.

Year	Georgia Demands (MGD)
2025	22.3
2030	23.0
2035	23.7
2040	24.5
2050	26.1
2060	27.9
2070	29.9
% Increase 2025-2070	**34%**

4.4.5 Other Demand Projections

Other demands, which include demands for golf courses, mining operations, and thermoelectic energy use were held constant into the future. For the Moderate Demand Scenario, demands were held constant based on median rates of recent historic use. For the High Demand Scenario, demands were held constant based on maximum rates of recent historic use. Golf course demands across the planning horizon were held at 0.9 MGD in the Moderate Demand Scenario and 1.8 MGD in the High Demand Scenario. Of this demand, 0.2 MGD is from groundwater for both Moderate and High Demand Scenarios. Mining demands were assumed to be 0.16 MGD from surface water in both the Moderate and High Demand Scenarios. Thermoelectric demands were held constant at 2,609.3 MGD in the Moderate Demand Scenario and at 2,849.0 MGD in the High Demand Scenario.

Chapter 5
Comparison of Water Resource Availability and Water Demand

This chapter describes the methods used to assess surface water availability in the Upper Savannah River basin. A surface water quantity model was used to evaluate water availability using current and projected water demands. Water availability was also assessed assuming surface water withdrawals at permitted and registered amounts. The results of these assessments are presented and compared, and potential water shortages and issues are identified.

5.1 Methodology

5.1.1 Surface Water

Surface water planning scenarios were constructed and simulated using the previously developed Savannah River basin surface water quantity model (CDM Smith 2017). This model was developed with CDM Smith's SWAM software. It simulates river basin hydrology, water availability, and water use across a dendritic network and over an extended timeseries.

SWAM provides efficient planning-level analyses of surface water supply systems. Beginning with naturally occurring water flowing in the river reaches, it calculates physically and permitted or allowable water, diversions, storage, consumption, and return flows at user-defined nodes in a networked river system. A range of water user types can be represented in the model, including municipal water suppliers, agricultural irrigators, and industrial water users, with time-variable demands either prescribed by the user or, in some cases, calculated internally. Multiple layers of complexity are available as options in SWAM to allow for easy development of a range of systems, from the very simple to the more complex. As an example, SWAM's reservoir object can include only basic hydrology-dependent calculations (storage as a function of inflow, outflow, and evaporation) or can include operational rules of varying complexity: prescribed monthly releases, a set of prioritized monthly releases or storage targets, or a set of conditional release rules (dependent on hydrology). Municipal water conservation programs similarly can be simulated with sets of rules of varying complexity. The model user chooses the appropriate level of complexity given the modeling objectives and data availability.

The Savannah River basin SWAM model simulates 82 years of variable historic hydrology (October 1939 through December 2021) with either a monthly or daily user-specified calculation timestep (the surface water scenarios presented in this chapter represent monthly analyses, unless noted otherwise). It is designed for three primary purposes:

- Accounting of current and past basin inflows, outflows, and consumptive uses
- Simulating streamflow and lake storage across a range of observed historical climate and hydrologic conditions, given current water use and operations

- Simulating future "what if" scenarios associated with changes in basin water use, management, and/or operations

The Savannah River basin model extends from the upstream headwaters to Savannah, Georgia. The portion of the Savannah River basin model that represents the Upper Savannah basin includes 11 municipal, eight golf course, six industrial, five agricultural (irrigation), one mining, and two thermoelectric water users. There are four additional water user objects that represent consolidated water withdrawals from Georgia water users. Hydroelectric projects, which are not operated as strictly run-of-river model, are represented through operating rules incorporated into reservoir objects. All water users with permitted withdrawals greater than 0.1 MGD are represented, either explicitly or implicitly. In the model version that represents current conditions, monthly water use is set equal to the average of a recent 10-year period (2012 through 2021) of reported use, with several exceptions. Exceptions include new surface water users and surface water users with recent demands that are significantly different from demands in the early part of the 10-year period. Model users also can adjust water use patterns to explore future water management scenarios, as discussed in this chapter.

A total of 27 "tributary objects" (rivers and streams) are represented discretely in the Upper Savannah portion of the model, including the mainstem Savannah River. Boundary condition (headwater) flows for each tributary object are prescribed in the model based on external analyses (CDM Smith 2017), which estimated naturally occurring historical flows "unimpaired" by human uses. Historical, current, and/or future uses then can be simulated against the same natural hydrology of the basin. Hydrologic flow gains (or losses) for each tributary are simulated in SWAM using lumped gain (or loss) factors, which are set based on a model calibration exercise, using gaged flow data, and/or guided by changes in reach drainage area. SWAM implicitly accounts for interaction between groundwater and surface water through the assignment of the gain/loss factors.

The Savannah River basin SWAM model was used to simulate current and potential future scenarios to evaluate surface water availability. Chapter 5.3 provides detailed descriptions of the surface water scenarios and their results.

Following are several key terms of the surface water modeling, introduced in the Planning Framework, used throughout this chapter.

- **Physically Available Surface Water Supply** – The maximum amount of water that occurs 100 percent of the time at a location on a surface water body with no defined Surface Water Conditions applied on the surface water body.

- **Reach of Interest** – A stream reach defined by the RBC that experiences undesired impacts, environmental or otherwise, determined from current or future water demand scenarios or proposed water management strategies. Such reaches may or may not have identified Surface Water Shortages. The Upper Savannah RBC did not identify any Reaches of Interest in the Upper Savannah River basin.

- **Reservoir Safe Yield** – The Surface Water Supply for a reservoir or system of reservoirs over the simulated hydrologic period of record.

- **Strategic Node** – A location on a surface water body or aquifer designated to evaluate the cumulative impacts of water management strategies for a given model scenario and that serves as a primary point of interest from which to evaluate a model scenario's performance measures. The RBC selected the Strategic Nodes.

- **Surface Water Condition** – A limitation, defined by the RBC, on the amount of water that can be withdrawn from a surface water source and that can be applied to evaluate Surface Water Supply for planning purposes. The Upper Savannah RBC did not establish a Surface Water Condition for any location in the Upper Savannah River basin.

- **Surface Water Shortage** – A situation in which water demand exceeds the Surface Water Supply for any water user in the basin.

- **Surface Water Supply** – The maximum amount of water available for withdrawal 100 percent of the time at a location on a surface water body without violating any applied Surface Water Conditions on the surface water source and considering upstream demands.

5.1.2 Groundwater

The Upper Savannah River basin is almost entirely in the Piedmont physiographic province where groundwater occurs in bedrock fractures and in the overlying saprolite. Groundwater use is limited in the basin; as such, no modeling or other analysis was performed to assess groundwater availability. In South Carolina, groundwater modeling is being used to assess current and future availability in the river basins that extend into the Coastal Plain. These include the Pee Dee, Santee, Edisto, and Lower Savannah-Salkehatchie.

5.2 Performance Measures

Performance measures were developed as a means for comparing water resource impacts (negative and positive) of each scenario. A performance measure is a quantitative measure of change in a user-defined condition from an established baseline, used to assess the performance of a proposed water management strategy or combination of strategies. Performance measures establish an objective means with which to compare scenarios. Performance measures were selected in collaboration with the RBC.

5.2.1 Hydrologic-Based Performance Measures

Table 5-1 presents the hydrologic surface water performance measures used to evaluate and compare simulation results. For each simulated scenario, performance measures were calculated as a post-processing step in the modeling. All metrics were calculated for the entire simulation period. Changes in performance measures between scenarios were particularly useful for the planning process. The first set of performance metrics were calculated for model output nodes that were identified by the RBC as Strategic Nodes. These Strategic Nodes are distributed throughout the river basin. Strategic Nodes are defined at four of the USGS streamflow gaging stations in the Upper Savannah basin and on the Keowee River, on Twelvemile Creek, on the Savannah River upstream of Lake Hartwell, and downstream of Lake Russell and Lake Thurmond. Figure 5-1 shows all Strategic Node locations.

Table 5-1. Surface water performance measures.

Strategic Node Metrics (generated for each Strategic Node)
Mean flow (cfs)
Median flow (cfs)
25th percentile flow (cfs)
10th percentile flow (cfs)
5th percentile flow (cfs)
Comparison to minimum instream flows (MIFs)
Basinwide Metrics (generated in aggregate for the entire modeled river basin)
Total basin annual mean shortage (MGD) - Sum of the average shortage for all users over the simulation period
Maximum water user shortage (MGD) - Maximum monthly shortage experienced by any single user over the simulation period
Total basin annual mean shortage (% of demand) - Sum of the average shortage for all users over the simulation period divided by the sum of the average demand for all users over the simulation period
Average frequency of shortage (%) - Average frequency of shortage of all users who experience a shortage, where each user's frequency of shortage is calculated as the number of months with a shortage divided by the total months in the simulation (for a monthly timestep simulation)

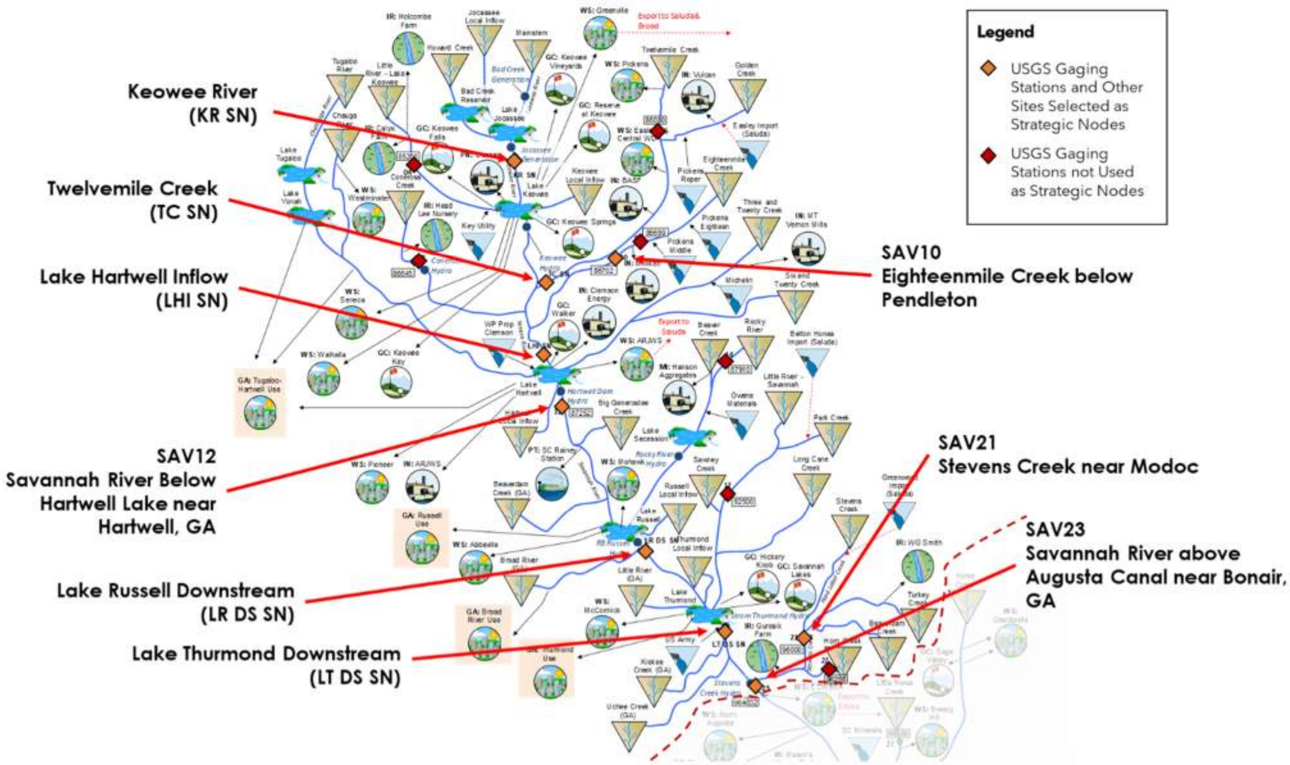

Figure 5-1. Strategic node locations.

5.2.2 Biological Response Metrics

As referenced in Chapter 3.2.2 and discussed in Bower et al. (2022) and The Nature Conservancy et al. (2024), biological response metrics were developed and combined with hydrologic metrics to identify statistically significant correlations between flow characteristics and ecological suitability for fish and macroinvertebrates. Select flow-ecology metrics (hydrologic metrics found to be most correlated to biological diversity) were used then as performance measures to help guide RBC discussions and recommendations for the Upper Savannah River basin. This section provides discussion of the relevant, selected biological response metrics and related hydrologic metrics (sometimes referred to as the "flow-ecology metrics"), and Chapter 5.3.9 presents their values and interpretation in the context of the Upper Savannah River basin.

The metrics were calculated at three of the Strategic Node locations shown in Figure 5-1 (Twelvemile Creek, Eighteenmile Creek below Pendleton, and Stevens Creek near Modoc), as well as at the USGS gage location on the Little River near Walhalla. These represent a general assessment of how aquatic life will be impacted by changes in flow based on SWAM scenarios. Results should not be considered as necessarily uniform throughout each subbasin. Local conditions may vary along the length of streams. Metrics were based on flow-ecology relationships calculated using data from streams and small rivers with watershed areas less than or equal to 2,715 sq mi. Because streams of this size comprise 86 percent of all surface water in South Carolina, results are broadly applicable across the basin. However, the results should not be extrapolated to large rivers or reservoirs.

Of the 14 biological response metrics identified in Bower et al. (2022), the following two biological response metrics were used in the Upper Savannah River basin because of the relevance and strong correlation to hydrologic statistics that could be readily extracted from the SWAM model (descriptions from The Nature Conservancy et al. 2024):

- **Species richness:** number of species found at a given site
- **Shannon diversity:** index of biodiversity that accounts for both species richness and proportional representation of each species

Hydrologic statistics that correlated well to these biological metrics included mean daily flow, a metric that could be easily extracted from SWAM model results (The Nature Conservancy et al. 2024). Mean daily flow is the mean (average) daily flow of the stream in cfs over the period of record. This flow metric, intended to support flow-ecology relationships, expands on the hydrologic metrics discussed in Chapter 5.2.1, which were used specifically for hydrologic comparisons.

Mapped together, these hydrologic metrics were used to estimate changes in the biological response metrics, which characterizes the ecological integrity of the basin. Table 5-2 helps illustrate the flow-ecology relationships for Piedmont Perennial Runoff (P1) and Piedmont Perennial Flashy (P4) stream types, which are the dominant stream types in the Upper Savannah River basin (The Nature Conservancy et al. 2024); however, this table is not exhaustive. Chapter 5.3.9 presents and provides discussion of the application of the biological response metrics for the Upper Savannah River basin.

Table 5-2. Relationship of hydrologic and biological response metrics.

Hydrologic Metric (Output from SWAM Scenarios)	Biological Response Metrics with High Conditional Importance (Bower et al. 2022)	Type of Evaluation
Mean Daily Flow	Shannon Diversity, Species Richness	Ecological Integrity

5.3 Scenario Descriptions and Surface Water Simulation Results

Four scenarios were used to evaluate surface water availability and to identify any anticipated Surface Water Shortages: the Current Surface Water Use Scenario (Current Scenario); the Permitted and Registered Surface Water Use Scenario (P&R Scenario); the Moderate Water Demand Scenario (Moderate Scenario); and the High Water Demand Scenario (High Demand Scenario). The Moderate Scenario was originally referred to as the Business-as-Usual Scenario in the Planning Framework. The RBC requested a fifth scenario, the Unimpaired Flow Scenario (UIF Scenario), and a model simulation was completed. The UIF Scenario removes all surface water withdrawals and discharges and simulates conditions before any surface water development. The following scenarios were simulated over the approximately 82-year period of variable climate and hydrology spanning October 1939 to December 2021. All simulation results, except where noted, are based on model simulations using a monthly timestep.

5.3.1 Current Surface Water Use Scenario

The Current Scenario represents current operations, infrastructure, and water use in the Upper Savannah River basin. Water demands were generally set based on average reported water usage in the 10-year period spanning 2012 to 2021, with several minor exceptions. The model includes conservation rules for two water users (City of Greenville and Seneca Light and Water) that are subject to the Duke Energy Low Inflow Protocol (LIP). The LIP calls for reductions in withdrawals when certain drought-related triggers are met. Conservation triggers are discussed further in Chapter 6. This simulation provides information on the potential for Surface Water Shortages that could immediately result under a repeat of historical drought conditions in the basin and highlights the need for short-term planning initiatives, including the development of strategies to mitigate shortages and/or increase Surface Water Supply.

No surface water users have a calculated Surface Water Shortage for one or more months over the approximately 82-year (987-month) simulation for the Current User Scenario (using a monthly timestep). Table 5-3 presents the mean flow, median flow, and Surface Water Supply at each Strategic Node. Also presented are the 25th, 10th, and 5th percentile flows, which are useful in characterizing low flows. Table 5-4 presents the basinwide performance metrics. The "0 cfs" minimum flows at the Keowee River Strategic Node and the Savannah River below Hartwell Lake (SAV12) Strategic Node are a result of application of the complex reservoir operating rules at a monthly timestep. In both cases, Lake Jocassee and Lake Hartwell reservoir releases were simulated to be 0 cfs for brief periods of time in order to meet prescribed reservoir storage levels.

Table 5-3. Surface water model simulation results at Strategic Nodes, Current Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	537	483	0	321	182	117
Lake Hartwell Inflow Strategic Node	4,276	3,716	629	2,407	1,757	1,427
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	3,986	3,384	0	2,000	2,000	1,871
Lake Russell Downstream Strategic Node	6,680	5,420	1,426	3,377	2,655	2,391
Lake Thurmond Downstream Strategic Node	8,040	5,872	3,101	4,502	4,003	3,801
SAV23 Savannah River above Augusta Canal near Bonair, GA[1]	8,840	6,405	3,300	4,756	4,368	4,117
Twelvemile Creek Strategic Node	264	227	28	147	100	76
SAV10 Eighteenmile Creek Below Pendleton	73	62	9	40	27	21
SAV21 Stevens Creek near Modoc	389	173	3	53	21	12

[1] The USGS gage on the Savannah River above Augusta Canal near Bonair, GA is located in the Lower Savannah River basin, at the boundary of the Upper and Lower Savannah River basins. The gage is shown here, and in subsequent tables in this chapter because it is reflective of all inflows and withdrawals upstream in the Upper Savannah River basin.

Table 5-4. Basinwide surface water model simulation results, Current Scenario.

Performance Measure	Result
GA-Side and SC-Side Water Users	
Total basin annual mean shortage (MGD)	0
Total basin annual mean demand (MGD)	2,679
Maximum water user shortage (MGD)	0
Total basin annual mean shortage (% of demand)	0
Percentage of water users experiencing shortage	0
Average frequency of shortage (%)	0
SC Water Users Only (Not Including GA-Side Water Users)	
Total basin annual mean shortage (MGD)	0
Total basin annual mean demand (MGD)	2,657
Maximum water user shortage (MGD)	0
Total basin annual mean shortage (% of demand)	0
Percentage of water users experiencing shortage	0
Average frequency of shortage (%)	0

5.3.2 Permitted and Registered Surface Water Use Scenario

In the P&R Scenario, modeled demands were set to permitted or registered values for all water users. In other words, this simulation explored the question of, "What if all water users used the full volume of water allocated through permits and registrations?". The scenario provides information to determine whether surface water is currently over-allocated in the basin. Like the Current Use Scenario, two water users (City of Greenville and Seneca Light and Water) have demands in the P&R Scenario that are subject to the Duke Energy LIP, which calls for reductions in withdrawals with increasing drought phase.

Tables 5-5 through 5-8 summarize the simulation results for the P&R Scenario (monthly timestep). In this scenario, river flows are predicted to decrease, compared to the Current Scenario, throughout the basin, resulting in Surface Water Shortages for several surface water users. Table 5-5 lists only the surface water users with one or more months of a simulated Surface Water Shortage. Figure 5-2 shows locations of these water users on the SWAM model framework. Also shown are the average annual demand for each water user experiencing a shortage; the minimum physically available (monthly average) flow at the point of withdrawal; the maximum (monthly average) shortage; and the frequency of shortage.

All water users with calculated shortages rely on tributary streams for Surface Water Supply. A calculated water shortage exists for one water supply user (City of Pickens) under the P&R Scenario. Figure 5-2 shows the location of this water user on the SWAM model framework. The P&R Scenario assumes the City of Pickens will continue to rely on Twelvemile Creek as its source water; however, the City of Pickens intends to switch their source to Lake Keowee in the future, which would alleviate this projected shortage. The agricultural irrigator (WG Smith) with a calculated shortage has access to a 2.2-acre impoundment, which is not included in the model. This impoundment may provide enough water to prevent shortages during times when Turkey Creek is simulated to have very low or no flow. Two additional water users (Vulcan Construction Materials and Hanson Aggregates) also have calculated water shortages under this scenario.

Table 5-5. Identified Surface Water Shortages, P&R Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
IN: Vulcan	Golden Creek	2.06	0.67	1.35	11.2%
WS: Pickens	Twelvemile Creek	7.21	2.55	4.52	6.6%
MI: Hanson Aggregates	Beaver Creek	0.95	0.29	0.65	3.4%
IR: WG Smith	Turkey Creek	0.13	0.00	0.13	0.8%

IR = agricultural (irrigation) water user; WS = water supply water user; MI = mining water user; IN = industrial water user

Table 5-6 presents the mean flow, median flow, and Surface Water Supply at each Strategic Node. Also presented are the 25th, 10th, and 5th percentile flows, which are useful in characterizing low flows. Table 5-7 shows the percent change in P&R Scenario flow statistics compared to the Current Scenario. Mean and median flows at the most downstream site of the Upper Savannah River mainstem (SAV23 Savannah River above Augusta Canal near Bonair, GA) are predicted to decrease by approximately 4 to 12 percent, respectively, if all upstream users withdrew water from the system at their permitted or registered amount. At the Stevens Creek near Modoc Strategic Node, P&R Scenario mean flows are 1 percent higher than Current Use Scenario mean flows because of the upstream wastewater discharge from Greenwood. The impact of full allocation withdrawals on downstream water users is evident in the predicted increase in mean annual water shortage and the increase in the number and frequency of water users experiencing a shortage during the simulation period, as shown in Table 5-8. As explained in Chapter 4, the fully permitted and registered withdrawal rates greatly exceed current use rates. The results of the P&R Scenario demonstrate that, while there are a few locations in the basin that cannot support withdrawals at the fully permitted and registered rates, there is sufficient surface water to meet most of the demands, when considering the range of hydrologic conditions over the 1939 and 2021 period of record.

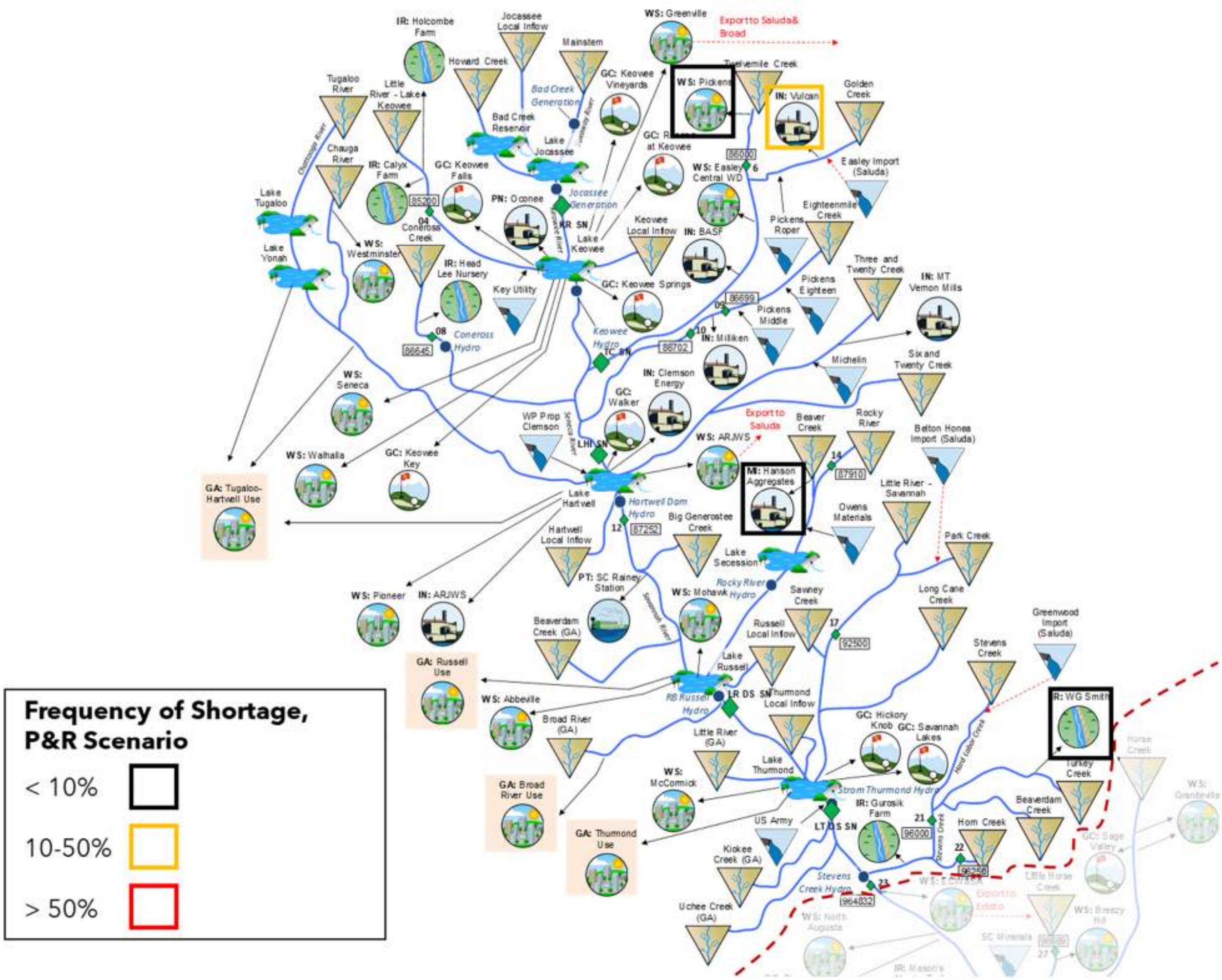

Figure 5-2. Water users with Surface Water Shortages and frequency of shortages, P&R Scenario.

Table 5-6. Surface water model simulation results at Strategic Nodes, P&R Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	537	488	0	324	187	78
Lake Hartwell Inflow Strategic Node	4,042	3,428	638	2,210	1,578	1,308
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	3,608	2,788	0	2,000	2,000	1,495
Lake Russell Downstream Strategic Node	6,315	4,892	547	3,227	2,636	2,332
Lake Thurmond Downstream Strategic Node	7,657	5,092	3,101	4,501	4,001	3,801
SAV23 Savannah River above Augusta Canal near Bonair, GA	8,495	5,650	3,305	4,765	4,332	3,994
Twelvemile Creek Strategic Node	252	215	23	136	87	65
SAV10 Eighteenmile Creek Below Pendleton	73	62	9	40	27	21
SAV21 Stevens Creek near Modoc	393	177	6	56	24	16

Table 5-7. Percent change in P&R Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
Keowee River Strategic Node	0.001%	1%	*NA*	1%	3%	-33%
Lake Hartwell Inflow Strategic Node	-5%	-8%	1%	-8%	-10%	-8%
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	-9%	-18%	*NA*	-0.0%	-0.0%	-20%
Lake Russell Downstream Strategic Node	-5%	-10%	-62%	-4%	-1%	-2%
Lake Thurmond Downstream Strategic Node	-5%	-13%	-0.003%	-0.003%	-0.03%	-0.01%
SAV23 Savannah River above Augusta Canal near Bonair, GA	-4%	-12%	0.2%	0.2%	-1%	-3%
Twelvemile Creek Strategic Node	-4%	-5%	-18%	-8%	-13%	-14%
SAV10 Eighteenmile Creek Below Pendleton	-0.1%	-0.2%	-1%	-0.3%	-0.3%	-1%
SAV21 Stevens Creek near Modoc	1%	2%	117%	5%	13%	27%

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Table 5-8. Basinwide surface water model simulation results, P&R Scenario.

Performance Measure	Result
GA-Side and SC-Side Water Users	
Total basin annual mean shortage (MGD)	0.18
Total basin annual mean demand (MGD)[1]	3,561
Maximum water user shortage (MGD)	4.5
Total basin annual mean shortage (% of demand)	0.01%
Percentage of water users experiencing shortage	10.8%
Average frequency of shortage (%)	0.6%
SC Water Users Only (Not Including GA-Side Water Users)	
Total basin annual mean shortage (MGD)	0.18
Total basin annual mean demand (MGD)[1]	3,496
Maximum water user shortage (MGD)	4.5
Total basin annual mean shortage (% of demand)	0.01%
Percentage of water users experiencing shortage	12.1%
Average frequency of shortage (%)	0.7%

1. The total basin annual mean demand under the Current Use Scenario is 2,679 MGD (GA- and SC-side water users), 2,657 MGD of which is from SC water users.

5.3.3 Moderate Water Demand Projection Scenario

For the Moderate Scenario, modeled demands were set to projected future levels based on an assumption of moderate population and economic growth, as described in Chapter 4.3. The year 2070 planning horizon was targeted using the demand projections developed by SCDES and presented in Chapter 4.4. As discussed in Chapter 4, future municipal water demands above current demands from Greenville were assumed to be met by Lake Keowee. The Moderate Scenario explores a plausible future where water demands increase with moderate population growth and climate change impacts are negligible, in both the short- and long-term. Existing agricultural users' current demands were kept constant. Additional future agricultural irrigation demands were represented in the SWAM model by new simulated water users located at the outlet of select watersheds where growth in agricultural irrigation was projected to occur. Like the Current Use and P&R Scenarios, two water users (City of Greenville and Seneca Light and Water) have demands in the Moderate Scenario that are subject to the Duke Energy LIP, which calls for reductions in withdrawals with increasing drought phase.

Tables 5-9 through 5-12 summarize the Moderate Scenario (monthly timestep) simulation results for the 2070 planning horizon. A calculated water shortage exists for one water user (City of Pickens) under the Moderate 2070 Scenario. As discussed previously, the City of Pickens intends to switch their source to Lake Keowee in the future, which would alleviate this projected shortage. Given current climate conditions and existing basin management and regulatory structure, basin surface water supplies are predicted to be adequate to meet increased demands resulting from moderate economic and population growth.

In the Moderate Scenario, flows are predicted to decrease modestly compared to the Current Use Scenario. By 2070, at the most downstream Strategic Node (SAV23 Savannah River above Augusta Canal near Bonair, GA), mean and median flows are predicted to decrease by approximately 1 to 3 percent, and low flows are projected to increase by less than 1 percent, if population and economic growth is moderate and climate change impacts are negligible.

Table 5-9. Identified Surface Water Shortages, Moderate 2070 Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
WS: Pickens	Twelvemile Creek	2.14	2.55	0.04	0.1%

WS = water supply water user

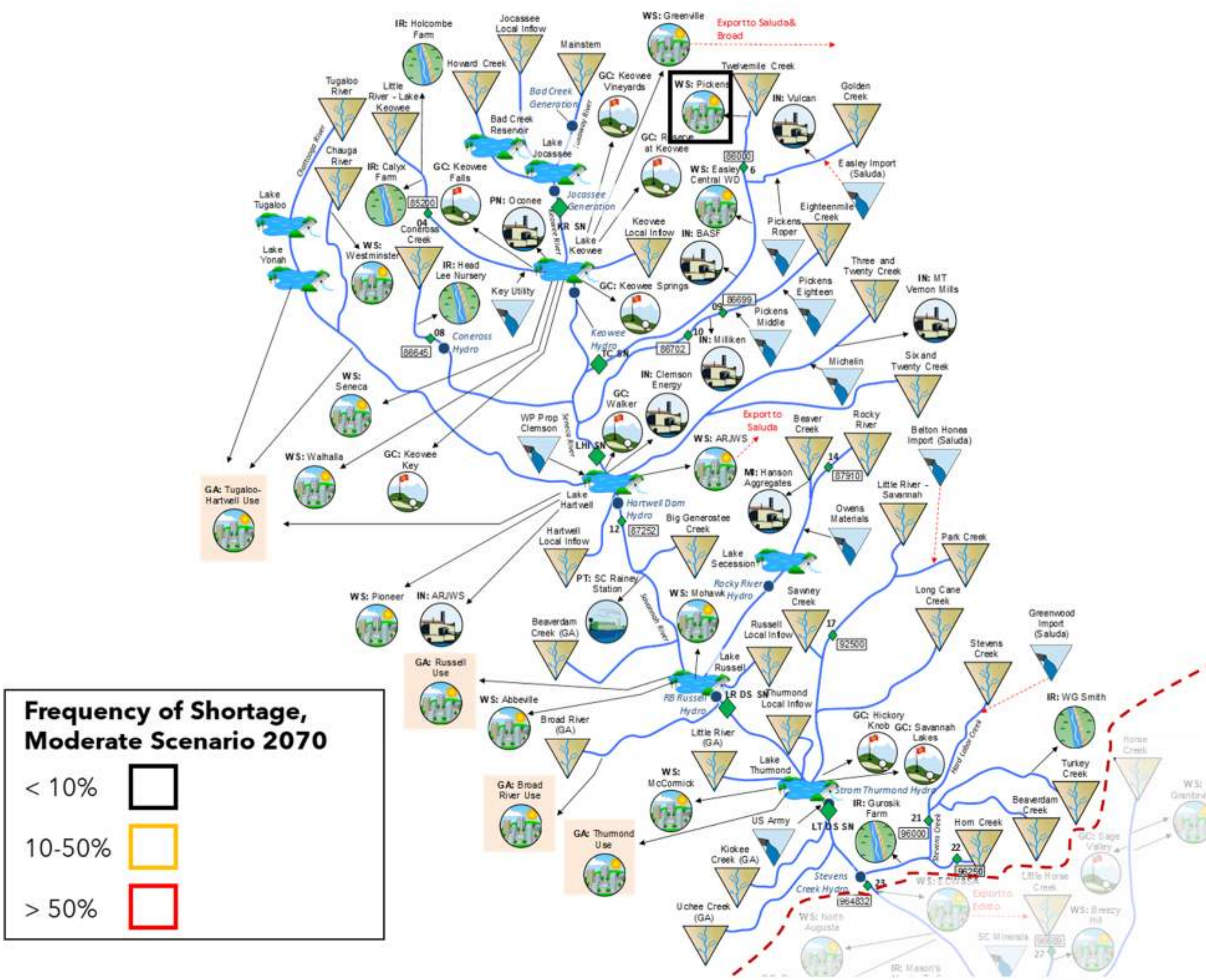

Figure 5-3. Water users with Surface Water Shortages and frequency of shortages, Moderate 2070 Scenario.

Table 5-10. Surface water model simulation results at Strategic Nodes, Moderate 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	537	488	0	319	183	112
Lake Hartwell Inflow Strategic Node	4,219	3,657	583	2,350	1,713	1,425
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	3,894	3,227	0	2,000	2,000	1,774
Lake Russell Downstream Strategic Node	6,592	5,299	1,204	3,301	2,657	2,378
Lake Thurmond Downstream Strategic Node	7,952	5,753	3,102	4,502	4,002	3,801
SAV23 Savannah River above Augusta Canal near Bonair, GA	8,752	6,212	3,301	4,748	4,354	4,065
Twelvemile Creek Strategic Node	263	226	27	146	98	74
SAV10 Eighteenmile Creek Below Pendleton	73	62	9	40	27	21
SAV21 Stevens Creek near Modoc	389	172	2	53	20	12

Table 5-11. Percent change in Moderate 2070 Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
Keowee River Strategic Node	0.01%	1%	*NA*	-1%	1%	-4%
Lake Hartwell Inflow Strategic Node	-1%	-2%	-7%	-2%	-3%	-0.1%
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	-2%	-5%	*NA*	-0.0%	-0.0%	-5%
Lake Russell Downstream Strategic Node	-1%	-2%	-16%	-2%	0%	-1%
Lake Thurmond Downstream Strategic Node	-1%	-2%	0.03%	-0.001%	-0.01%	-0.001%
SAV23 Savannah River above Augusta Canal near Bonair, GA	-1%	-3%	0.04%	-0.2%	-0.3%	-1%
Twelvemile Creek Strategic Node	-0.4%	-1%	-6%	-1%	-1%	-2%
SAV10 Eighteenmile Creek Below Pendleton	-0.1%	-0.1%	-1%	-0.2%	-0.3%	-0.4%
SAV21 Stevens Creek near Modoc	-0.1%	-0.3%	-16%	-1%	-2%	-4%

Table 5-12. Basinwide surface water model simulation results, Moderate 2070 Scenario.

Performance Measure	Result
GA-Side and SC-Side Water Users	
Total basin annual mean shortage (MGD)	<0.001
Total basin annual mean demand (MGD) [1]	2,764
Maximum water user shortage (MGD)	0.04
Total basin annual mean shortage (% of demand)	<0.001%
Percentage of water users experiencing shortage	2.5%
Average frequency of shortage (%)	0.003%
SC Water Users Only (Not Including GA-Side Water Users)	
Total basin annual mean shortage (MGD)	<0.001
Total basin annual mean demand (MGD) [1]	2,734
Maximum water user shortage (MGD)	0.04
Total basin annual mean shortage (% of demand)	<0.001%
Percentage of water users experiencing shortage	2.8%
Average frequency of shortage (%)	0.003%

1. The total basin annual mean demand under the Current Use Scenario is 2,679 MGD (GA- and SC-side water users), 2,657 MGD of which is from SC water users.

5.3.4 High Water Demand Projection Scenario

For the High Demand Scenario, modeled demands are set to the 90th percentile of variability in reported withdrawals for each user, and the projections are based on aggressive growth within the range of uncertainty of the referenced driver variable projections, as described in Chapter 4. Like the Moderate Scenario, a year 2070 planning horizon was targeted using the demand projections developed by SCDES. This set of scenarios represents the combined impacts of all sectors experiencing high growth and all water users experiencing conditions of high water demand. These assumptions are intended to represent an unlikely maximum for total water demand; it is very unlikely these demands would occur month after month and year after year for all water users. The purpose of this scenario is to provide the RBC with information on which to base conservative management strategies. Other methods and assumptions used in constructing the High Demand Scenario were the same as for the Moderate Scenario. Like the Current Use, P&R, and Moderate Scenarios, two water users (City of Greenville and Seneca Light and Water) have demands in the High Demand Scenario that are subject to the Duke Energy LIP, which calls for reductions in withdrawals with increasing drought phase.

Tables 5-13 through 5-16 summarize the High Demand Scenario (monthly timestep) simulation results for the 2070 planning horizon. The one water user with shortages in the Moderate 2070 Scenario (City of Pickens) exhibits a slightly greater shortage under the High Demand 2070 Scenario. As mentioned before, the High Demand 2070 Scenario assumes the City of Pickens will continue to rely on Twelvemile Creek as its source water; however, the City of Pickens intends to switch their source to Lake Keowee in the future, which would alleviate this projected shortage. One mining water user and one industrial water user also experience shortages.

In the High Demand Scenario, river flows are predicted to decrease modestly to moderately, compared to the Current Scenario, depending on the location. Mean and median flows at the most downstream site of the mainstem (SAV23 Savannah River near Augusta Canal near Bonair, GA) are predicted to decrease by approximately 2 to 5 percent, and low flows are projected to increase by less than 1 percent, based on 2070 demands. Calculated water user shortages increase slightly, in terms of both duration and intensity, for the 2070 planning horizon, as compared to the Moderate Scenario results.

Table 5-13. Identified Surface Water Shortages, High Demand 2070 Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
IN: Vulcan	Golden Creek	1.39	0.67	2.49	12.5%
WS: Pickens	Twelvemile Creek	2.82	2.55	0.96	0.4%
MI: Hanson Aggregates	Beaver Creek	0.51	0.29	0.29	1.3%

WS = water supply water user; IN = industrial water user; MI = mining water user

Table 5-14. Surface water model simulation results at Strategic Nodes, High Demand 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	537	485	0	321	194	111
Lake Hartwell Inflow Strategic Node	4,166	3,573	573	2,323	1,666	1,339
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	3,816	3,097	0	2,000	2,000	1,694
Lake Russell Downstream Strategic Node	6,521	5,244	1,102	3,250	2,620	2,353
Lake Thurmond Downstream Strategic Node	7,880	5,546	3,101	4,502	4,002	3,801
SAV23 Savannah River above Augusta Canal near Bonair, GA	8,682	6,089	3,302	4,746	4,353	4,048
Twelvemile Creek Strategic Node	260	223	25	144	96	72
SAV10 Eighteenmile Creek Below Pendleton	73	62	9	40	27	21
SAV21 Stevens Creek near Modoc	391	174	4	55	22	14

Table 5-15. Percent change in High Demand 2070 Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
Keowee River Strategic Node	-0.01%	0.5%	*NA*	0%	7%	-5%
Lake Hartwell Inflow Strategic Node	-3%	-4%	-9%	-4%	-5%	-6%
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	-4%	-8%	*NA*	-0.0%	-0.0%	-9%
Lake Russell Downstream Strategic Node	-2%	-3%	-23%	-4%	-1%	-2%
Lake Thurmond Downstream Strategic Node	-2%	-6%	-0.003%	-0.001%	-0.02%	-0.002%
SAV23 Savannah River above Augusta Canal near Bonair, GA	-2%	-5%	0.1%	-0.2%	-0.3%	-2%
Twelvemile Creek Strategic Node	-1%	-2%	-11%	-3%	-4%	-6%
SAV10 Eighteenmile Creek Below Pendleton	-0.3%	-0.3%	-2%	-1%	-1%	-1%
SAV21 Stevens Creek near Modoc	0.4%	1%	44%	3%	6%	11%

Table 5-16. Basinwide surface water model simulation results, High Demand 2070 Scenario.

Performance Measure	Result
GA-Side and SC-Side Water Users	
Total basin annual mean shortage (MGD)	0.12
Total basin annual mean demand (MGD)[1]	3,068
Maximum water user shortage (MGD)	2.5
Total basin annual mean shortage (% of demand)	0.004%
Percentage of water users experiencing shortage	7.5%
Average frequency of shortage (%)	0.4%
SC Water Users Only (Not Including GA-Side Water Users)	
Total basin annual mean shortage (MGD)	0.12
Total basin annual mean demand (MGD)[1]	3,038
Maximum water user shortage (MGD)	2.5
Total basin annual mean shortage (% of demand)	0.004%
Percentage of water users experiencing shortage	8.3%
Average frequency of shortage (%)	0.4%

1. The total basin annual mean demand under the Current Use Scenario is 2,679 MGD (GA- and SC-side water users), 2,657 MGD of which is from SC water users.

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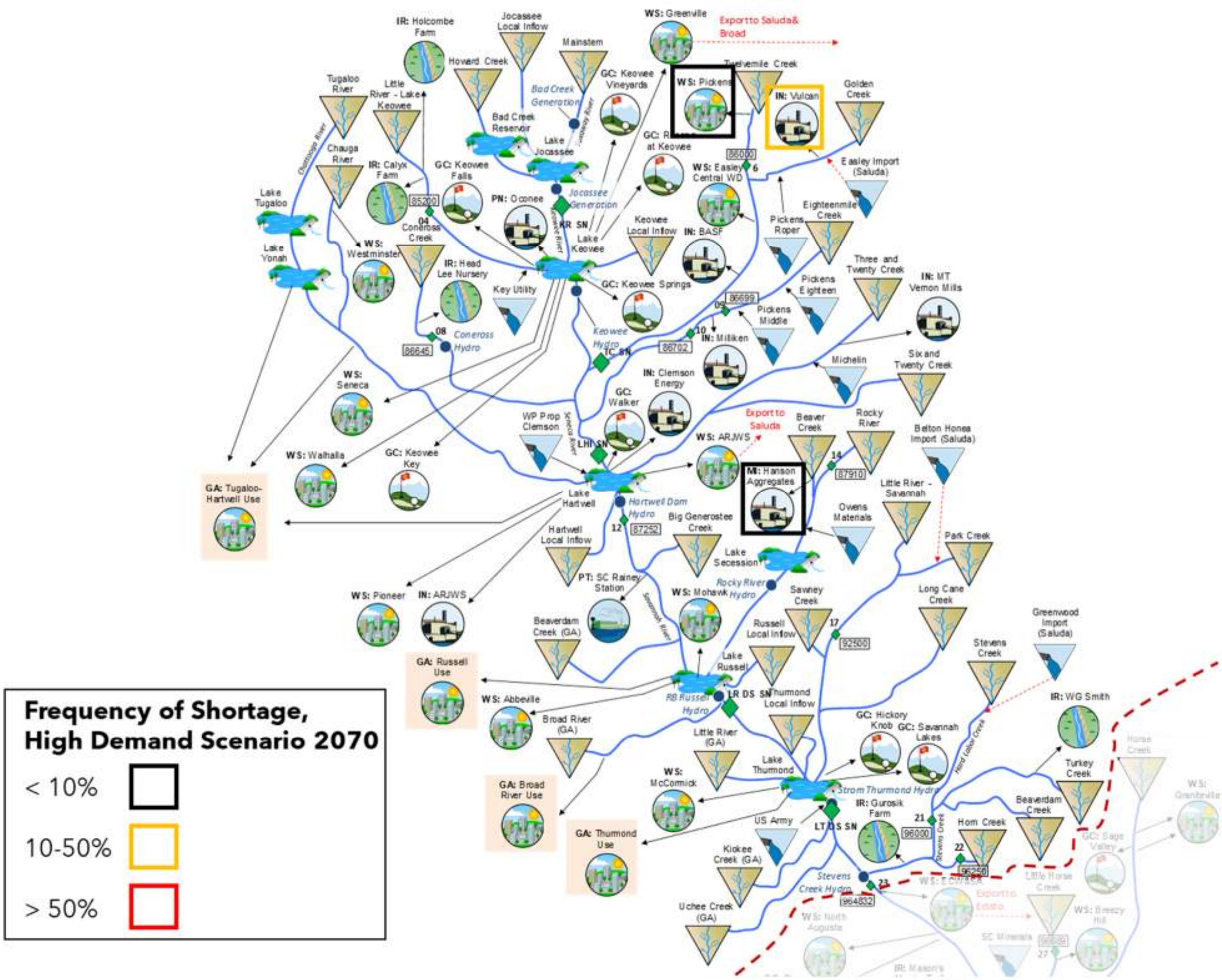

Figure 5-4. Water users with Surface Water Shortages and frequency of shortages, High Demand 2070 Scenario

The High Demand Scenario for the 2070 planning horizon was also modeled using a daily timestep. Tables 5-17 through 5-19 summarize the results. Not surprisingly, mean modeled flows are similar for the daily and monthly calculation timesteps, but modeled extreme low flows (25th, 10th, and 5th percentiles) are lower for the daily timestep model compared to the monthly timestep model. A greater range of flow variability is simulated with the higher-resolution daily model, compared to the monthly model. Because of the higher temporal resolution, the daily model captures a basinwide maximum daily water user shortage that is significantly higher than that quantified by the monthly timestep model.

Table 5-17. Daily timestep surface water model simulation results at Strategic Nodes, High Demand 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	536	370	0	178	0	0
Lake Hartwell Inflow Strategic Node	4,159	3,060	287	1,773	1,078	829
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	3,815	1,722	0	0	0	0
Lake Russell Downstream Strategic Node	6,513	3,774	25	1,617	767	507
Lake Thurmond Downstream Strategic Node	7,874	4,502	3,101	4,501	4,002	3,801
SAV23 Savannah River above Augusta Canal near Bonair, GA	8,673	4,966	3,202	4,705	4,323	3,959
Twelvemile Creek Strategic Node	260	194	10	125	81	60
SAV10 Eighteenmile Creek Below Pendleton	73	54	3	35	23	18
SAV21 Stevens Creek near Modoc	389	94	4	32	14	8

Table 5-18. Percent change in High Demand 2070 Scenario daily flows at Strategic Nodes relative to Current Scenario daily flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
Keowee River Strategic Node	0.01%	-1%	*NA*	-4%	*NA*	*NA*
Lake Hartwell Inflow Strategic Node	-3%	-4%	10%	-6%	-6%	-3%
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	-4%	-13%	*NA*	*NA*	*NA*	*NA*
Lake Russell Downstream Strategic Node	-2%	-4%	-12%	-5%	-2%	1%
Lake Thurmond Downstream Strategic Node	-2%	-0.001%	-0.0%	-0.001%	-5%	-0.01%
SAV23 Savannah River above Augusta Canal near Bonair, GA	-2%	-0.4%	0.1%	-0.1%	-1%	-3%
Twelvemile Creek Strategic Node	-1%	-2%	-9%	-3%	-5%	-7%
SAV10 Eighteenmile Creek Below Pendleton	-0.3%	-0.4%	-2%	-1%	-1%	-1%
SAV21 Stevens Creek near Modoc	0.4%	2%	44%	4%	11%	21%

Table 5-19. Basinwide surface water model daily simulation results, High Demand 2070 Scenario.

Performance Measure	Result
GA-Side and SC-Side Water Users	
Total basin annual mean shortage (MGD)	0.17
Total basin annual mean demand (MGD) [1]	3,070
Maximum water user shortage (MGD)	3.0
Total basin annual mean shortage (% of demand)	0.01%
Percentage of water users experiencing shortage	10.0%
Average frequency of shortage (%)	0.4%
SC Water Users Only (Not Including GA-Side Water Users)	
Total basin annual mean shortage (MGD)	0.17
Total basin annual mean demand (MGD) [1]	3,040
Maximum water user shortage (MGD)	3.0
Total basin annual mean shortage (% of demand)	0.01%
Percentage of water users experiencing shortage	11.1%
Average frequency of shortage (%)	0.5%

1. The total basin annual mean demand under the Current Use Scenario is 2,679 MGD (GA- and SC-side water users), 2,657 MGD of which is from SC water users.

5.3.5 Unimpaired Flow Scenario

At the request of the RBC, the SWAM model was used to simulate UIFs throughout the Upper Savannah River basin. For this simulation, all water demands and discharges in the model were set to zero. Simulation results represent river hydrologic conditions without the impact of reservoirs, surface water users, dischargers, or water imports, as modeled. In other words, results represent "naturalized" surface water conditions in the basin.

Tables 5-20 and 5-21 summarize UIF Scenario monthly simulation results. Simulated UIFs are generally higher than simulated Current Scenario flows, as expected. This reflects the removal of consumptive water use for the UIF Scenario simulation. However, at the Strategic Nodes on Eighteenmile Creek below Pendleton (SAV10) and on Stevens Creek near Modoc (SAV21), Current Use Scenario mean flows are approximately 1 percent higher than UIF Scenario mean flows because of upstream wastewater discharges. At three of the Strategic Nodes on the mainstem Savannah River, the Current Use Scenario minimum flows are greater than the UIF Scenario flows. This is because of required minimum releases from the reservoirs, which result in higher minimum flows during drought, compared to UIF conditions. At the most downstream Strategic Node (SAV23 Savannah River above Augusta Canal near Bonair, GA), mean and median UIFs are approximately 9 and 24 percent higher than Current Scenario flows, respectively. At this same location, UIF low flows (10th percentile, 5th percentile, and minimum flows) are approximately 20 to 66 percent lower than Current Scenario flows.

Table 5-20. Surface water model simulation results at Strategic Nodes, UIF Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
Keowee River Strategic Node	572	503	91	339	237	191
Lake Hartwell Inflow Strategic Node	4,482	3,949	700	2,645	1,794	1,470
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	4,482	3,949	700	2,645	1,794	1,470
Lake Russell Downstream Strategic Node	7,270	6,130	912	4,008	2,702	2,146
Lake Thurmond Downstream Strategic Node	8,901	7,429	1,080	4,777	3,262	2,621
SAV23 Savannah River above Augusta Canal near Bonair, GA	9,671	7,951	1,133	5,078	3,476	2,857
Twelvemile Creek Strategic Node	266	229	31	150	102	78
SAV10 Eighteenmile Creek Below Pendleton	72	61	9	40	26	20
SAV21 Stevens Creek near Modoc	386	169	0	50	18	10

Table 5-21. Percent change in UIF Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
Keowee River Strategic Node	7%	4%	*NA*	6%	30%	63%
Lake Hartwell Inflow Strategic Node	5%	6%	11%	10%	2%	3%
SAV12 Savannah River below Hartwell Lake near Hartwell, GA	12%	17%	*NA*	32%	-10%	-21%
Lake Russell Downstream Strategic Node	9%	13%	-36%	19%	2%	-10%
Lake Thurmond Downstream Strategic Node	11%	27%	-65%	6%	-18%	-31%
SAV23 Savannah River above Augusta Canal near Bonair, GA	9%	24%	-66%	7%	-20%	-31%
Twelvemile Creek Strategic Node	1%	1%	9%	1%	2%	3%
SAV10 Eighteenmile Creek Below Pendleton	-1%	-1%	-7%	-2%	-3%	-4%
SAV21 Stevens Creek near Modoc	-1%	-2%	-100%	-6%	-14%	-23%

5.3.6 Comparison to Minimum Instream Flows

At the request of the RBC, model-simulated flows for the UIF, Current Use, 2070 Moderate, 2070 High Demand, and P&R Scenarios were compared to the calculated MIF at a subset of the Strategic Nodes. As defined in R.61-119, Surface Water Withdrawal, Permitting, Use and Reporting regulations, the MIF is the "flow that provides an adequate supply of water at the surface water withdrawal point to maintain the biological, chemical, and physical integrity of the stream taking into account the needs of downstream users, recreation, and navigation" (SCDHEC 2012). Under SCDNR's 2009 Minimum Instream Flow Policy, the MIF for the Piedmont region is set at 40 percent of the mean annual daily flow for the months of January, February, March, and April; 30 percent of the mean annual daily flow for the months of May, June, and December; and 20 percent of the mean annual daily flow for the months of July through

November for surface water withdrawers. Table 5-22 shows the calculated MIFs at a subset of Strategic Nodes. The MIF regulation applies to new surface water permits only. In the Upper Savannah River basin, nearly all permitted surface water users are “grandfathered” and are not subject to the MIFs. Grandfathered water users are those who had surface water withdrawals before January 1, 2011.

For these comparisons, modeled flows from daily timestep simulations were used. Table 5-23 presents and compares the percentage of days for all scenarios when flows are simulated to drop below the calculated MIF at selected USGS gages. The gages were selected primarily because of their longer periods of record. The most downstream Strategic Node (Savannah River above Augusta Canal) was also selected for MIF comparison. The entire simulation period of record covered 82.25 years or 30,043 days. The calculated MIF, which comes from measured flow at each USGS gaging station, is based on a shorter period that coincides with the gaging station’s period of record (Table 5-22).

Table 5-22. Calculated MIF at select USGS gages.

Gage Name	Gage ID	Period of Record	Mean Annual Daily Flow[1] (cfs)	MIF (cfs)		
				Jan–Apr	May, Jun, and Dec	Jul–Nov
Coneross Creek near Seneca	02186645	1989–2003; 2023–2024	114	46	34	23
Savannah River above Augusta Canal near Bonair, GA	021964832	2010–2017	6,720	2,688	2,016	1,344
Little River near Walhalla	02185200	1967–2003	174	69	52	35
Twelvemile Creek near Liberty	02186000	1954–1964; 1989–2001; 2004–2024	183	73	55	37
Percent of mean annual daily flow for calculating MIF -->				**40%**	**30%**	**20%**

1. Mean annual daily flow was calculated using streamflow data through the end of water year 2023 (September 30, 2023).

From Table 5-23, results of the comparison to MIFs suggests the following:

- Under UIF conditions, flows drop below MIFs at all selected USGS gages, except for the Savannah River above Augusta Canal, at which UIF flows are above the MIF for February through May. This happens most often at the Coneross Creek near Seneca gage, where UIFs drop below MIFs more than 9 percent of the time in September.
- On Twelvemile Creek and Coneross Creek, there is a minor increase in the percentage of days when flows are below MIFs moving from the Current Use to the 2070 Moderate and 2070 High Demand Scenarios. This is because of the higher surface water withdrawals simulated in the 2070 Moderate and 2070 High Demand Scenarios.
- At most of the selected sites, the percentage of days when flows in the 2070 Moderate and 2070 High Demand Scenarios drop below the MIF ranges from 1 to 12 percent. A notable exception to this occurs at the Savannah River above Augusta Canal gage, which sees an increase in flows under the 2070 Moderate and 2070 High Demand Scenarios, and, consequently, experiences flows below the MIF 0 percent of the time. This is because of the reservoir operating rules, which control flows at this location.

- At the Little River gage, there is little to no change in the percentage of days below MIFs between the various scenarios, because there are only two upstream water users. Both water users are agricultural with permit limits of only 3 and 4 MGM.
- On Twelvemile Creek and Coneross Creek, there is a relatively large increase in the percentage of days when P&R Scenario flows are below MIFs, compared to the other scenarios.

Table 5-23. Percent of days below MIF at select USGS gages.

Strategic Node	Scenario	Percentage of days below MIF[1]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coneross Creek near Seneca	UIF	3.6	3.0	1.5	1.0	1.9	7.8	5.2	7.0	9.1	7.8	1.5	4.2
	Current Use	3.6	3.0	1.5	1.0	1.9	7.9	5.5	7.2	9.3	8.1	1.5	4.2
	2070 Moderate	3.6	3.0	1.5	1.0	1.9	7.8	5.5	7.2	9.3	7.8	1.5	4.2
	2070 High Demand	3.6	3.0	1.5	1.1	1.9	7.9	5.5	7.3	9.3	8.2	1.5	4.2
	P&R	4.1	3.4	1.5	1.2	2.5	8.7	5.7	7.8	11.1	9.1	2.4	4.9
Savannah River above Augusta Canal near Bonair, GA	UIF	0.7	0	0	0	0	2.8	1.6	3.1	4.1	4.4	1.5	0.5
	Current Use	0	0	0	0	0	0	0	0	0	0	0	0
	2070 Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	2070 High Demand	0	0	0	0	0	0	0	0	0	0	0	0
	P&R	0	0	0	0	0	0	0	0	0	0	0	0
Little River near Walhalla	UIF	5.5	3.1	1.8	0.3	0.8	7.5	3.8	5.1	7.1	8.4	4.0	6.8
	Current Use	5.5	3.1	1.8	0.3	0.8	7.5	3.8	5.1	7.1	8.4	4.0	6.8
	2070 Moderate	5.5	3.1	1.8	0.3	0.8	7.5	3.8	5.1	7.1	8.4	4.0	6.8
	2070 High Demand	5.5	3.1	1.8	0.3	0.8	7.5	3.8	5.1	7.1	8.4	4.0	6.8
	P&R	5.6	3.1	1.8	0.3	0.8	7.5	4.0	5.4	7.5	9.2	4.3	6.9
Twelvemile Creek near Liberty	UIF	3.4	2.5	1.3	0.8	1.0	6.9	5.6	6.8	8.5	5.8	0.4	3.2
	Current Use	3.7	2.8	1.4	0.9	1.2	7.6	5.7	7.7	9.6	7.3	1.0	3.8
	2070 Moderate	3.8	3.0	1.4	0.9	1.4	8.1	6.2	8.5	10.7	8.2	1.3	3.8
	2070 High Demand	3.8	3.0	1.4	1.0	1.7	8.6	6.4	8.7	11.8	9.2	2.1	4.1
	P&R	5.1	4.5	2.1	1.5	2.7	10.9	7.0	10.2	14.7	11.2	4.6	5.5

[1] There were 30,043 days in the simulation period.

5.3.7 Extended Drought Scenario Analysis

One of the uncertainties in the planning process identified by the RBC is future climate conditions. The RBC recognizes that climate conditions may be different in the future than the modeled historical (1939 through 2021) period. Given the uncertainty about future climate conditions and to further evaluate water supply resiliency in the basin, the SWAM model was used to test additional, hypothetical hydrologic conditions using the 2070 High Demand Scenario water demands. Following are the three extended drought scenarios tested:

- **Scenario 1** – A repeating 5-year drought constructed by splicing together the five driest water years in the baseline simulation period (2001, 2008, 1981, 1988, and 2017), with respect to mainstem total annual flow

- **Scenario 2** – A repeating single-year drought corresponding to the second driest water year (2008) and identified as the critical single-year drought with respect to Lake Thurmond water supply availability during critical summer months

- **Scenario 3** – A repeating synthetic drought year constructed by splicing together the 12 driest calendar month flows in the baseline simulation period

These three scenarios were compared against the baseline hydrology over the 10-year period of 2000 to 2009, which captures the 2002 and 2007 to 2008 drought periods. The results reflect the simulated balance between projected (2070) water demands and a low-flow supply condition based on historical observed surface flows. While the sequences of monthly flows and reservoir evaporation rates are synthetic, the magnitudes of the values are grounded in the historical baseline. No attempts have been made in the modeling to directly incorporate future hydrologic nonstationarity as projected by, for example, global climate models. Further, the modeling approach applied neglects any potential changes in groundwater/surface water interactions that could result from reduced recharge and depleted alluvial groundwater storage.

Results show water user shortages, as compared to baseline hydrology, for the constructed extended drought scenarios. Table 5-24 summarizes the shortages. Over this period under the baseline hydrology, no shortages occur on the Savannah River mainstem. Under Scenario 1, shortages occur for Lake Russell and Lake Thurmond water users. Under Scenarios 2 and 3, shortages also occur for Lake Hartwell water users.

Table 5-24. Basinwide surface water model simulation results for baseline hydrology (2000–2009) and extended drought scenarios.

Performance Measure	Baseline Hydrology (2000–2009)	Scenario 1	Scenario 2	Scenario 3
GA-Side and SC-Side Water Users				
Total basin annual mean shortage (MGD)	0.12	2.4	37.5	68.8
Percentage of water users experiencing shortage (%)	7.5%	20.0%	32.5%	32.5%
Average frequency of shortage (%)	0.4%	3.3%	21.8%	29.2%

Water levels in Lake Thurmond and Lake Hartwell were compared to critical pool levels for boating and swimming access, as defined in the *Keowee-Toxaway Hydroelectric Relicensing Project Water Supply Study Report* (HDR 2014). The critical boat access level is the point when 70 percent of boat access points remain usable; the critical swimming access level is the level below which all USACE-operated designated swimming areas are dry. Figures 5-5 and 5-6 show the water levels in Lake Hartwell and Lake Thurmond, respectively, for the baseline hydrology (2000 to 2009) and the three extended drought scenarios over 10 years under 2070 High Demand water demands. Lake levels are lower with each successive drought scenario, with Scenario 3 resulting in water levels in Lake Thurmond at the dead pool after approximately 16 months. Water levels drop below the boat access and swimming access levels 3 percent and 6 percent, respectively, on Lake Hartwell, and 2 percent and 11 percent, respectively, on

Lake Thurmond, with the baseline hydrology. For all extended drought scenarios, lake levels drop below boating and swimming access levels most of the time.

Although lake levels were modeled and compared to ramp and access level requirements for recreational activities, the RBC did not identify any recommendations to mitigate potential impacts. The RBC recognized that recreational access impacts will occur during severe and extreme drought conditions.

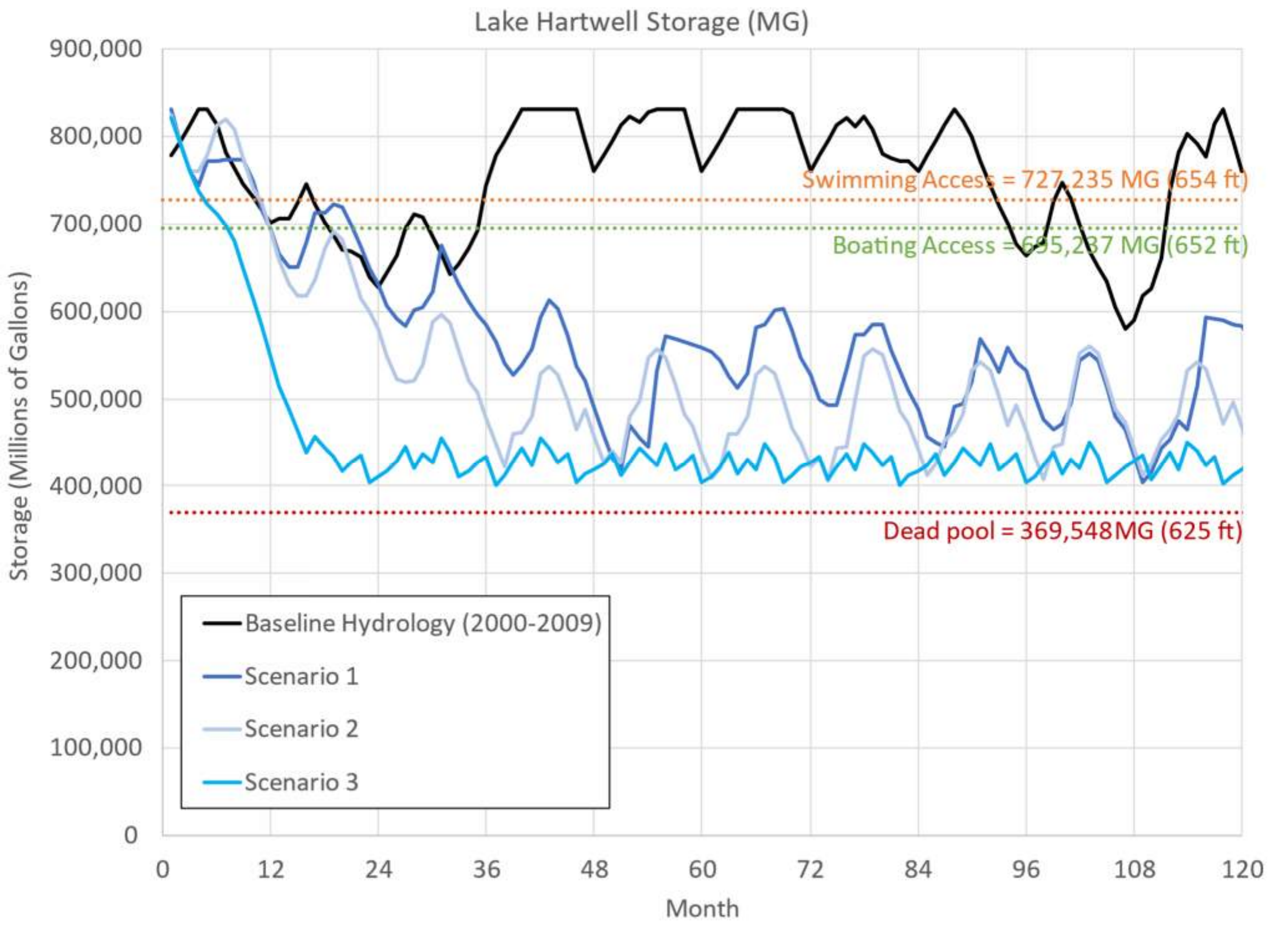

Figure 5-5. Extended drought scenario results for Lake Hartwell.

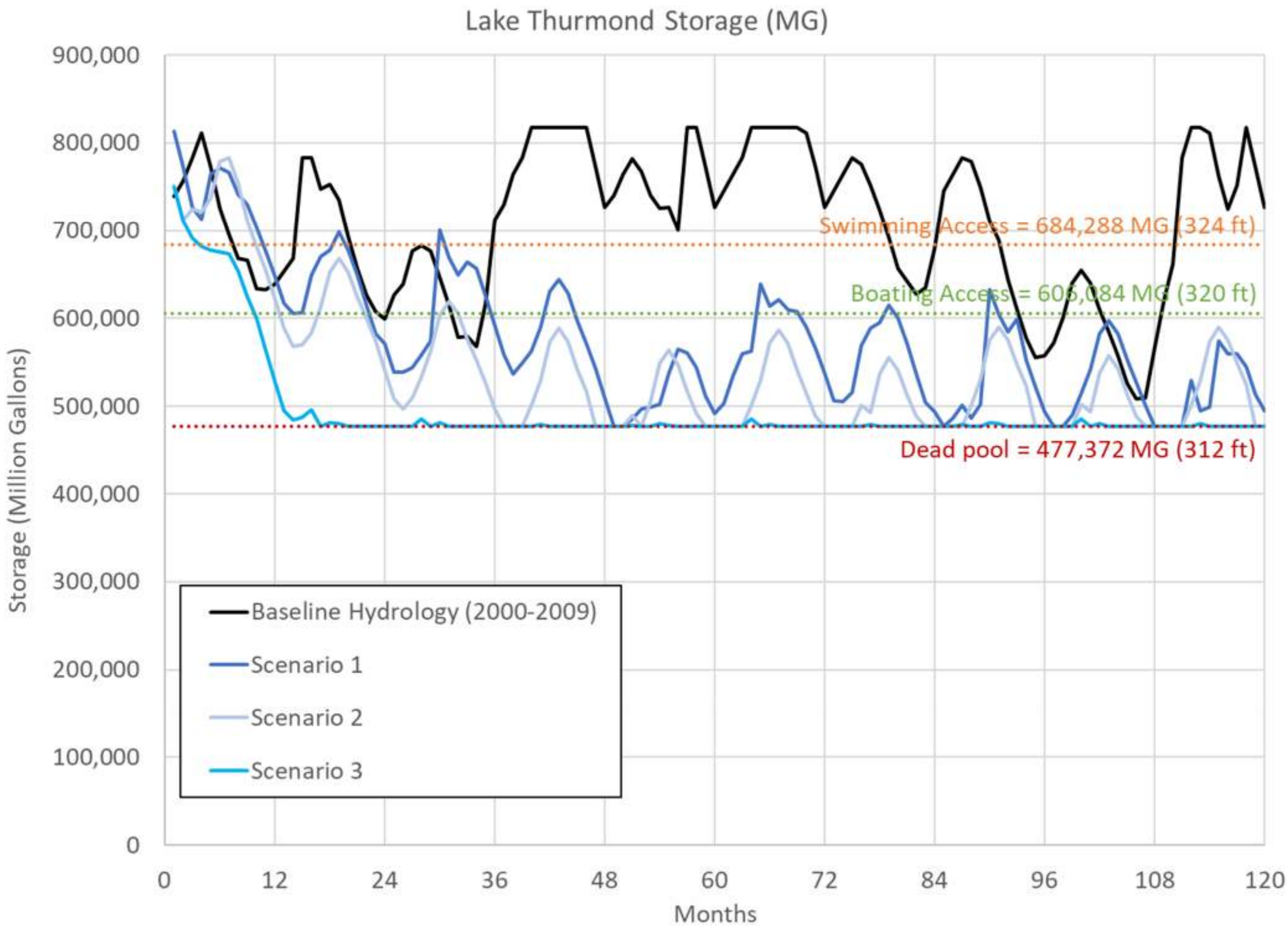

Figure 5-6. Extended drought scenario results for Lake Thurmond.

In general, the simulations performed here highlight significant water supply vulnerabilities if historical observed drought conditions were to occur in the future with greater frequency and/or duration. While modified reservoir storage operations (i.e., holding back water) could mitigate some of the quantified shortages, this would come at a cost of severely reduced flows in the Savannah River. Acceptable instream and environmental flow levels are a key driver of the vulnerability of water supplies to potential future extreme drought conditions.

5.3.8 Future Sedimentation Analysis

Another uncertainty in the planning process identified by the RBC is infrastructure maintenance. Related to this, USACE recently completed surveys of the entireties of Lake Hartwell, Lake Russell, and Lake Thurmond to better understand the locations and rates of sedimentation in these lakes since their construction. These surveys indicate the following storage losses (reported below the top of the summer conservation pool) have occurred since the initial construction surveys:

- **Lake Hartwell** – 14 percent loss (approximately 1,900 million gallons per year since 1962)
- **Lake Russell** – 10 percent loss (approximately 1,100 million gallons per year since 1983)
- **Lake Thurmond** – 7 percent loss (approximately 900 million gallons per year since 1952)

Based on these surveys and sedimentation rates, USACE developed stage-storage curve projections (Figure 5-7) for the year 2072, assuming the same rate of sedimentation continues annually. These projections were incorporated into the Savannah River Basin 2070 High Demand SWAM model to assess the impact of continued sedimentation in these reservoirs over the approximately 50-year planning horizon. Results indicate that the projected levels of storage loss will have a minor impact on water availability, as shown in Figure 5-8, and there will continue to be no projected shortages on the Savannah River mainstem under the High Water Demand Scenario.

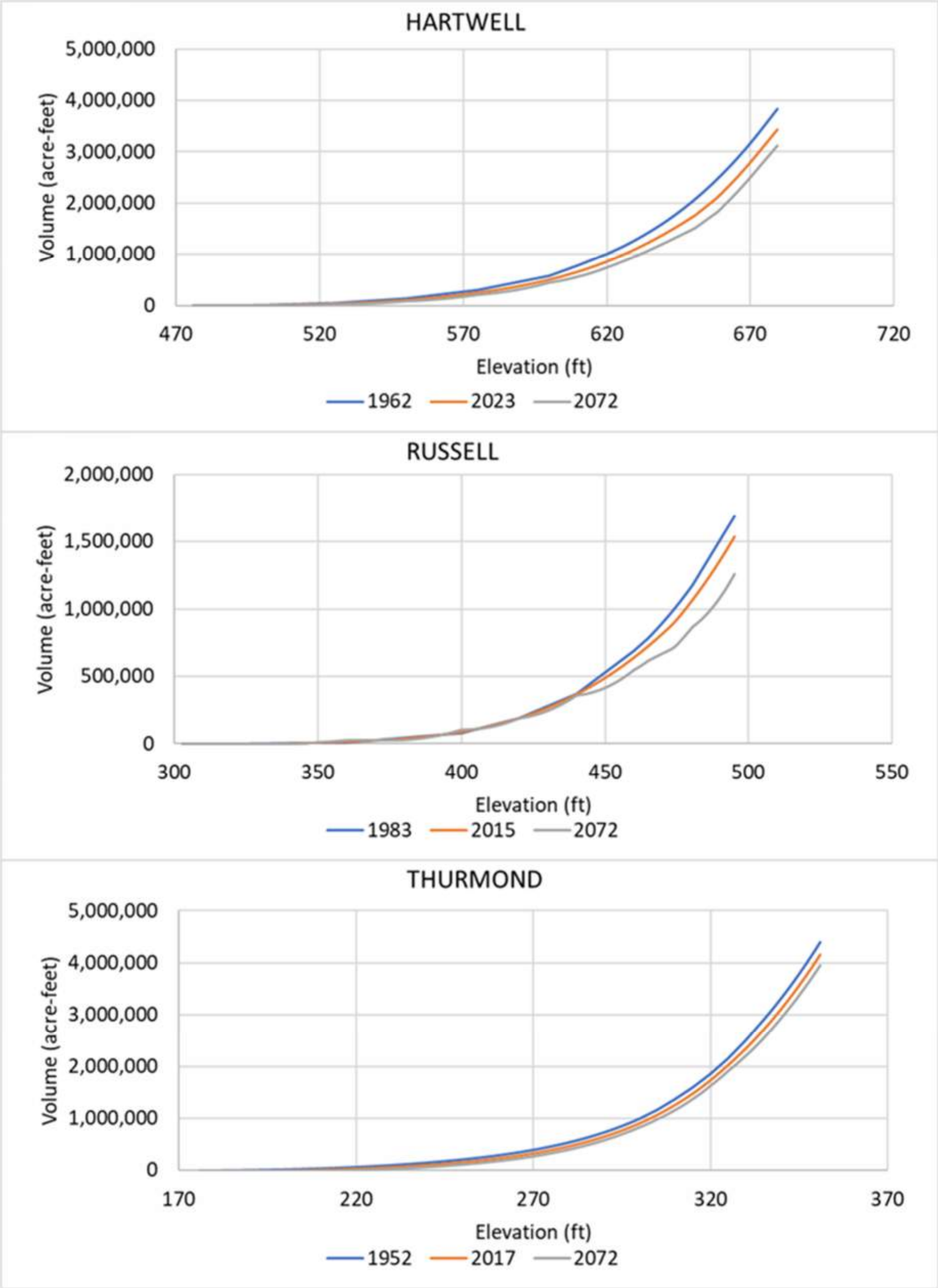

Figure 5-7. USACE stage-storage curves from initial construction surveys, recent surveys, and 2072 projections.

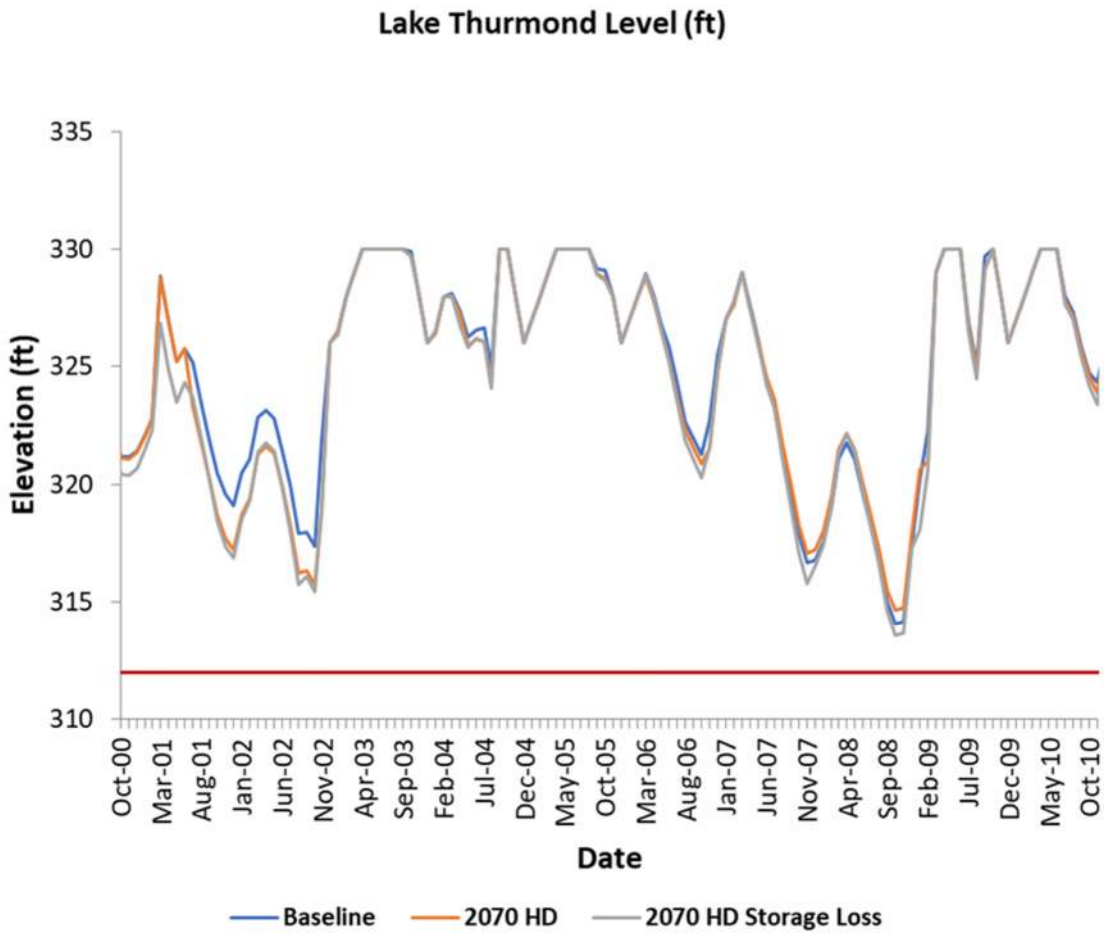

Figure 5-8. Change in Lake Thurmond water levels over the 2002 and 2007–2008 drought periods, with and without projected sedimentation.

5.3.9 Application of Biological Response Metrics

The biological response metrics developed by Bower et al. (2022) were correlated to model-simulated flows from the various planning scenarios to assess the potential for ecological risk, as described in The Nature Conservancy et al. (2024) report provided in Appendix B.

The consistent methodology used is discussed in Bower et al. (2022) and summarized in this plan in Chapter 5.2.2. Fundamentally, the selected hydrologic metric (mean daily flow) is compared to current conditions and expressed as a percentage change relative to future demand scenarios. This percentage change is converted into a percentage change in the biological response metric using the pre-developed correlation relationships between these factors and plotted on a risk scale. Table 5-25 and Figure 5-9 illustrate how the process works.

Table 5-25. Example of calculating changes in the biological metrics at the Twelvemile Creek Strategic Node[1]

Demand Scenario	Current Scenario Flow (cfs)	Projected Demand Scenario Flow (cfs)	Percentage Change in Flow Metric	Biometric	Percentage Change in Biometric	95% Confidence Interval[2]
UIF	263.60	265.58	0 to 1%	Richness	-1 to 0%	-13.9 to 12.9% (approximate)
Moderate 2070		262.64	-1 to 0%	Richness	0%	-13.4% to 13.4%
High Demand 2070		259.79	-1.1%	Richness	-1%	-14.4% to 12.4%
P&R		251.94	-4.4%	Richness	-4%	-17.4% to 9.4%

[1]This table is one example, extracted from the analysis at the Twelvemile Creek Strategic Node, and looks at the single hydrologic metric of mean daily flow (MA1) and its correlation with the single biological metric of species richness for fish taxa.
[2] Ninety-five percent confidence interval for the percentage change in biometric estimates.

Once the changes in flow-ecology relationships are quantified via machine learning techniques, they are converted into a risk chart. The three risk categories, high, medium, and low, are determined by sudden and significant changes in biological health, driven by the change in the hydrologic metric, as shown in Figure 5-9.

Biological response metrics were applied at three Strategic Nodes (Twelvemile Creek, Eighteenmile Creek below Pendleton, and Stevens Creek near Modoc), as well as at the USGS gage location on the Little River near Walhalla. Figure 5-10 presents representative results for many of the combinations of hydrologic metrics and biological response metrics at these locations. Stevens Creek near Modoc was only assessed for fish species richness.

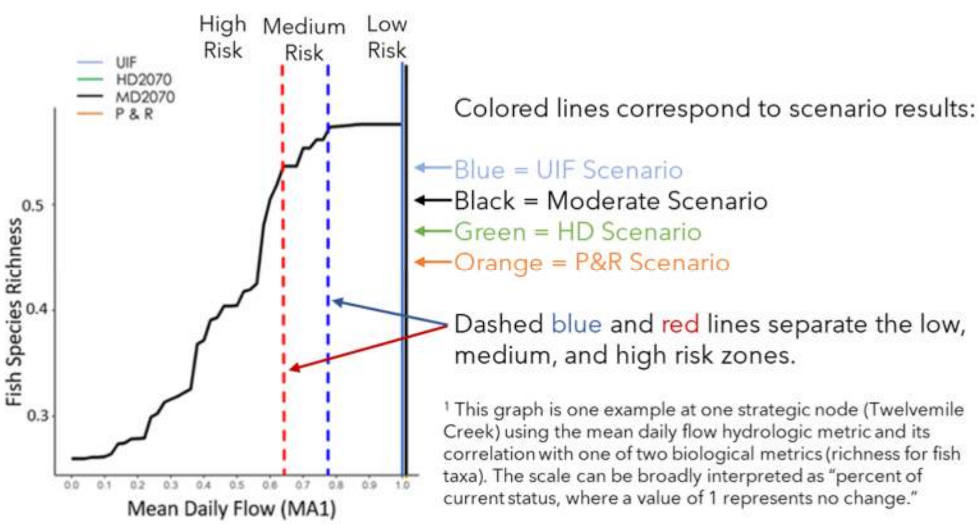

Figure 5-9. Example of the conversion of changes in biological metrics into risk (The Nature Conservancy et al. 2024).

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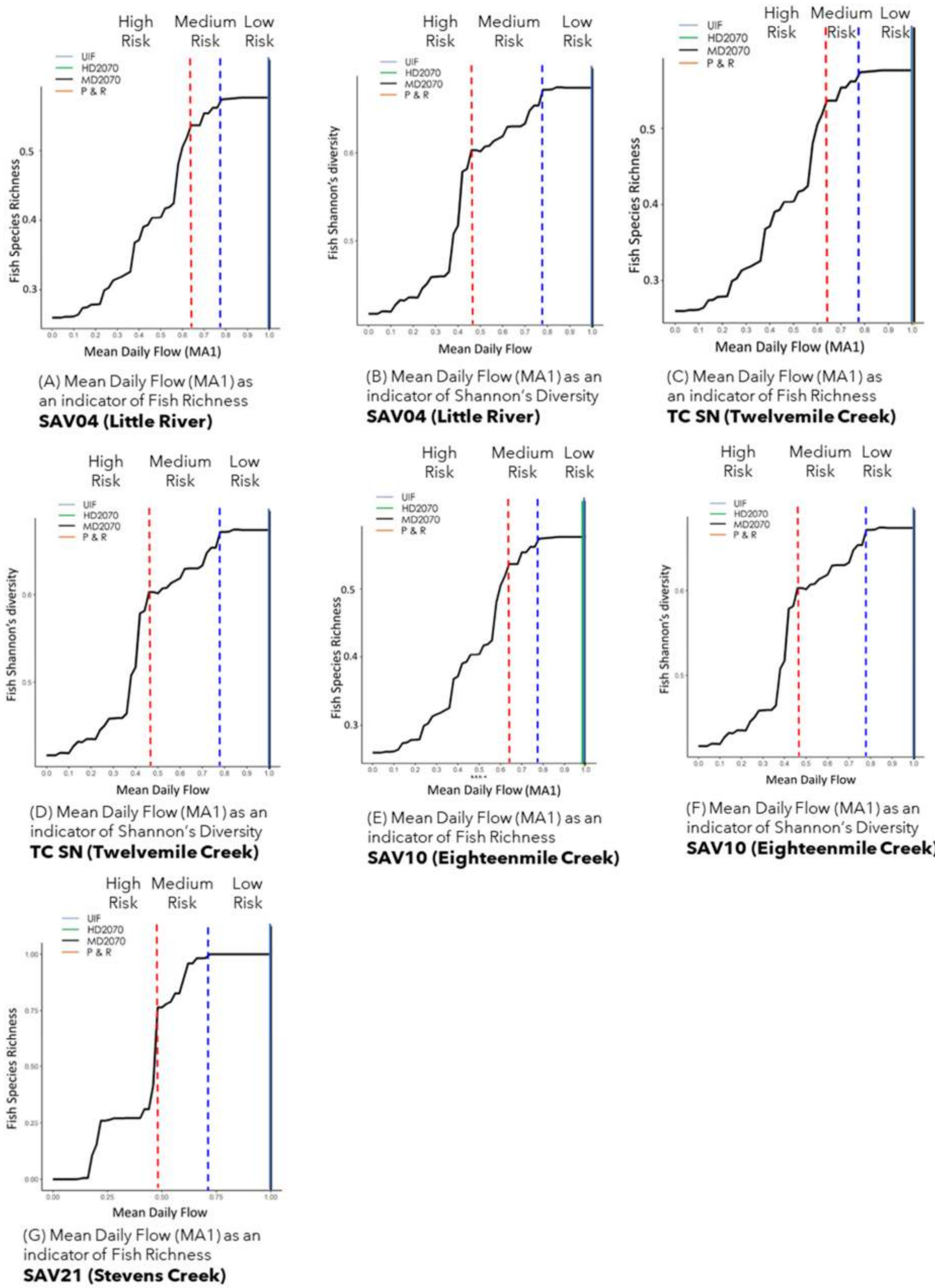

Figure 5-10. Selected biological risk level results for various biological metrics and Strategic Node locations (The Nature Conservancy et al. 2024).

As illustrated in Figure 5-10, SWAM model–simulated flow metrics for all scenarios result in low risk for ecological integrity (The Nature Conservancy et al. 2024). Overall, SWAM estimated no significant change in mean daily flow (MA1) for all scenarios and at selected nodes. The largest change in mean daily flow was predicted at Twelvemile Creek, showing a 4.4 percent reduction in mean daily flow P&R water use scenario. The linear relationships predicted a reduction in the number of species and Shannon's diversity by 4 percent and 3 percent, respectively. All other SWAM scenarios predicted small changes in mean daily flow between less than (<) 1 percent to 1.1 percent, resulting in low reductions in the number of fish species and Shannon's diversity predicted by linear models. The standard error associated with these estimates is important to consider because it provides a range associated with each prediction.

The performance measures showed all SWAM scenarios as remaining in the low-risk zone at all Strategic Nodes for species richness as well as Shannon's diversity. The linear relationships and performance measures suggest a low risk of fish species loss because of water use. However, these findings do not rule out all potential risks to ecological integrity or aquatic biodiversity related to other metrics or flow alterations.

5.4 Safe Yield of Reservoirs

An important factor in estimating the reliability of current water supply systems against future demand forecasts is the ability of reservoir systems to provide anticipated levels of supply without interruption. The safe yield of a reservoir, or system of reservoirs, is a measure of its long-term reliability. The Planning Framework defines Reservoir Safe Yield as "the Surface Water Supply for a reservoir or system of reservoirs over the simulated hydrologic period of record." Since the Surface Water Supply is the maximum amount of water available for withdrawal 100 percent of the time, the safe yield of a reservoir or system of reservoirs can be thought of as the maximum annual average demand that can be sustained through the period of record without depleting available storage.

For the Upper Savannah River basin, safe yield was computed for each reservoir or system of reservoirs that provide water to essential water users. Because of their pumped storage connection, the safe yield for Bad Creek, Jocassee, and Keowee reservoirs was determined as a system. The USACE Savannah River reservoirs were assessed individually. Standard methods were used, in which the SWAM model was used to gradually increase hypothetical water demand over the entire period of record until a reservoir, or reservoir system, could no longer satisfy that demand with 100 percent reliability.

Several important factors in the analysis include:

- Future demand assumptions at the point of withdrawal are not relevant to safe yield calculations, since the question is simply "how much can be supplied reliably." However, if there are upstream withdrawals, the demand scenarios used for RBC planning purposes are important. For any demands upstream of the reservoirs being evaluated, the Current Use, conservative 2070 High Demand, and P&R assumptions were applied.

- Reservoir safe yield results presented are based on the shallowest intake for an essential water use in a reservoir (highest critical public water supply intake, for example). Essential water users on Lake Keowee are the City of Seneca, the City of Walhalla, Greenville Water, and Oconee Nuclear

Station. Essential water users are Clemson Energy, ARJWS, and Pioneer Water on Lake Hartwell; the City of Abbeville and Mohawk on Lake Russell; and McCormick on Lake Thurmond. The shallowest essential water user intakes were determined to be at or below the deadpool elevation (set by hydropower operations) for Lake Keowee, Lake Russell, and Lake Thurmond. On Lake Hartwell, the shallowest essential water user intake belongs to Pioneer Water at elevation 632.37 feet, which is above the bottom of the conservation pool and hydropower operations limit of 625 feet.

- For each analysis, all water user demands for the reservoir being assessed were consolidated into a single water user object in the model.

- Reservoir operations on the Savannah River follow well-established operating protocols. For this safe yield analysis, the seasonal guide curve for the reservoir being assessed was not used during the analysis, but guide curves for the other reservoirs remained active. When determining safe yield for the Keowee system, water levels in Lake Keowee were limited to below the top of the operating pool. When assessing the USACE reservoirs, water levels were limited to below the top of the flood pool. Downstream minimum release rules were maintained.

- Safe yield of a reservoir system is not always the linear addition of the yield of individual reservoirs. In some cases, total system yield may be higher because of operational efficiencies and, in other cases, may be lower because of operational constraints.

Table 5-26 provides results of the safe yield analysis. For all reservoirs, the simulated safe yield exceeds the anticipated level of demand in the conservative 2070 High Demand Scenario. These projections are based solely on historical hydrology, which may or may not exhibit similar dry-period trends in the future. The analysis was also conducted at a monthly timestep, which does not necessarily account for all operational flexibility of reservoirs.

Table 5-26. Safe yield results for Savannah River basin water supply reservoirs.

Reservoir System	Reservoir (Total System)	Safe Yield with SWAM Model (MGD)			Comparative Results from Other Studies (MGD)	Sufficiency for 2070 High Demand Scenarios	Notes
		Baseline	2070 High Demand	Permitted and Registered			
Lake Keowee	Bad Creek	No critical water user withdrawals			<69 (HDR 2014)[1]	Sufficient to satisfy 2070 High Demand of 146 MGD (average annual)[2]	Because of their pumped storage connection, Bad Creek, Jocassee, and Keowee reservoirs were assessed as a system.
	Lake Jocassee	No critical water user withdrawals					
	Lake Keowee	421	419	369			
	Total System	**421**	**419**	**369**			
USACE Savannah River[3]	Lake Hartwell	832	709	509	24–38 (HDR 2014)[1]	Sufficient to satisfy 2070 High Demand of 82 MGD (average annual)	Reservoirs are interdependent because of complex operating rules, including during various drought stages. The safe yield analysis was performed for each reservoir independently. Total system safe yield is likely less than the total shown here.
	Lake Russell	1,263	1,054	750	>10 (HDR 2014)[1]		
	Lake Thurmond	441	345	301	>53 (HDR 2014)[1]		
	Total System	**<2,536**	**<2,108**	**<1,560**	NA		

[1] The approach and assumptions used for the previous safe yield analysis in HDR (2014) had several differences from the approach used here, which limit comparison. These differences include, but are not limited to the following: did not suspend reservoir guide curves (target elevations); used the previous intake elevation for Oconee Nuclear Station of 794.6 feet, which has since been lowered to 790 feet; used Clemson Energy's middle intake as the critical intake, while this analysis used the Pioneer Water intake as the critical intake for Lake Hartwell; only assessed demand amounts up to the 2066 demand projections, and no greater; and conducted the safe yield analyses for all reservoirs simultaneously instead of individually.

[2] The approximate 2070 High Demand withdrawal total from Lake Keowee includes only the consumptive portion (99% of total demand) of the Oconee Nuclear Station.

[3] Most yield values were determined with adjusted Hartwell release rules, such that Hartwell and Thurmond reservoirs draw down and recover with synchronicity.

5.5 Summary of Water Availability Assessments

Application of the surface water model using current and projected rates of water withdrawals resulted in the identification of several key observations and conclusions regarding the availability of water resources in the Upper Savannah River basin. Following are specific observations and conclusions relative to each planning scenario.

- Surface water availability modeling suggests a low risk of water supply shortages under the Current Use Scenario. No water supply shortages were identified using current, monthly average demands when considering the 82-year period of record covering hydrologic conditions observed from 1939 to 2021.
- The P&R Scenario explored the question of, "What if all water users used the full volume of water allocated through permits and registrations?". The results, which include projected shortages for one public water supplier, one agricultural operation, one industrial water user, and one mining water user demonstrate that, while there are a few locations in the basin that cannot support withdrawals at the fully permitted and registered rates, there is sufficient surface water to meet most of the demands, when considering the range of hydrologic conditions over the 1939 and 2021 period of record. The City of Pickens shortage may be alleviated when the source water is changed to Lake Keowee in the future, and the agricultural water user with a projected shortage (WG Smith) may have access to enough water from an impoundment (not included in the model) to prevent shortages when Turkey Creek has low flow. Projected mean, median, and low flows at Strategic Nodes for the P&R Scenario are generally lower than the same performance measures for the Current Use Scenario. At the most downstream Strategic Node (SAV23 Savannah River above Augusta Canal near Bonair, GA), mean and median flows are predicted to decrease by approximately 4 to 12 percent, and low flows are predicted to increase by less than 1 percent. At the Stevens Creek near Modoc Strategic Node, P&R Scenario mean flows are 1 percent higher than Current Use Scenario mean flows because of the upstream wastewater discharge from Greenwood.
- For the Moderate Scenario, modeled demands were set to projected future levels based on an assumption of moderate population and economic growth. Given current climate conditions and existing basin management and regulatory structure, basin surface water supplies are predicted to be adequate to meet increased demands, resulting from moderate economic and population growth. Based on 2070 moderate demands, one water user (City of Pickens) is simulated to experience shortages at a frequency of less than 1 percent; this shortage may be alleviated in the future with the planned source water change from Twelvemile Creek to Lake Keowee. River flows are predicted to decrease modestly compared to the Current Use Scenario. At the most downstream Strategic Node (SAV23 Savannah River above Augusta Canal near Bonair, GA), mean and median flows are predicted to decrease by approximately 1 to 3 percent, and low flows are projected to increase by less than 1 percent, based on 2070 demands.
- For the High Demand Scenario, modeled demands are set to the 90th percentile of variability in reported withdrawals for each user, and the projections are based on aggressive growth assumptions. This scenario represents an unlikely maximum for total water demand because it is very unlikely these demands would occur month after month and year after year for all water users; however, this scenario provides the RBC with information on which to base conservative management strategies. The one water user with a shortage in the Moderate Demand 2070 Scenario (City of Pickens) exhibits slightly greater shortages under the High Demand 2070 Scenario. Two additional water users (Vulcan Construction Materials and Hanson Aggregates) experience shortages as well. River flows are predicted to decrease modestly to moderately, compared to the Current Scenario, depending on the location. Mean and median flows at the most downstream site of the mainstem (SAV23 Savannah River near Augusta Canal near Bonair, GA) are predicted to decrease by approximately 2 to 5 percent, and low flows are projected to increase by less than 1 percent, based on 2070 demands.

- Lake levels were modeled and compared to ramp and access level requirements for recreational activities during extended, severe and extreme droughts. The RBC recognized that recreational access impacts will occur during severe and extreme drought conditions, but ultimately did not identify any recommendations to mitigate potential impacts.
- The SWAM model was also used to simulate hydrologic conditions without the impact of surface water users, discharges, or water imports. Under UIF conditions, flows drop below MIFs at all selected USGS gages, except for the Savannah River above Augusta Canal, at which UIF flows are above the MIF for February through May. The Savannah River above Augusta Canal location sees an increase in flows under the Current Use, 2070 Moderate, 2070 High Demand, and P&R Scenarios when compared to the UIF Scenario. This is because of the reservoir operating rules, which control flows at this location.
- Based on the SWAM model, mean daily flow is not expected to be strongly impacted more by water use across all SWAM scenarios and Strategic Nodes. Ecological flow performance measures suggest a low risk of fish species loss due to water use. However, these findings do not rule out all potential risks to ecological integrity or aquatic biodiversity related to other metrics or flow alterations.

Results and conclusions are based on modeling that assumed historical climate patterns. In subsequent phases of river basin planning, the RBC may decide to evaluate potential impacts to Surface Water Supply availability resulting from changing climate conditions such as increasing temperatures and more variable precipitation. Modeling results led to the RBC identifying a suite of water management strategies to address projected Surface Water Shortages, and to identify strategies to protect Surface Water Supply and maintain adequate river flows. Chapter 6, Water Management Strategies, discusses the selection and evaluation of water management strategies.

Chapter 6
Water Management Strategies

This chapter summarizes the evaluation of potential water management strategies identified by the Upper Savannah RBC. The Planning Framework identifies a two-step process to evaluate water management strategies. As a first step, the Planning Framework states that the proposed management strategies are to be simulated using the available models to assess each strategy's effectiveness in eliminating or reducing identified shortages, or in increasing surface water or groundwater supply. For strategies deemed effective, a second step addresses each strategy's feasibility for implementation. The Planning Framework identifies multiple considerations for determining feasibility, including potential costs and benefits, consistency with state regulations, reliability, environmental and socioeconomic impacts, and potential interstate or interbasin impacts.

6.1 Surface Water Management Strategies

Under the Planning Framework, a surface water management strategy is any water management strategy proposed to eliminate a surface water shortage, reduce a surface water shortage, or generally increase surface water supply to reduce the probability of future shortages. Strategies include demand-side management strategies that reduce supply gaps by reducing demands, and supply-side strategies that reduce supply gaps by directly increasing supply.

6.1.1 Overview of Strategies

The Upper Savannah RBC identified a portfolio of demand-side strategies consisting of municipal water conservation and efficiency practices and agricultural water efficiency practices, as listed in Tables 6-1 and 6-2, respectively. While the demand-side strategies were identified for surface water withdrawers, they also apply to the basin's limited groundwater withdrawers. The RBC did not identify any strategies that increase the amount of surface water available for withdrawal (supply-side strategies) because no significant Surface Water Shortages were identified under the 2070 High Demand Scenario.

Table 6-1. Municipal water conservation and efficiency practices[1].

Municipal Practices	
Development, Update, and Implementation of Drought Management Plans	Leak Detection and Water Loss Control Programs
Public Education of Water Conservation	Reclaimed Water Programs
Conservation Pricing Structures/Drought Surcharge	Time-of-Day Watering Limits
Residential Water Audits	Water Efficiency Standards for New Construction
Landscape Irrigation Programs and Codes	

[1] Here, and throughout Chapter 6, "municipal" includes local governments, special purpose districts, authorities, and other organizations that provide water to the public.

Table 6-2. Agricultural water efficiency practices.

Agricultural Practices	
Water Audits and Nozzle Retrofits	Crop Variety, Crop Types, and Crop Conversions
Irrigation Scheduling and Smart Irrigation	Irrigation Equipment Changes
Soil Management and Cover Cropping	Future Technologies

The RBC additionally outlined water conservation approaches for manufacturing (industrial) and energy water users. In the Upper Savannah River basin, these water users include Clemson Energy, Milliken & Company, Hanson Aggregates, Oconee Nuclear Station, and Santee Cooper's Rainey Generating Station. The identified strategies are water audits, rebates on energy-efficient appliances, water recycling and reuse, water-saving equipment and efficient water systems, water-saving fixtures and toilets, and educating employees about water conservation. Several of these approaches overlap those listed for municipal users, described in Section 6.1.2.

These strategies do not represent an exhaustive list of possible strategies that water users in the Upper Savannah River basin could implement. Similarly, not all strategies will be applicable to all users in the basin. The most appropriate strategies for a water withdrawer will depend on their location, end use, water source, financial resources, and other constraints or opportunities.

The sections that follow detail the surface water management strategies identified by the RBC. Technical evaluation of their potential effectiveness, and assessment of their feasibility are also presented.

6.1.2 Municipal Water Efficiency and Conservation Demand-Side Strategies

This subchapter describes the municipal water efficiency practices considered as part of the toolbox of strategies. These demand-side strategies also apply to groundwater users.

Development, Update, and Implementation of Drought Management Plans

This strategy is already ongoing in the basin because public suppliers were required to develop drought management plans as part of the state's Drought Response Act of 2000. Each drought management plan has a set of measurable triggers indicating when conditions enter one of three phases of drought, and the corresponding response actions to reduce demand by a target percentage. Chapter 8 describes the drought management plans in the Upper Savannah River basin. Under this strategy, public suppliers would continue to implement their drought management plans during drought conditions and update their plans to reflect any changes to the system. The Upper Savannah RBC recognizes the importance of the drought management plans for reducing demand and conserving water during critical low-flow periods.

Public Education of Water Conservation

This strategy would involve expanding existing public education programs or developing new programs as needed. Water conservation education could occur through public schools, civic associations, or other community groups. Water utilities and local governments could create informational handouts and/or include additional water conservation information on water utility bills. For this strategy to remain effective, public outreach would need to continue on a regular basis to maintain public engagement and motivation. The RBC discussed the possibility of larger water utilities sharing staffing or other conservation resources with smaller utilities.

In the Upper Savannah River basin, organizations including Clemson, Lake Keowee Source Water Protection Team, Lake Hartwell Partners for Clean Water, Anderson Pickens Stormwater Partners, and others have, and may continue to offer programs that help educate the public about water conservation. One potential action to support this strategy is for the Upper Savannah RBC to coordinate with groups that have existing education and outreach efforts.

The Upper Savannah RBC could also look to the 2014 Water Use Efficiency Plan developed by the Catawba-Wateree Water Management Group (CWWMG) for an example of a basinwide approach to reduce demand. The 2014 Plan includes measures such as a public information campaign, education and outreach, and landscape water management and demonstration gardens. The Upper Savannah RBC may request that members of the CWWMG provide an update on actions and results since the 2014 Plan to guide Upper Savannah RBC actions.

Conservation Pricing Structures/Drought Surcharges

Conservation pricing structures increase the unit cost of water as consumption increases. Utilities may have pricing structures that use a flat rate, rates that vary with consumption, or some combination of the two. Conservation pricing sets higher unit-use rates for customers whose usage exceeds set thresholds. This strategy assumes that consumers will curtail their personal use to avoid paying higher prices. The extent of demand reduction depends on the magnitude of the price increase and the local price elasticity of demand for water usage.

In the Upper Savannah River basin, several utilities, including Greenville Water and the City of Anderson, have drought surcharges that may be implemented during severe and/or extreme drought phases. These surcharges are like conservation pricing structures, because the intent is to discourage customers to from using more water. If implemented during an extreme drought, Greenville Water charges the regular water rate for the first 5,000 gallons used in a month, three times the regular water rate for up to 7,500 gallons used, four times the regular water rate for up to 10,000 gallons used, and five times the regular rate for more than 10,000 gallons used. This primarily discourages landscape irrigation, filling of swimming pools, and other uses of water beyond what's normally required for human health purposes.

Residential Water Audits

Residential water audits allow homeowners to better understand their personal water use and identify methods to reduce water use. Homeowners can perform these audits themselves using residential water audit guides, or water utilities may provide free residential water audits to their customers. Residential water audits involve checking indoor uses (e.g., toilets, faucets, showerheads) and outdoor uses (e.g., lawn sprinklers). Based on the results of the audit, homeowners may invest in low-flow systems, repair leaks, and/or adjust personal water use behaviors.

Landscape Irrigation Programs and Codes

Landscape irrigation programs or water-efficient landscaping regulations can encourage or require homeowners to adopt water-efficient landscaping practices. Such practices seek to retain the natural hydrological role of the landscape, promote infiltration into groundwater, preserve existing natural vegetation, and conserve water. Water-efficient landscaping may include incorporating native or low-water-use plants into landscape design (City of Commerce, CA 2021).

Local governments can require use of these water efficiency measures through municipal codes or encourage their use through incentives or educational programs. Potential practices include:

- Smart Irrigation Controller Rebate – Utilities may offer rebates to homeowners who replace their existing irrigation controllers with smart irrigation controllers that adjust irrigation according to soil moisture levels. Smart irrigation controllers incorporate soil moisture sensors (SMSs) and/or precipitation and/or evapotranspiration sensors (called weather-based irrigation controllers [WBICs]). Controllers can be WaterSense-certified by meeting U.S. Environmental Protection Agency (EPA) criteria.

- Turf Replacement Rebate – Utilities may offer rebates to homeowners or businesses who replace irrigable turf grass with landscaping that requires minimal or no supplemental irrigation.

- Developer Turf Ordinance – Ordinances can be set that require new developments to have reduced irrigable turf grass area. Such development may be required to have low flow or microirrigation in plant beds, spray or rotor heads in separate zones for turf grass, or smart irrigation controllers to manage remaining turf areas.

- Education Programs – Programs could be offered for homeowners to learn about water-efficient landscaping practices. Some examples of landscape irrigation improvements include:

  - Verifying the best irrigation schedule for the climate and soil conditions
  - Verifying the recommended nozzle pressure in sprinklers
  - Adjusting sprinkler locations to ensure water falls on lawns and/or gardens (not on sidewalks or other impervious surfaces)
  - Using a water meter to measure the water used in landscape irrigation

The need for landscape irrigation programs and codes can potentially be reduced with effective conservation pricing structures.

Leak Detection and Water Loss Control Programs

A water loss control program identifies and quantifies water uses and losses from a water system through a water audit. Once identified, sources of water loss can be reduced or eliminated through leak detection, pipe repairs or replacement, and/or changes to standard program operations or maintenance protocols. Following these interventions, the water loss program can evaluate the success of the updates and adjust strategies as needed.

Automated meter reading (AMR) and advanced metering infrastructure (AMI) are technologies that can assist with leak detection. AMR technology allows water utilities to automatically collect water use data from water meters, either by walking or driving by the property. AMI systems automatically transmit water usage data directly to the utility without requiring an employee to travel to the property. AMI systems collect data in real time. Both technologies reduce the staff time required to read meters and allow utilities to more frequently analyze actual consumption (as opposed to predicting usage based on less frequent manual meter readings). Higher-than-expected readings can be flagged as potential leaks. Because of their ability to collect data more frequently, AMI systems may detect consumption anomalies sooner than AMR systems. AMI systems allow for earlier detection of smaller leaks so repairs can be made before a major pipe breaks. However, AMI systems are more expensive to install than AMR systems and therefore may not be economical for smaller utilities. Hybrid systems on the market allow for future migration from AMR to AMI.

An example of a basinwide water audit and water loss control program is that of CWWMG, which is undertaking a significant water audit project to identify real (leaks) and apparent (meter inaccuracy) water losses throughout the basin. This project identified 17 billion gallons of nonrevenue water that could be managed, thereby increasing utility revenue by $16.8 million (CWWMG 2023). Subsequent phases involve conducting economic analyses and identifying water loss goals for each CWWMG member and the entire group. A similar effort could be pursued within the Upper Savannah River basin.

Georgia is one of the few states that have implemented statewide water loss control requirements. In 2010, the Georgia Water Stewardship Act was enacted. The Act set water loss control requirements that apply to public water systems serving populations over 3,300, which include:

- Completing an annual water loss audit using American Water Works Association (AWWA) M36 Methodology
- Developing and implementing a water loss control program
- Developing individual goals to set measures of water supply efficiency
- Demonstrating progress toward improving water supply efficiency

Reclaimed Water Programs

Reclaimed water programs reuse highly treated wastewater for other beneficial purposes, reducing demands on surface water and groundwater. Water can be reclaimed from a variety of sources then treated and reused for beneficial purposes such as irrigating crops, golf courses, and landscapes; supporting industrial processes including cooling water at thermoelectric plants; and restoring the environment. The quality of reclaimed water would need to meet the water quality requirements of the end use. Emerging contaminants of concern (e.g., per- and polyfluoroalkyl substances [PFAS] and microplastics) would also need to be considered.

Time-of-Day Watering Limits

A time-of-day watering limit prohibits outdoor watering during the hottest part of the day, usually 10:00 a.m. to 6:00 p.m. This practice reduces water loss from evaporation.

Water Efficiency Standards for New Construction

Local ordinances can require that renovations and new construction meet established water efficiency metrics. These ordinances may either be set by the local government or rely on existing water efficiency certification programs such as Leadership in Energy and Environmental Design (LEED) or U.S. EPA's WaterSense. These programs have set water efficiency requirements for all household fixtures, such as a maximum rating of 2.5 gpm flow rate for showers and maximum rating of 1.6 gallons per flush for toilets (Mullen 2022).

6.1.3 Agriculture Water Efficiency Demand-Side Strategies

This section provides a more detailed description of the agricultural water efficiency practices considered as part of the toolbox of strategies. These demand-side strategies also apply to groundwater users.

Water Audits and Nozzle Retrofits

Water audits monitor water use in an agricultural irrigation system to identify potential opportunities for water efficiency improvements. Water audits consider water entering the system, water uses, water costs, and existing water efficiency measures. Water audits gather information on the size, shape, and topography of the agricultural field, depth to groundwater, vulnerability to flooding, pumping equipment, irrigation equipment, and past and present crop use and water use (Texas Water Development Board 2013).

Across South Carolina, Clemson University Cooperative Extension Service specialists and researchers have held meetings to talk with farmers about center pivot irrigation and discuss the Clemson Center Pivot Irrigation Test Program, a type of water audit offered by the Clemson Extension Water Resources, Agronomic Crops, and Horticulture Teams. These audits measure irrigation uniformity—the consistency of irrigation depth across the irrigated area. Without irrigation uniformity, some crops may experience overirrigation and some may experience underirrigation, leading to wasted water and lost profit. The Center Pivot Irrigation Test Program can provide growers with a map of irrigation depths, observed issues such as leaks and clogs, estimated costs of over- or underwatering, estimated costs for nozzle retrofits, and design versus observed flow rates and system pressure (Clemson Cooperative Extension 2022a). After the audit, a report is provided that includes an estimated cost of under- or overirrigation based on crop type. The cost of suboptimal irrigation is compared to the estimated cost of a sprinkler retrofit.

The South Carolina Mobile Irrigation Laboratory pilot project is another example water audit program. This project was the result of a partnership with South Carolina Department of Agriculture (SCDA) and Aiken Soil and Water Conservation District. Pilot project audits identified areas of over- and underwatering, suggested energy savings opportunities, and recommended upgrades or operational changes (SCDNR 2019d). The project provided no-cost water and energy audits of 24 agricultural center pivot irrigation systems throughout South Carolina over 3 years (SCDNR 2020).

Irrigation Scheduling and Smart Irrigation

Irrigation scheduling refers to the process of scheduling when and how much to irrigate crops based on the needs of the crops and the climatic/meteorological conditions. It ensures that crops are receiving the correct amount of water at the right time. The three main types of irrigation scheduling methods are soil water measurement, plant stress sensing, and weather-based methods. To measure soil water, farmers can use SMSs at varying depths. SMSs are of two types: those that measure volumetric water content and those that measure soil tension (University of Minnesota Extension 2024). Water application can be controlled and limited by identifying precise periods when irrigation is needed by using soil moisture measurements and other factors such as soil temperature, crop growth stage, localized evapotranspiration, and even weather forecasts. For weather-based methods, farmers can research regional crop evapotranspiration reports to develop an irrigation schedule. Additionally, farmers can use thermal sensors to detect plant stress (Freese and Nichols, Inc. 2020). The use of thermal and/or moisture sensors to automatically schedule irrigation is referred to as smart irrigation. Advanced irrigation scheduling and use of sensors and smart irrigation technology may reduce water use by 15 percent on average (Smart Irrigation 2019).

A Clemson University study on intelligent water and nutrient placement (IWNP) combines smart watering strategies with smart fertilizer applications. IWNP uses smart sensing with model-based decision support systems to determine the irrigation water and nutrient application required by crops at a given time (Clemson College of Agriculture, Forestry and Life Sciences 2021). The IWNP systems are installed on existing overhead irrigation systems as a retrofit. Clemson seeks to develop the IWNP system, then develop a training program to teach farmers how to use the system.

Feedback from the Upper Savannah RBC on this strategy was that irrigation scheduling can be a useful tool, but it needs to be conducted correctly to be effective. This strategy can be used in both agricultural and municipal settings (although the specific approaches and technologies may be different).

Soil Management and Cover Cropping

Soil management includes land management strategies such as conservation tillage, furrow diking, and the use of cover crops in crop rotations. The USDA defines conservation tillage as "any tillage or planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water" (USDA 2000). Conservation tillage can conserve soil moisture, increase water use efficiency, and decrease costs for machinery, labor, and fuel. Types of conservation tillage include:

- No Till – Soil is left undisturbed from harvest to planting except for nutrient injection. Planting is done in narrow seedbeds and a press wheel may be used to provide firm soil–seed contact (Janssen and Hill 1994).
- Strip Till – This practice involves tilling only the seed row prior to planting, disturbing less than one-third of the row width (Conservation Technology Information Center 1999).
- Ridge Till – This practice involves planting into a seedbed prepared on ridges using sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges to reduce soil loss (Janssen and Hill 1994).
- Mulch Till – This practice uses chisel flows, field cultivators, disks, sweeps, or blades to till soil in such a way that it does not invert the soil but leaves it rough and cloddy (Janssen and Hill 1994).

- Furrow Diking – The practice of creating small dams or catchments between crop rows to slow or prevent rainfall runoff and increase infiltration. Increased water capture reduces the supplemental irrigation needed, resulting in direct water savings.

- Cover Crops – This practice involves planting cover crops, such as cereal grains or legumes, following the harvest of summer crops. Cover crops use nutrients not used by previous crops, and protect against nutrient runoff and soil erosion. Cover crops can increase infiltration and the water-holding capacity of the soil, which may indirectly result in water savings because applied water is used more efficiently.

Crop Variety, Crop Type, and Crop Conversion

Changing crop types from those requiring relatively large amounts of water to those requiring less water can save significant amounts of irrigation water. Exact savings vary by crop, but could potentially be on the order of 15.8 acre-inches per acre (Freese and Nichols, Inc. 2020). Switching the variety of a particular crop may also be a water conservation strategy. For example, switching from full/mid-season corn to short-season corn could result in a savings of 3.7 acre-inches per acre. However, such a change could also result in substantial yield loss, making it an unviable option for some growers (Freese and Nichols, Inc. 2020).

In South Carolina, transitioning away from corn and small grains, such as wheat, rye, oats, and barley, and increasing cotton crops can reduce water use. However, because the choice of crops is market-driven and certain machinery, infrastructure, and skills are specific to different crops, changing crop type may not be economical for growers, especially in the Upper Savannah River basin. Conversion programs that offer growers incentives may be necessary.

Irrigation Equipment Changes

Changing from low-efficiency to higher-efficiency irrigation equipment can reduce water use but requires significant financial investment. Irrigation methodologies may include mid-elevation, low-elevation, low-elevation precision application, or drip/trickle irrigation. These methodologies have application efficiencies of 78, 88, 95, and 97 percent, respectively (Amosson et al. 2011).

Future Technologies

There are several emerging technologies to improve irrigation efficiency and water conservation that are under development or in the early stages of being adopted on a larger scale. An example of a future technology, as discussed herein, is smart irrigation systems that rely on soil moisture levels, weather conditions, and crop water needs in real time. High-efficiency irrigation control systems use weather data to adjust irrigation schedules automatically (HydroPoint 2012). Precision agriculture methods use Global Positioning System and satellite imagery to apply water, fertilizers, and pesticides more accurately. As new technologies are developed and commercialized, agricultural water users in the basin should consider how they might apply these technologies to conserve water.

6.1.4 Supply-Side Strategies

The Upper Savannah RBC did not identify any strategies that increase the amount of surface water available for withdrawal (supply-side strategies) since no significant water shortages were identified under the 2070 High Demand Scenario.

6.1.5 Technical Evaluation of Strategies

The effectiveness of surface water management strategies in the Upper Savannah River basin were evaluated using the SWAM surface water model. This analysis focused on the impact of the identified strategies on projected shortages and water availability.

Demand-Side Strategies

A demand-side management scenario was developed using the SWAM model to evaluate potential actions that could be used to reduce water demands and mitigate shortfalls. This scenario evaluated the effectiveness of municipal drought management plans. Although the Upper Savannah RBC included additional municipal and agricultural demand-side management strategies in the River Basin Plan, strategy effectiveness was not explicitly evaluated in the SWAM model. Agricultural water use accounts for less than 1 percent of current water use in the Upper Savannah River basin and is not projected to substantially increase over the planning horizon. Impacts to agricultural demand reduction are expected to have minimal impact on other water users or stream flows in the basin.

Drought Management Plans

This scenario evaluated the effectiveness of existing municipal water supply drought management plans with respect to mitigating drought impacts on water supply. Chapter 8, Drought Response, summarizes the municipal drought management plans. To model these plans, each municipal water provider was assumed to fully achieve water use reduction targets for a given drought condition, as specified in their drought management plans. Drought triggers and reduction goals identified in the drought management plans were incorporated into the SWAM model using the software's water user conservation rules. Rules were prescribed for the following surface water withdrawers, as outlined in Table 6-3: Seneca Light and Water, City of Greenville, ARJWS, Abbeville Public Water System, and McCormick CPW. For each of these users, water use was curtailed in the model in stages according to the user-specific drought triggers. Modeled triggers were based on effective system storage (volume or elevation). Other triggers included in the drought management plans but not modeled are based on factors such as drought declarations by the DRC or local entity, equipment failures, or sustained high water demands. Given the exclusion of some drought management triggers, the modeling results presented here could be deemed as slightly conservative, with respect to quantified gains in river flow or storage levels.

Table 6-3. Simulated drought management plans.

Water User	Reduction in Water Use (%)	Drought Phase	Drought Flow Trigger
Seneca Light and Water[1]	4	Low	LIP Stage 1
	7.5	Moderate	LIP Stage 2
	15	Severe 1	Storage falls below 35 percent of capacity OR LIP Stage 3
	20	Severe 2	Reservoir (Lake Keowee) at 15 feet below full
	25	Extreme	Reservoir (Lake Keowee) at 20 feet below full OR LIP Stage 4
City of Greenville[1]	4	Low	LIP Stage 1
	7.5	Moderate	LIP Stage 2
	15	Severe	LIP Stage 3
	25	Extreme	LIP Stage 4
ARJWS	No Specific Goal	Moderate	Reservoir (Lake Hartwell) at 652 feet mean sea level (msl)
	10	Severe	Reservoir (Lake Hartwell) at 646 feet mean sea level (msl)
	20	Extreme	Reservoir (Lake Hartwell) at 638 feet mean sea level (msl)
Abbeville Public Water System	15	Moderate	Lake Russell is 4.5 feet below full pool
	20	Severe	Lake Russell is 7 feet below full pool
	25	Extreme	Lake Russell is 10 feet below full pool
McCormick CPW	15	Moderate	Lake Thurmond is 5 feet below full pool
	20	Severe	Lake Thurmond is 10 feet below full pool
	25	Extreme	Lake Thurmond is 15 feet below full pool

1. Conservation rules for Seneca and Greenville were included in the Current Use, Moderate Demand, High Demand, and P&R Scenario results presented in Chapter 5.

Conservation rules were implemented for the Current Use, 2070 High Demand, and P&R Scenarios. There are no shortages reported for any of these scenarios without conservation rules, so the impacts of the conservation rules were assessed based on the frequency with which conservation rules are triggered. Table 6-4 outlines the frequency that demand reductions were triggered over the 1939 to 2021 hydrologic period for the five water users using the rules prescribed in the SWAM model. As expected, demand restrictions for the utilities shown are triggered more frequently as water demand throughout the Upper Savannah River basin increases and reservoir levels decline.

Table 6-4. Conservation rule trigger frequency.

Water User	Source Water	Current Use	2070 High Demand	Permitted & Registered
Seneca Light and Water	Lake Keowee	22.2%	23.2%	23.8%
City of Greenville		22.2%	23.2%	23.8%
ARJWS	Lake Hartwell	0.7%	1.7%	5.6%
Abbeville Public Water System	Lake Russell	0.0%	0.0%	0.0%
McCormick CPW	Lake Thurmond	10.3%	12.0%	14.5%

Additionally, the potential demand reduction because of conservation from these five water users was compared to the conservation pool storage of their source water reservoirs. This exercise illustrates the difference in scale between water user demands and reservoir usable storage volumes. Table 6-5 details how a 25 percent reduction in 2070 High Demand water user demands would reduce daily demands from Lakes Keowee, Hartwell, Russell, and Thurmond by 38.9 MGD. If the 25 percent demand reduction is enacted over a year, demands would be reduced by 14,200 million gallons over the year, which is only 1.7 percent of the total summer conservation pool of the four reservoirs. While this is a relatively small percentage, this conservation amount could translate to a few additional months of water availability, especially for water users with lower demands.

Table 6-5. Comparison of drought plan demand reductions to reservoir storage.

Water User	Source Water	Summer Conservation Pool Storage (million gallons)	Average Annual Demand in the 2070 High Demand Scenario (MGD)	25 Percent Conservation Reduction (MGD)	Reduction in Yearly Demand (million gallons)	Reduction in Yearly Demand as a Percentage of Conservation Pool Storage
Seneca Light and Water	Lake Keowee	52,714	9.5	2.4	869	1.6%
City of Greenville			104.1	26.0	9,499	18.0%
ARJWS	Lake Hartwell	395,663	36.2	9.1	3,308	0.8%
Abbeville Public Water System	Lake Russell	34,714	3.8	1.0	348	1.0%
McCormick CPW	Lake Thurmond	345,328	1.9	0.5	177	0.1%
	Total	**828,419**	**155.6**	**38.9**	**14,201**	**1.7%**

6.1.6 Feasibility of Surface Water Management Strategies

The Upper Savannah RBC assessed the feasibility of the strategies described in Sections 6.1.2 and 6.1.3 considering consistency with regulations, reliability of water source, environmental impacts, socioeconomic impacts, potential interstate or interbasin impacts, and water quality impacts. Table 6-6 presents this assessment. Agricultural/irrigation and golf course practices are presented first, followed by municipal, industrial, and thermoelectric practices that are generally evaluated as a single group of practices.

Color coding was used to identify the expected effect of the strategy within each category. Expected effects range from moderate to high adverse effects to moderate to high positive effects. The assignment of effects, whether adverse, neutral, or positive, was largely subjective and based on professional judgment and feedback from the RBC. The color coding used for the expected effects listed in Table 6-6 are shown below.

Color Coding for Assigning Expected Effects in Table 6-6.

Potential Moderate/High Adverse Effect	Potential Low Adverse Effect	Likely Neutral Effect (either no effect, or offsetting effects)	Potential Low Positive Effect	Potential Moderate/High Positive Effect

Table 6-6. Water management strategy feasibility assessment.

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Demand-Side Agricultural/Irrigation Practices							
Water Audits and Nozzle Retrofits	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits:** Prevention of overwatering may limit runoff, erosion, and sedimentation.	No to low anticipated effects – Financial gains from reduced delivery and pumping costs likely outweigh costs of audit and nozzle retrofits.	No anticipated effects	See Environmental Benefits.
Irrigation Scheduling and Smart Irrigation	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits**: May reduce overfertilization and prevention of overwatering may limit runoff, erosion, and sedimentation.	Low to moderate effects – Initial costs of advanced technology may be partially offset by savings from reduced water and nutrient use.	No anticipated effects	See Environmental Benefits.
Soil Management and Cover Cropping	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Increase in herbicides may be required. **Benefits:** May improve soil quality and reduce runoff.	Low to moderate effects – Initial costs of new equipment plus training and operations and maintenance (O&M) costs. Costs may be partially offset by reduction in soil, water, and nutrient loss.	No anticipated effects	No to low anticipated impacts – Conservation tillage may increase potential leaching of nitrogen or pesticide to groundwater. See also Environmental Benefits.
Crop Variety, Crop Type, and Crop Conversions	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Variation in chemical application for different crops must be considered.	Medium to high anticipated effects – Potential profit loss from switching to lower demand crop or from a full season to short-season crop.	No anticipated effects	No anticipated impacts.

Table 6-6 (continued). Water management strategy feasibility assessment.

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Demand-Side Agricultural/Irrigation Practices							
Irrigation Equipment Changes, including Drip/Trickle Irrigation	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Changing equipment may disturb environmentally sensitive areas.	Low anticipated effects – Initial costs of equipment changes may be partially offset by water use savings. Investments in drip/trickle irrigation may not be economical for low value crops.	No anticipated effects	No anticipated impacts.
Future Technologies	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits**: May reduce overfertilization and overwatering; may limit runoff, erosion, and sedimentation.	Low to moderate effects – Initial costs of advanced technology may be partially offset by savings from reduced water and nutrient use.	No anticipated effects	See Environmental Benefits.
Demand-Side Municipal Practices							
Development, Update, and Implementation of Drought Management Plans	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability during droughts.	**Impacts:** None anticipated.	Low anticipated effects – Effects to utility revenue if demand reductions are substantial. Positive effect to residential users from reduced water bills (if billed at unit rates).	No anticipated effects	No anticipated impacts.

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Table 6-6 (continued). Water management strategy feasibility assessment.

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Demand-Side Municipal Practices							
Public Education of Water Conservation	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated.	Low to no anticipated effects – Effects to utility revenue if demand reductions are substantial. Positive effects to residential users from reduced water bills (if billed at unit rate).	No anticipated effects	No anticipated impacts.
Conservation Pricing Structures	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated.	Moderate anticipated effects – Customers who cannot reduce water use may face economic hardship. Reduced billing revenue for utilities may cause financing issues or lead to further rate increases.	No anticipated effects	No anticipated impacts.
Residential Water Audits	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated.	No to low anticipated effects – Revenue effects to utility from reduced demand may be offset by lower delivery costs. Effects to homeowners from repairs may be offset by reduced water bills (if billed at unit rate). The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	No anticipated impacts.

Table 6-6 (continued). Water management strategy feasibility assessment.

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Demand-Side Municipal Practices							
Leak Detection and Water Loss Control	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts**: None anticipated.	Cost of program implementation could result in rate increase, no impact, or potential rate decrease, depending on circumstances.	No anticipated effects	No anticipated impacts.
Time-of-Day Watering Limit	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts**: None anticipated.	The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	No anticipated impacts.
Reclaimed Water Programs/ Water Reuse and Recycling (a demand- and supply-side strategy)	Demand-side – Municipal	SCDES regulates reclaimed wastewater systems for irrigation use with public contact; there are no laws or regulations pertaining to indirect potable reuse or direct potable reuse.	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low to moderate anticipated impacts: Depending on the extent of reclaim demand, reduced discharge from wastewater treatment facilities may reduce low-flow levels. **Benefits:** Depending on the extent of reclaim demand, reduced discharge from wastewater treatment facilities may result in improved receiving water quality.	Moderate anticipated effects – Higher initial water bills to finance a reclaimed water program may be offset by long-term savings from postponing the need for new supplies and raw water treatment facilities. The need to hire operations staff could contribute to rate increase.	No anticipated effects	See Environmental Benefits Need to match end use with quality of reclaimed water. Consider emerging contaminants of concern (e.g., PFAS and microplastics).

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Table 6-6 (continued). Water management strategy feasibility assessment.

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Demand-Side Municipal Practices							
Landscape Irrigation Program and Codes	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits:** Water quality of receiving waters may be improved by reducing runoff from landscaping.	Low anticipated effects – Mandates to meet standards may cause financial hardship for homeowners. No anticipated effects to homeowners from educational programs. The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	See Environmental Benefits.
Building Code Requirements (Water Efficiency Standards for New Construction)	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands	**Impacts:** None anticipated	Low anticipated effects – Efficiency standards may make renovations or construction more expensive and limit access to renovate or build. The need to hire implementation and compliance staff would contribute to rate increase	No anticipated effects	No anticipated impacts

[1]For the purposes of this comparison, "impacts" can be understood as potentially adverse consequences, while "benefits" are potential advantageous consequences.

6.1.7 Cost-Benefit Analysis

Cost and benefit information for each strategy, in terms of potential cost or water savings, is discussed in this section. These are generalized values from literature or other locations and should be considered for planning-level assessment only, to help screen and understand the alternatives. Implementation planning would require more specific analysis.

The information provided in this chapter is not intended to rule any alternative into or out of a recommended River Basin Plan for the Upper Savannah River basin. Rather, the information is for comparison purposes, so that the potential benefits, risks, and impacts of the alternatives can be better understood and decision-makers can make more informed decisions about priorities.

Demand-Side Municipal Strategies

Public Education of Water Conservation

Building water conservation awareness will not only save water but will reduce operational and production costs. Savings are estimated at 5,000 gallons per household per year for 30 percent of households targeted. Public education and outreach costs more per person in smaller communities than in larger ones ($2.75 per person per year for communities less than 20,000 and $1.80 per person per year for communities with more than 20,000) (Freese and Nichols, Inc. 2020).

Conservation Pricing Structures/Drought Surcharge

Implementing conservation pricing rate structures that discourage the inefficient use or waste of water is a cost-effective option for utilities because there are no direct costs to them to achieve a reduction in demand. However, reduction in billing revenue associated with decreased customer usage must be considered. On average, in the United States, a 10 percent increase in the marginal price of water in the urban residential sector can be expected to diminish demand by about 3 to 4 percent in the short run (Olmstead and Stavins 2009). An example application in the Texas Panhandle assumed 10 percent of households would respond and change their water consumption behavior, resulting in 6,000 gallons saved per household per year (Freese and Nichols, Inc. 2020).

Residential Water Audits

Residential water audits may result in implementing various strategies, retrofits, and other measures that may save up to 20 to 30 gallons of water per day per household. Costs include costs for water audits (if applicable) and for replacing or repairing household water systems.

Landscape Irrigation Programs and Codes

If water efficiency measures are required, costs would be associated with enforcement. If not required, costs would be associated with incentives or education programs. If programs include rebate offerings, the cost of the rebate itself and costs for administering the program must be considered. Smart irrigation controllers with an EPA WaterSense certification are commercially available for between $120 and $280. These costs assume there is already a compatible irrigation system in place. Costs to the homeowner would be greater if irrigation system installation or renovation is required. Irrigation with a smart irrigation meter rather than a standard irrigation meter may result in a water use efficiency reduction of 30 percent. An example of a turf replacement rebate is from California's Metropolitan Water District, which offers a

$2 per square foot rebate for up to 5,000 square feet. The cost to the utility or municipality would be dependent on the rebate rate and percent uptake by customers.

Leak Detection and Water Loss Control Programs

EPA estimates that the average water loss in water systems is 16 percent, with up to 75 percent of the water loss potentially recoverable through a water loss control program (U.S. EPA 2013). Since 2010, Georgia's public water systems have reported, on average, between 13.5 and 17.4 percent water loss; however, 43 of 263 systems reported over 30 percent average annual water loss since 2010. Costs for a water loss control program would include the time spent conducting the water audit and costs for needed repairs, which would be system-dependent. However, water audits generally have been proven to be cost-effective. The AWWA M36 Manual of Water Audits and Loss Control Programs includes an example of a utility with a $79,000 water audit cost, which, in 2022 dollars, translates to a unit cost of $310 per water main mile (AWWA 2016).

AMI and AMR technologies greatly reduce the labor required for water meter reading. Davie County Public Utilities, a water system in North Carolina, required 50 days (with frequent misreads) to manually read all 11,000 service connections in their network. After using AMR technology, they reduced their meter reading rate to 3,000 meters in 2 days, with nearly 100 percent accuracy (Atkinson 2016). In Michigan, the Oakland County Water Resources Commission achieved a 99 percent read success rate and reduced their meter reading staff by half after implementing an AMR system (Atkinson 2016).

A cost-benefit analysis for Washington Suburban Sanitary Commission Water concluded that an AMI system would pay for itself in 11 years, and savings would exceed $286 million over a 20-year period (Arcadis 2020). The project cost was estimated to total $208 million dollars, with the primary cost driver of replacing 492,000 meters. The analysis estimated that 29 of the existing 37 meter reader employee positions would be eliminated, and the utility would have a revenue gain of more than $580 million over 20 years because of improved meter accuracy. The improved domestic leak detection would save customers approximately $56 million over 20 years. Intangible benefits include safer working environments for utility employees from reducing meter reading field activities, water and energy conservation by customers, identification of meter tampering and potential water theft, and benefits from more frequent billing cycles.

Another example is Red Star Water District, a small water system in Leedey, Oklahoma. The district conducted a water loss audit and found real losses of 28.9 million gallons per year, valued at $71,962 and representing 25.2 percent of the total water supplied to the system. After identifying 29 leaks, the district adopted an aggressive program of leak repair and was able to repair all leaks, saving the system 26 million gallons of water per year at a value of $71,000 annually (Oklahoma Department of Environmental Quality 2021).

Reclaimed Water Programs

Benefits include increased water supply, increased reliability, and reduced effluent disposal. Initial costs may be substantial and include construction/retrofit costs to wastewater facilities for full reuse capabilities and construction of distribution lines to end users. Benefits may result by lowering demand on highly treated potable water, thereby extending the source of supply and delaying the need for future upgrades to treatment processes or procuring additional water sources. The overall cost benefit depends on the system, the end user, the cost of the treatment, and many other factors. Utilities and others that have implemented reclaimed water programs have typically done so after careful analysis and planning to demonstrate the long-term financial viability of a reclaimed water program.

Time-of-Day Watering Limits

Setting a time-of-day watering limit may save up to 1,000 gallons of water per household per year, depending on the amount of irrigated landscape. Costs are associated with enforcement and can vary depending on the size of the utility, but these costs are expected to be low. Utilities may benefit from reduced water use and a reduction in peak demands if a time-of-day water limit restricts usage before typical morning peak demands.

Water Efficiency Standards for New Construction

High efficiency toilets can save more than $100 per family per year (Mullen 2022). U.S. EPA estimates that fixtures meeting the WaterSense requirements can save approximately 700 gallons of water per year per household (U.S. EPA 2021). The costs associated with implementing local ordinances outlining water efficiency standards is low. There are numerous examples that can be used to guide ordinance development and implementation.

Demand-Side Agricultural Strategies

Water Audits and Nozzle Retrofits

The cost of a Clemson Center Pivot Irrigation Test Program audit is $125.00 per pivot. Costs of other water audits vary significantly depending on whether they are conducted internally, by a consultant, or by a government entity. While the process of conducting a water audit does not alone provide benefits, if improvements such as nozzle retrofits are made, benefits can include increased water efficiency and energy savings. An approximately 15 percent reduction in water use could be expected from nozzle retrofits made following a center pivot sprinkler audit (Walther, pers. comm. 2021).

A sample audit report provided by Clemson Cooperative Extension estimates the cost of a retrofit sprinkler package at $5 per foot of pivot length (Clemson Cooperative Extension 2022b). In this example, the total cost to retrofit is estimated at $2,982. Using an assumed crop value, irrigation need, and cost of under- or overirrigation, the estimated suboptimal irrigation cost is $4.39 per acre. With an irrigated area of 37.4 acres, this is an estimated loss of $164. Over the estimated 23.6-year lifespan of the retrofit, this equates to $3,875 in savings compared to the total cost of $3,107 ($2,982 cost of the retrofit plus the $125 cost of the initial audit).

Irrigation Scheduling and Smart Irrigation

According to the 2021 Texas Panhandle Water Plan, the cost of a typical smart irrigation system ranges from $6.50 to $12.00 per acre and benefits amount to approximately 10 percent of the water used on each crop seasonally (Freese and Nichols, Inc. 2020). Other studies suggest that irrigation scheduling may reduce water use by 15 percent on average (Smart Irrigation 2019). The overall cost savings is hard to quantify, given the variability in irrigation rates, the cost of pumping, the potential increase in crop yield that results from optimizing irrigation, and other factors. A simple example assuming a center pivot irrigated area of 81 acres, a cost of $648 for a smart irrigation system ($8 per acre), and an annual cost of $1,374 ($16.96 per acre) for energy associated with pumping (North Carolina State University 2007), suggests that if a smart irrigation system is able to reduce water use by 15 percent, then the $648 capital cost of the system will be recovered in just over 3 years.

Soil Management

The 2021 Texas Panhandle Water Plan assumed a 1.75 acre-inches per acre of water savings from soil management strategies (Freese and Nichols, Inc. 2020). While conservation tillage may result in savings from reduced machine, fuel, and labor costs, depending on the conservation type implemented, it also has initial costs to transition from conventional to conservation tillage, including the purchase of new equipment and any chemical control costs (herbicides or pesticides). For example, ridge tilling requires specially designed equipment such as a ridge cultivator or ridge planter.

Implementing furrow diking can range from less than $2,000 to several thousand dollars. Per crop per season per acre estimates range from $5 to $30. The Texas Water Development Board estimates water savings of 3 inches per season (0.2 acre-feet per acre), but savings will vary by field and season. Using the irrigation of corn with a 113-day growing season as an example, a reduction in 3 inches per season would be expected to lower the seasonal irrigation need from 9.9 inches to 6.9 inches, assuming average seasonal precipitation of 16 inches, and an average seasonal corn crop watering need of 25.9 inches. The reduction of 3 inches would save approximately $10 per acre in irrigation system operating cost.

Crop Variety, Crop Type, and Crop Conversion

The cost of implementation and the actual reduction in irrigation water used will depend on numerous local factors including market pricing, cost of seed, cost of harvesting, and the value of crops.

If farmers are encouraged to switch from long-season varieties to short-season varieties, they may experience loss in yield and therefore revenue. However, they will see savings from reduced seed, pumping, fertilizer, harvest, and water use costs.

Irrigation Equipment Changes

Irrigation equipment changes may focus on lowering the elevation of nozzles on center pivot systems. Total replacement of a system (assumed 125-acre, 30-inch spacing) with a new 60-inch spacing system is estimated at $151.20 an acre, including labor and new hoses, heads, and weights. Conversion instead of full replacement of the same system is estimated at $44 per acre. Costs assume that the system is converting from low elevation spray application (LESA) or mid-elevation spray application (MESA) systems to low elevation precision application (LEPA) systems (Freese and Nichols, Inc. 2020). This transfer in irrigation practice may result in a 7 to 17 percent increase in irrigation efficiency and, consequently, decreased water usage. In most cases, irrigation equipment changes will be a combination of replacement and conversion.

Drip irrigation systems can cost between $500-$1,200 per acre (Simonne et al. 2024). Drip irrigation can improve the efficiency of both water and fertilizer applications, lowering the cost associated with pumping water and lowering fertilizer cost. Nutrient applications may also be better timed to meet plant needs. Drip systems can also be easily automated, lowering labor costs. One Texas cotton grower reported increasing their yield to 3 bales of cotton per acre using 16 inches of drip system water, compared to only 2.25 bales of cotton per acre using 16 inches of water from a center pivot system (Toro 2010). A Kansas corn grower who installed a drip system on 4,000 acres experienced a combined savings considering fuel, labor, chemical/fungicide, fertilizer, and cultivation of $160.05 per acre, compared to flood irrigation. At an initial capital cost of $1,200 per acre, the payback period for the drip system was 3.6 years (Toro 2007).

6.2 Groundwater Management Strategies

In the Upper Savannah River basin, less than 1 percent of current demands are met by groundwater and these demands are not projected to significantly increase over the planning horizon (SCDNR 2023b). The Upper Savannah RBC, therefore, focused the evaluation and selection of water management strategies on surface water management strategies. The demand-side strategies described in the previous section for surface water withdrawers also apply to the basin's limited groundwater withdrawers.

Chapter 7 Water Management Strategy Recommendations

The Upper Savannah RBC considered a wide variety of water management strategies for implementation in the Upper Savannah River basin. As water management strategies were identified and discussed, the RBC recognized that significant surface water shortages or ecological risk due to low surface water flows are not projected to occur over the approximately 50-year planning horizon. As such, the RBC focused their efforts on the demand-side strategies. While demand-side strategies are not likely to be needed for the purpose of reducing or eliminating projected shortages, they may have other benefits including reducing the cost of water production and use, building resilience, mitigating potential localized shortages that are difficult to capture in the modeling, and sustaining and extending surface water supplies if unforeseen conditions occur such as changes in climate patterns, higher than expected growth, or higher than expected water use.

The water management strategy recommendations presented in this chapter align with the RBC vision and goal statements for the basin. By assessing and recommending a portfolio of demand-side strategies, the stakeholders comprising the RBC are recommending actions that help achieve the RBC's vision statement: "***A resilient Upper Savannah River Basin that collaboratively, sustainably, and equitably manages and balances human and ecological needs.***" The selection and recommendation of the demand-side strategies also supports the RBC-identified goal to "***Improve the resiliency of the water resources and help minimize disruptions within the basin***".

7.1 Selection, Prioritization, and Justification for each Recommended Water Management Strategy

Demand-side strategies recommended by the Upper Savannah RBC to conserve surface water resources, enhance instream flows, and increase water supply availability are identified and discussed below.

Municipal Demand-side Strategies: The recommended municipal demand-side water management strategies are summarized in Table 7-1. The Upper Savannah RBC prioritized public education of water conservation. It was recognized that education is the cornerstone to building a water conservation ethic and that focusing education on youth is the most-effective, long-term approach. Conservation pricing structures and leak detection and water loss control programs were considered to be the next highest priority, as they can have significant benefits in sustaining supplies during drought, if implemented. The RBC did not prioritize the remaining strategies because of the significance of individual utility circumstances (e.g., current operations and programs, utility size, financial means) in determining which is the most desirable strategy to pursue. The strategies represent a "toolbox" of potential approaches to reduce water demands. Utility managers may find the descriptions and feasibility assessment presented in Chapter 6 helpful for determining which strategies to pursue.

Table 7-1. Municipal demand-side water management strategies.

Water Management Strategy	Prioritization
Public Education of Water Conservation	First
Conservation Pricing Structures	Second
Leak Detection and Water Loss Control Programs	
Reclaimed Water Programs	Toolbox of strategies. Applicability and priority vary by utility (see discussion below)
Residential Water Audits	
Landscape Irrigation Program and Codes	
Water Efficiency Standards for New Construction	
Time-of-Day Watering Limit	

As part of their discussions, the RBC identified several additional considerations related to these recommended, municipal demand-side water management strategies and other strategies that may be part of the overall toolbox:

- Stormwater best management practices should be used to encourage infiltration and reduce runoff. Allowing stormwater to infiltrate rather than runoff directly to streams and rivers enhances baseflow to streams, reduces flashiness, lowers sediment loading to lakes and reservoirs, and improves water quality.
- Water efficiency standards for new construction and the use of individual meters at multi-family residences can help reduce water demand.
- SCDES's sanitary survey requirements should be strengthened to focus more on the importance of leak detection and water loss control programs. Targets should be established. Leak detection-flyovers to identify leaks have proven useful for some utilities in the Upstate and elsewhere.
- Decreasing (also known as declining) block rate structures should not be used. Decreasing block rate structures encourage customers to use more water. Drought surcharges (discussed in Chapter 8) or increasing block rate structures should be considered to disincentivize high water use, especially during droughts.
- The RBC noted that some strategies can be complimentary, such as the implementation of conservation pricing structures with leak detection and water loss control programs to help water users identify opportunities to reduce water use and save money.
- The RBC also noted that some strategies may be cost-prohibitive to smaller utilities. Having a consortium of utilities to collaborate on implementation of conservation strategies can be beneficial. This communal knowledge sharing could also aid smaller utilities that do not have a dedicated conservation program with staff to assess the financial impacts of demand reductions and coordinate education and outreach programs.
- For effective implementation of strategies, it may be necessary to engage local governments.

Industrial and Energy Sector Strategies: The RBC identified and discussed water conservation approaches for manufacturing (industrial) and energy water users. In the Upper Savannah River basin, these water users include Clemson Energy, Milliken & Company, Hanson Aggregates, Oconee Nuclear Station, and Santee Cooper's Rainey Generating Station. The strategies identified by the RBC are water audits, rebates on energy-efficient appliances, water recycling and reuse, water saving equipment and efficient water systems, water-saving fixtures and toilets, and educating employees about water conservation. As with municipal strategies, these represent a "toolbox" of potential approaches to reduce water demands for the industrial and energy sectors.

Agricultural Demand-side Strategies: Agricultural surface water use accounts for less than 1 percent of current surface water use in the Upper Savannah River basin and is not projected to increase over the planning horizon. Although this use category is small, the RBC considered and has recommended several agricultural demand-side water management strategies. Some of these practices are likely already used in the basin. The recommended agricultural water management strategies are summarized in Table 7-2. The RBC chose not to prioritize strategies to recognize that the most appropriate strategy for a given agricultural operation will depend on the size of the operation, crops grown, current irrigation practices, and financial resources of the owner/farmer. The descriptions and feasibility assessment presented in Chapter 6 may be helpful to owners/farmers for determining which strategy to pursue.

Table 7-2. Agricultural water management strategy prioritization.

Water Management Strategy	Prioritization
Water Audits and Nozzle Retrofits	Toolbox of strategies. Priority varies by operation.
Irrigation Scheduling	
Soil Management	
Crop Variety, Crop Type, and Crop Conversion	
Irrigation Equipment Changes	

7.2 Remaining Shortages

The surface water modeling described in Chapter 5 did not indicate any significant projected shortages that may need to be addressed using surface water management strategies. The Current Use, Moderate, and High Demand planning scenarios all demonstrated no significant shortages and no ecological risk driven by future stream flow reductions. The recommended demand-side management strategies presented in this chapter will provide basin-wide benefit by increasing water supply and helping to maintain instream flows that support a healthy and diverse aquatic ecosystem. Implementation of these strategies also serves to protect against future climate conditions such as more frequent or severe droughts and water demands that exceed current projections.

7.3 Remaining Issues Regarding Designated Reaches of Interest or Groundwater Areas of Concern

The evaluation presented in Chapters 5 and 6 enabled the RBC to identify any Reaches of Interest or Groundwater Areas of Concern. Reaches of Interest are defined in the Framework as "specific stream reaches that may have no identified Surface Water Shortage but experience undesired impacts, environmental or otherwise, determined from current or future water-demand scenarios or proposed water management strategies" (SCDNR 2019a). The RBC did not identify any Reaches of Interest.

A Groundwater Area of Concern is defined in the Framework as "an area in the Coastal Plain, designated by a River Basin Council, where groundwater withdrawals from a specified aquifer are causing or are expected to cause unacceptable impacts to the resource or to the public health and well-being" (SCDNR 2019a). The Coastal Plain does not extend into the Upper Savannah River basin and therefore the RBC did not consider designating any Groundwater Areas of Concern.

7.4 Adaptive Management

Adaptive management is a flexible framework used to implement options as the future unfolds in a structured way to avoid the pitfalls of either underperformance or overinvestment. This allows for management adjustments based on real-time data and evolving conditions. Adaptive management can provide a means to more effective decisions and enhanced benefits while helping meet environmental, social, and economic goals; increasing scientific knowledge; and reducing tensions among stakeholders (National Research Council 2004).

Several pitfalls may occur because of uncertainties identified during river basin planning. The Upper Savannah RBC identified and discussed the following potential uncertainties, which an adaptive management approach may help to address (Bing 2024a, 2024b) as the planning process continues:

- **Climate change** – Adaptive management involves monitoring climate data, updating hydrologic models, and adjusting water management strategies accordingly. If a region experiences more frequent droughts than anticipated, water conservation measures can be implemented or intensified, and alternative water sources can be explored.

- **Population growth** – Population projections can be incorporated into water resource models and updated periodically. This allows planners to anticipate future water needs and develop infrastructure accordingly. If a municipality is expected to grow rapidly, adaptive management might involve expanding water treatment facilities or developing new water sources to meet an increasing demand.

- **Infrastructure maintenance** – Regular inspections and maintenance of water resources infrastructure allow for data-driven decision-making. Planners can prioritize maintenance activities based on the condition and criticality of infrastructure components. This approach helps in extending the lifespan of infrastructure and reducing the likelihood of unexpected failures.

- **Industrial growth and types of industry in the basin** – Adaptive management takes into account the types of industries present and their water usage patterns and may include monitoring industrial growth and adjusting water allocation and treatment processes to ensure that industrial water needs are met without compromising the overall water supply. An approach to monitor industrial growth may be to study and map changes in industrial parks and associated properties. LocateSC and the SC PowerTeam have statewide industrial property databases that can be used.

- **Cyberwarfare** – Adaptive management involves the integration of cybersecurity measures into water resources planning. This may include regular updates to security protocols, continuous monitoring for potential threats, and developing contingency plans to ensure the resilience of water management systems against cyberattacks.

- **PFAS and emerging contaminants** – Adaptive management allows for incorporating new scientific findings and regulatory changes into water quality management practices. By continuously updating treatment processes and monitoring programs, planners can better address the technical, financial, and human health risks posed by emerging contaminants and ensure the safety of water supplies.

- **Future land use patterns** – Land use changes (and related impacts on water supplies) should be continuously assessed. This could be accomplished through studying the counties' land use plans. The RBC has developed recommendations (discussed in Chapter 9) and implementation actions (discussed in Chapter 10) that are intended to provide information on the potential impact to water quantity and quality from land use changes.

- **Extreme flood events** – Adaptive management could involve using hydrological models and real-time data to predict and respond to flood risks. This approach enables planners to implement adaptive flood management strategies, such as dynamic reservoir operations and floodplain management, to mitigate the impacts of floods.

- **Modeling and data gaps** – Adaptive management addresses modeling and data gaps by continuously updating models with new data and refining them based on observed outcomes. This iterative process helps improve the accuracy of water resource models and ensures they remain relevant and reliable.

- **Georgia water use** – By engaging in continuous dialogue and data sharing with neighboring states, planners can develop mutually beneficial water allocation agreements and adapt to changing water demands and availability.

- **Energy uncertainty and loss of power** – Adaptive management plans for power outages by incorporating backup power systems and alternative energy sources into water management infrastructure. This ensures that water supply and treatment processes can continue uninterrupted during power outages.

As part of future Plan updates, the RBC will review these uncertainties, determine if and to what degree they have impacted current and projected water demand, water availability, or other factors, and identify or update strategies and develop recommendations to address them as needed.

Chapter 8
Drought Response

8.1 Existing Drought Management Plans and Drought Management Advisory Groups

8.1.1 Statewide Drought Response

The South Carolina Drought Response Act of 2000 (Code of Laws of South Carolina, 1976, Section 49-23-10, et seq., as amended) was enacted to provide the state with a mechanism to respond to drought conditions (SCDNR 2009). The Act stated that SCDNR will formulate, coordinate, and execute a statewide drought mitigation plan. The Act also created the South Carolina DRC to be the major drought decision-making entity in the state. The DRC is a statewide committee chaired and supported by SCDNR's SCO with representatives from local interests.

To help prevent overly broad response to drought, the Act assigned SCDNR the responsibility of developing smaller DMAs within the state. SCDNR split the state into four DMAs that generally follow the boundaries of the four major river basins but are delineated along geopolitical county boundaries rather than basin boundaries. The Upper Savannah River basin is largely within the West (Savannah Basin) DMA but has portions of its eastern area in the Central (Santee Basin) DMA as shown in Figure 8-1. The Governor appoints members from various sectors to represent each DMA within the DRC. The organizational relationship of the DRC, DMAs, SCDNR, and SCO are illustrated in Figure 8-2.

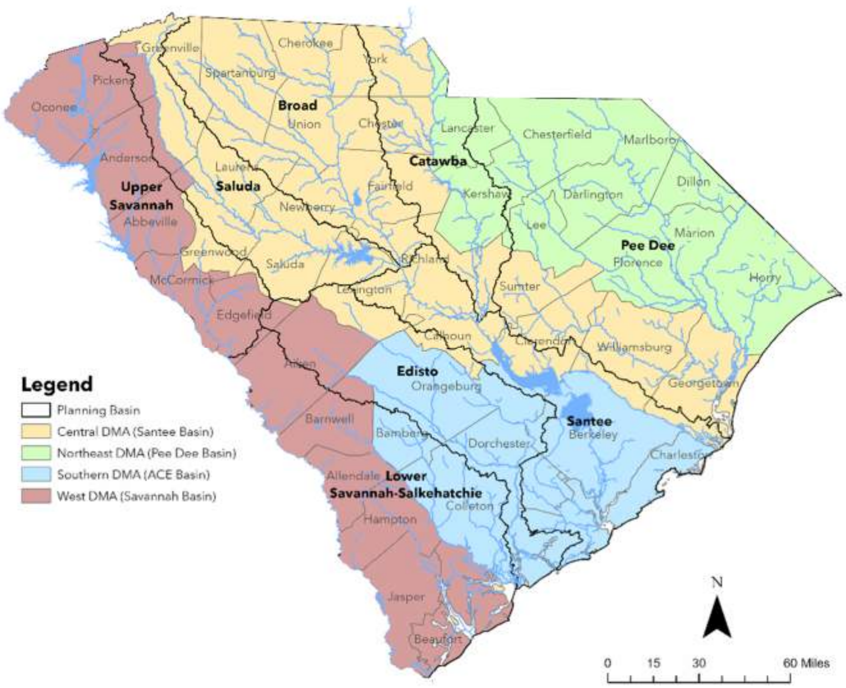

Figure 8-1. The four Drought Management Areas.

In accordance with the Drought Response Act of 2000, SCDNR developed the South Carolina Drought Response Plan, which is included as Appendix 10 of the South Carolina Emergency Operations Plan. South Carolina has four drought alert phases: incipient, moderate, severe, and extreme. SCDNR and the DRC monitor a variety of drought indicators to determine when drought phases are beginning or ending. Examples of drought indicators include streamflows, groundwater levels, the Palmer Drought Severity Index, the Crop Moisture Index, the Standardized Precipitation Index, and the United States Drought Monitor. The South Carolina Drought Regulations establish thresholds for these drought indicators corresponding to the four drought alert phases. Declaration of a drought alert phase is typically not made based only on one indicator, rather a convergence of evidence approach is used. The need for the declaration of a drought alert phase is also informed by additional information including water supply and demand, rainfall records, agricultural and forestry conditions, and climatological data.

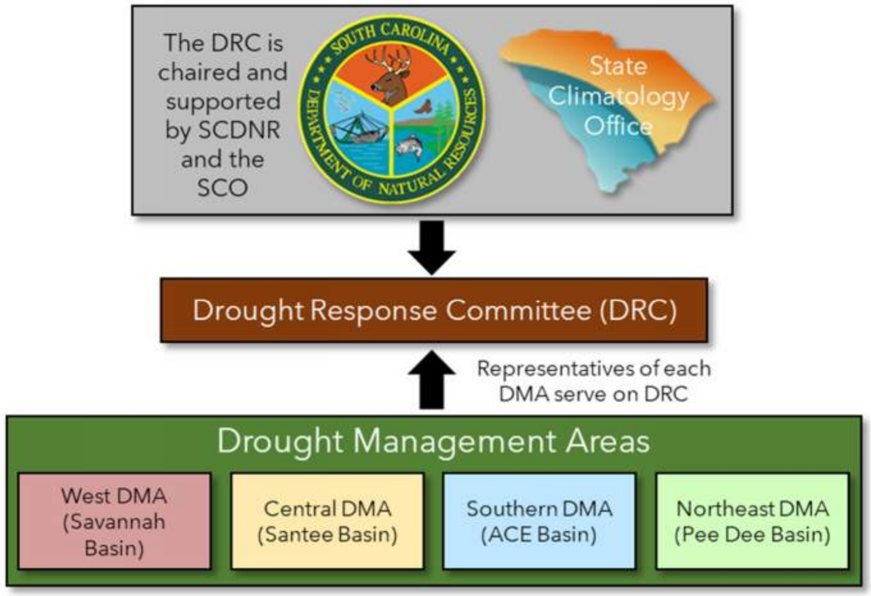

Figure 8-2. Drought Act organizational chart.

Based on their assessment of drought conditions, SCDNR and the DRC coordinate the appropriate response with the affected DMAs or counties. Local drought response is discussed in more detail in the following section. Under Section 49-23-80 of the Drought Response Act, if SCDNR and the DRC determine that drought has reached a level of severity such that the safety and health of citizens are threatened, the DRC shall report such conditions to the Governor. The Governor is then authorized to declare a drought emergency and may require curtailment of water withdrawals.

8.1.2 Local Drought Response

At a local level, Section 49-23-90 of the Drought Response Act states that municipalities, counties, public services districts, and commissions of public works shall develop and implement drought response plans or ordinances. These local plans must be consistent with the State Drought Response Plan. The SCO developed model drought management plan and response ordinance for local governments and water systems to use as templates, and more recently prepared a Drought Planning Guidebook which serves as a sister document to the model drought plan and helps provide context for building a robust local drought plan for water systems. The guidebook uses case studies and best practices taken from water systems within South Carolina.

In a drought mitigation plan, each phase of drought has a set of responses that are set in motion to reduce demand, bolster supply, or both. The drought plans and ordinances include system-specific drought indicators, trigger levels, and responses. Responses include a variety of actions that would be taken to reduce water demand at the levels indicated in Table 8-1. When drought conditions have reached a level of severity beyond the scope of the DRC and local communities, the State Drought Response Plan, Emergency Management Division, and State Emergency Response Team are activated.

The drought response plans and ordinances prepared by public water suppliers located in the Upper Savannah River basin or who draw water from the basin largely follow the templates prepared by SCDNR. The drought response plans for all water systems in the Upper Savannah River basin are summarized in Table 8-2. Many of the plans were submitted to SCDNR in 2003, shortly after the Drought Response Act went into effect in 2000. As such, they may present information that is outdated. The Drought Response Act of 2000 did not explicitly require drought plans to be updated at a specific interval.

Table 8-1. Demand reduction goals of drought response plans in South Carolina.

Drought Phase	Response
Incipient	None specified
Moderate	Seek voluntary reductions with the goal of: ▪ 20% reduction in residential use ▪ 15% reduction in other uses ▪ 15% overall reduction
Severe	Mandatory restrictions for nonessential use and voluntary reductions of all use with the goal of: ▪ 25% reduction in residential use ▪ 20% reduction in other uses ▪ 20% overall reduction
Extreme	Mandatory restrictions of water use for all purposes with the goal of: ▪ 30% reduction in residential use ▪ 25% reduction in other uses ▪ 25% overall reduction

Table 8-2. Drought response plans for water suppliers withdrawing water from the Upper Savannah River basin.

Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Abbeville Public Water System [2]	2003	West	**Surface Water** - Lake Russell	- Lake Russell is 4.5 feet, 7 feet, or 10 feet below full pool. - The upper water intake screen at Raw Water Pump Station is only partially submerged, the upper raw water intake is completely out of the water, or the lower raw water intake is only partially submerged. - Average daily flow is greater than 4.5 MGD for 3, 10, or 14 consecutive days. - Reservoir is completely full. - There are 3 days or 1 day of supply remaining.	None
ARJWS	2008	West	**Surface Water** - Lake Hartwell	- Reservoir at 652, 646, or 638 feet msl. - Average daily demands greater than 80%, 90%, or 95% of rated treatment capacity for 3 consecutive days. - Equipment failure that impacts 10%, 15%, or 25% of plant capacity.	None
Bethlehem Roanoke Water District (BRWD) and Dacusville-Cedar Rock Water Company (DCWC)	2003	West	**Purchase** - City of Pickens, City of Greenville	- Determination is made by the source suppliers and then by BRWD leadership.	Emergency 6 in. tap from the City of Easley for use during peak demand or emergency situations.

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively.

[2] Abbeville drought triggers stating the reservoir is completely full correspond to moderate and severe drought phases. Drought triggers related to days of supply remaining relate to severe and extreme drought phases.

Table 8-2. Drought response plans for water suppliers withdrawing water from the Upper Savannah River basin (Continued).

Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Broadway Water District (WD)	2003	West	**Surface Water Purchase** - ARJWS (Lake Hartwell)	*No plan on file, other than a statement that says, "Due to the past history of our demand for water and to the availability of water supplied by Lake Hartwell, we foresee no reason to restrict our users beyond limitations outlined in our Plan."*	
City of Anderson/ Electric City Utilities	2008	West	**Surface Water Purchase** - ARJWS (Lake Hartwell)	- Reservoir at 652, 646, or 638 feet msl. - Equipment failure that affects 10%, 15%, or 25% or more of plant capacity. - Average daily use greater than or equal to 24 MGD, 28 MGD, or 32 MGD for 3 consecutive days.	None
City of Liberty	2003	West	**Purchase** - Greenville Water System and Pickens County Water Authority	- Storage falls below 75, 50, or 25 percentage of capacity. - Average daily use greater than 0.8 MGD for 30 consecutive days, 0.93 MGD for 10 consecutive days, or 1.05 MGD for 5 consecutive days. - If restrictions are imposed by Greenville Water System or Pickens County Water Authority.	Auxiliary supply is available through a 10 in. main connection to Easley-Central Water District.
City of Pickens	2003	West	**Surface Water** - City Reservoir, Middle Fork Creek	- Reservoir gets 2 inches, 11 inches, or 22 inches below top of dam.	Can obtain 4.5 MGD from Greenville Water System.
DCWC	2003	West	**Purchase** - City of Easley, City of Greenville	- Determination is made by the source suppliers and then by DCWC leadership.	None
Easley Central WD	2003	West	**Surface Water and Purchase** - Twelve Mile River, City of Liberty (potable water connection)	- Storage falls below 80, 70, or 60 percentage of capacity. - Average daily use greater than 1.8 MGD, 1.9 MGD, or 2.0 MGD for 30 consecutive days.	Verbal agreement with the City of Liberty to purchase up to 0.300 MGD as needed based on system demand.
Easley Central WD #2	2003	West	**Purchase** - Easley Combined Utilities (in Saluda basin)	- Storage falls below 80, 70, or 60 percentage of capacity.	Verbal agreement with the City of Liberty to purchase water as needed in emergency situations through a master meter
Greenville Water	2024	West and Central	**Surface Water** - Lake Keowee. In the Saluda River basin, Table Rock Reservoir and Poinsett (North Saluda) Reservoir	- When the LIP for the Keowee-Toxaway River Basin is in Stage 2 and both Table Rock Reservoir is below 1,245 feet and the North Saluda Reservoir is below 1,225 feet. - When the LIP for the Keowee-Toxaway River Basin is in Stage 3 and both Table Rock Reservoir is below 1,240 feet and the North Saluda Reservoir is below 1,220 feet. - When the LIP for the Keowee-Toxaway River Basin is in Stage 4 and both Table Rock Reservoir is below 1,235 feet and the North Saluda Reservoir is below 1,215 feet.	None
Highway 88 Water District	2003	West	**Purchase** - Town of Central, Southside District, and Easley Central WD	- Governed by the actions taken by its suppliers and will take actions consistent with theirs.	None

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively.

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Table 8-2. Drought response plans for water suppliers withdrawing water from the Upper Savannah River basin (Continued).

Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Homeland Park WD	2003	West	**Surface Water Purchase** - ARJWS (Lake Hartwell)	- Reservoir at 652, 646, or 638 feet msl. - Average daily use is greater than 0.90 MGD for 30 consecutive days, 1.0 MGD for 10 consecutive days, or 1.15 MGD for 5 consecutive days. - Pressure falls below 40, 30, or 25 pounds per square inch (psi).	None
Isaqueena Point Utility System	2003	West	**Groundwater** - one 250-foot well	- Reservoirs, streamflows, aquifer levels in the County and surrounding areas at below normal levels. - Communications and directives from SCDNR and SCDHEC (now SCDES) indicating moderate, severe, or extreme drought conditions.	Connection to the Town of Salem Water System for back-up and emergency water. Limitations can be set by Salem depending upon the level of drought conditions.
Keowee Key Utility System	2003	West	**Surface Water Purchase** - Lake Keowee, via Seneca	- Follows direction from Seneca.	None
McCormick CPW	2003	West	**Surface Water and Groundwater** - Strom Thurmond Reservoir, 630-foot deep well	- Strom Thurmond Lake is 5, 10, or 15 feet below full pool. - Average daily flow is greater than 2.0 MGD for 3, 10, or 14 consecutive days. - Reservoir is completely full. - Two feet of water above all raw water intakes at Lake Thurmond, one raw water intake inlet above lake level, or two raw water intake inlets above lake level.	Station on Rocky Creek for emergency use only.
Pioneer Rural Water District	2003	West	**Surface Water Purchase** - Westminster and Seneca	- Notification by one or more suppliers as to their inability to supply 100%, 90%, or 80% of requirements.	None
Powdersville Water District	2008	West	**Purchase** - Lake Hartwell, Lake Keowee, and Saluda Lake via Greenville Water System, Easley Combined Utilities, and ARJWS	- Average daily use greater than 2.50 MGD for 30 consecutive days, 3.72 MGD for 10 consecutive days, or 4.80 MGD for 5 consecutive days. Additional Moderate Triggers: - One of the 3 transmission lines has to be taken out of service. - Pressure falls below 40 psi. Additional Severe Triggers: - One pump is out of service. - One of the sources calls to cut back on water use. - One tank is out of service. Additional Extreme Triggers: - Two pumps are out of service. - Two tanks are out of service. - Two of the sources calls to cut back on water use.	Can reverse backflow at the master meters to be able to feed back to one of the 3 sources from the supply, and can receive water from 2 of the 3 sources.

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively.

Table 8-2. Drought response plans for water suppliers withdrawing water from the Upper Savannah River basin (Continued).

Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Seneca Light and Water [3]	2008	West	**Surface Water** - Lake Keowee	- Storage falls below 35 percentage of capacity. - Average daily use greater than 12 MGD for 2 consecutive days. - Reservoir at 15 feet or 20 feet below full. - Part of the Keowee-Toxaway Drought Management Group, so follows Duke's direction on drought stages.	Agreements with Westminster and Walhalla; however, this is primarily to provide (rather than receive) aid due to size differences.
Six Mile Rural Community Water District (RCWD)	2003	West	**Purchase** - City of Pickens, City of Greenville	- Based on City of Pickens and Greenville Water System triggers.	None
Southside RCWD	2003	West	**Purchase** - Easley Combined Utilities, City of Liberty, Easley-Central Water District	- Based on Easley Combined Utilities and City of Liberty triggers.	None
Town of Calhoun Falls	N/A	N/A	**Surface Water Purchase** - Abbeville	*No plan on file. It is assumed that they follow Abbeville's Plan.*	
Town of Central	2003	West	**Purchase** - Easley Central WD	- Based on Easley Central's trigger levels.	None
Town of Salem Water System	2003	West	**Groundwater and Surface Water Purchase and Groundwater** - City of Seneca and five groundwater wells	- Storage falls below 30, 20, or 10 percentage of capacity. - Reaching 1.2, 1.0, or 0.5 days of supply remaining. - Average daily use greater than 0.25 MGD for 15 consecutive days, 0.35 MGD for 10 consecutive days, or 0.50 MGD for 5 consecutive days.	None
Town of Walhalla [4]	2003	West	**Surface Water** - Coneross Creek (Poor Farm Reservoir), Negro Fork Creek, Lake Keowee	- Creek flow drops below 50% of capacity. Poor Farm Reservoir must be accessed to increase stream flow and meet demand Poor Farm Reservoir level falls 5 feet or more.	None

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively.

[3] Seneca drought triggers related to storage and average daily use correspond to moderate, severe, and extreme drought phases. Drought triggers related to reservoir levels correspond to severe and extreme drought phases.

[4] Walhalla drought triggers are cumulative, i.e., the first trigger indicates moderate drought phase, the first and second triggers indicate severe drought phase, and all three triggers indicate extreme drought phase.

Table 8-2. Drought response plans for water suppliers withdrawing water from the Upper Savannah River basin (Continued).

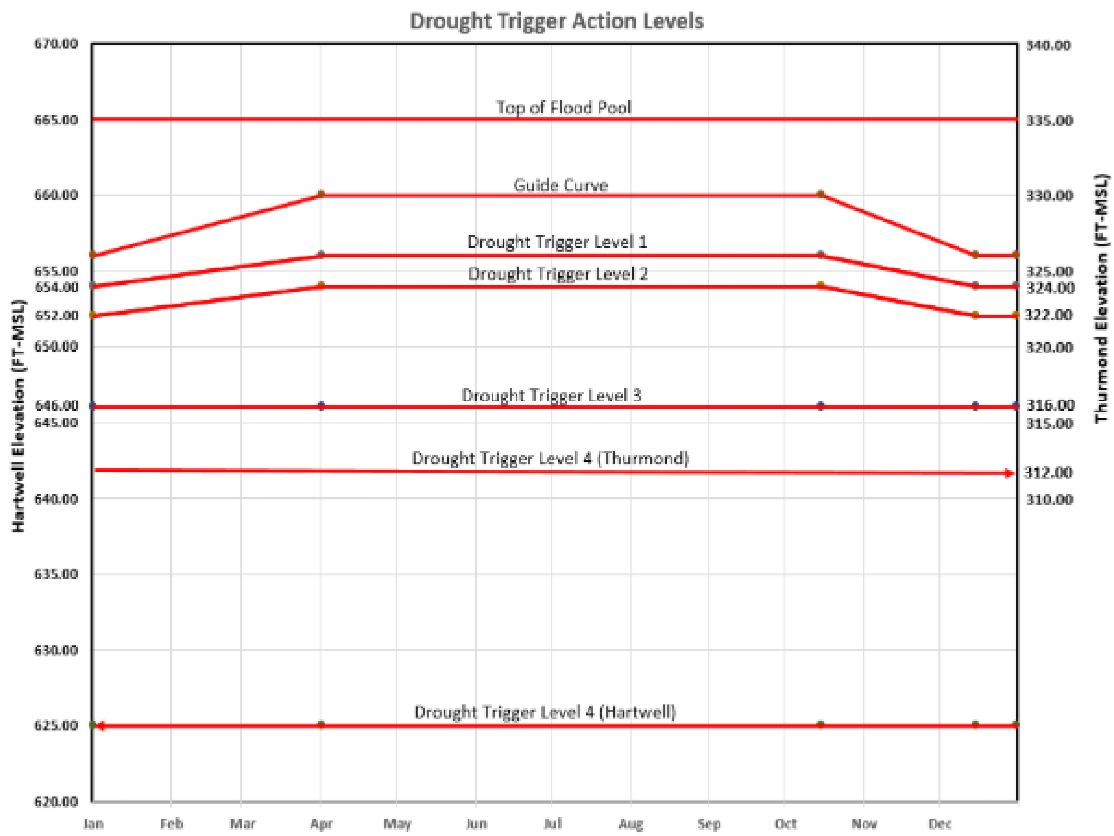
Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
West Anderson WD	2009	West	**Surface Water Purchase** - ARJWS (Lake Hartwell)	- Reservoir at 652, 646, or 639 feet msl. - Average daily use is greater than 1.6 MGD for 30 consecutive days, 1.9 MGD for 10 consecutive days, or 2.1 MGD for 5 consecutive days. - Water pressure falls below 40, 30, or 25 psi. Additional Moderate Trigger: - One pump is out of service at Station #1. Additional Severe Triggers: - One of the pump stations is out of service between the months of April and October. - ARJWS has a pump out of service. Additional Extreme Triggers: - Both pump stations are out of service. - ARJWS has pumps, filters out of service or other mechanical-electrical problems. - Both elevated tanks are out of service.	ARJWS, which provides water to West Anderson WD, has three customers who also purchase water from other systems: Big Creek/Hammond purchases from Greenville Water. Powdersville purchases from Easley Combined Utilities & Greenville Water. The Town of Williamston purchases from Greenville Water. ARJWS can reverse the back flow device at the master meters to allow water to flow the West Anderson WD (ARJWS) direction. Broadway Water District has 3 main water lines that can be connected.
Westminster CPW	2003	West	**Surface Water** - Chauga River	- Storage falls below 70, 70, or 80 percentage of capacity. - Average daily use greater than 3.8 MGD for 15 consecutive days, 4.0 MGD for 10 consecutive days, or 4.2 MGD for 10 consecutive days.	City of Walhalla for emergency water if available.

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively.

8.1.3 USACE Savannah District Drought Response

The USACE Savannah District operates three dams on the Savannah River in the Upper Savannah River basin where they manage lake levels and releases downstream: Hartwell Dam, Russell Dam, and Thurmond Dam. The Savannah River Basin Drought Management Plan has evolved from the initial DCP established in 1989 to the latest 2012 version, which includes a number of modifications made primarily as a result of the droughts of 1998-2002 and 2007-2009 (USACE 2012). Water management during droughts has been a major issue, and the USACE was requested to examine the DCP as part of the second interim of the Savannah River Basin Comprehensive Study. Environmental organizations have also requested the USACE consider the environmental benefits that would result from the restoring natural variability to downstream river flows. The Comprehensive Study ended in 2020 due to inadequate analysis, a lack of full partnership concurrence on the recommendation, and insufficient funding. The draft of the Comprehensive Study report tentatively recommended no seasonal variation in drought trigger levels, raising the trigger levels by 3 to 6 feet, and further restricting the flow of water from Thurmond Dam earlier during drought. This recommendation was identified in the study as Alternative 2 (USACE 2020); however, the recommendation was not implemented since the Comprehensive Study ended prior to completion.

The existing Drought Plan trigger action levels and definitions are provided in Figure 8-3. These have been updated slightly since the 2012 DCP, namely basing target releases on weekly average flows (as compared to daily average flows as designated previously) (USACE 2025a). The Drought Plan is implemented when either Hartwell or Thurmond pool elevations drop below the corresponding trigger level 1 elevation. On a rising pool, flow restrictions are lessened only after both Hartwell and Thurmond elevations are 2 feet above the trigger elevation. In Drought Levels 1 and 2, the 28-day running average streamflow measured at the USGS Broad River gage is used to further define the weekly average release from Thurmond. The 28-day running average (BR28) is compared to the 10th percentile of the historical 28-day running average (BR28Q10) for the particular day of the year. The 10th percentile is used as the breakpoint which delineates between normal and moderate drought.



Trigger Level	Time of Year	Drought Response
1	Jan 1 - Dec 31	IF BR index >10%, Target 4200 cfs (weekly average) release at Thurmond Dam
		IF BR index <10%, Target 4000 cfs (weekly average) release at Thurmond Dam
2	Feb 1 - Oct 31	IF BR index >10%, Target 4000 cfs (weekly average) release at Thurmond Dam
		IF BR index <10%, Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31	Target 3600 cfs (daily average) release at Thurmond Dam
3	Feb 1 - Oct 31	Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 - Feb 28) w/NMFS approval	Target 3100 cfs (daily average) release at Thurmond Dam
4	Feb 1 - Oct 31	Target 3600 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 – Feb 28) w/NMFS approval	Target 3100 cfs (daily average) release at Thurmond Dam

BR index refers to the relative percentile of the 28 day average flow for the Broad River Gage (02192000) at Bell, GA.

There may be up to a 2 week delay in reducing flows from the normal unrestricted releases at Thurmond to the level 1 drought flow restriction levels.

If in Drought operations, Thurmond will release 200 cfs more than the required Drought trigger target flow for an 11 day period during summer. This additional flow is mitigation for possible Harbor impacts implemented as part of the Storage Balance Agreement update with the Duke Energy.

Figure 8-3. USACE Savannah River reservoirs' Drought Trigger Action Levels and definitions (USACE 2025a).

8.1.4 Keowee-Toxaway Drought Management Low Inflow Protocol (LIP)

The Duke Energy LIP was established as part of the relicensing agreement for the Keowee-Toxaway Project reservoirs (Lake Jocassee and Lake Keowee) (Duke Energy Carolinas, LLC 2013). The purpose of the LIP is to establish a joint management plan that Duke Energy, public water suppliers with large water intakes withdrawing from project reservoirs, and public water suppliers with large water intakes on the Savannah River USACE reservoirs (Hartwell, Russell, and Thurmond) (that choose to participate) agree to follow under drought conditions.

The LIP has five stages (0 through 4) which specify how the reservoirs will be operated during drought conditions. The five stages are triggered by (1) remaining usable storage; (2) USACE Drought Plan levels; (3) composite average streamflow in three streams located in South Carolina, Georgia, and North Carolina; and (4) the U.S. Drought Monitor. The storage index is based on remaining useable storage in Bad Creek, Jocassee, and Keowee. Under Stage 1, the goal is to reduce water usage by 3 to 5 percent from the amount that otherwise would be expected. Similarly, stages 2, 3 and 4 call for 5 to 10 percent, 10 to 20 percent, and 20 to 30 percent reductions, respectively. The stages and triggers, as well as public water supplier withdrawal reductions and reservoir release amounts, are summarized in Figure 8-4.

Duke Energy Low Inflow Protocol

LIP Stage	Duke Energy Storage Index[1]	Minimum Reservoir Elevation ft AMSL		Maximum Weekly Keowee Water Flow Release ac-ft (cfs)	Public Water Supplier Withdrawal Reductions
		Jocassee	Keowee		
0	85% <= Storage Index < 90%	1096	796	25,000 (1800)	na
	80% <= Storage Index < 85%			20,000 (1440)	
1	na	1092	795	18,750 (1350)	3-5% (goal)
2	na	1087	793	15,000 (1080)	5-10% (goal)
3	na	1083	792	10,000 (720)	10-20% (goal)
4	12% < Storage Index < 25%	1080	791.5	7,500 (540)[2]	20-30%
	Storage Index < 12%		790	Leakage	

Notes:

[1] Storage Index includes remaining usable storage in Keowee, Jocassee, and Bad Creek

[2] No releases that would cause Keowee to fall below 791.5 ft AMSL

LIP Stage Triggers

Stage	Trigger		US Drought Monitor[2] (12-wk avg)	Streamflow (LTA versus previous 4 months)[3]
0	Duke Energy Storage Index[1] < 90% & USACE Storage Index[4] < 90%	and one of the following	>=0	< 85%
1	USACE in DP 1		1	< 75%
2	USACE in DP 2		2	< 65%
3	USACE in DP 3		3	< 55%
4	Duke Energy Storage Index < 25%		4	< 40%

Notes:

LTA - long-term average; DP - Drought Plan

[1] The Duke Energy Storage Index is based on the usable storage for Keowee, Jocassee, and Bad Creek as specified in the LIP

[2] The US Drought Monitor uses an area-weighted average

[3] Streamflow gages are composite averages of Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; French Broad River near Rosman, NC

[4] USACE Storage Index includes usable storage for Hartwell, Russell, and Thurmond

Figure 8-4. Duke Energy Low Inflow Protocol (LIP) release amounts, demand reductions, and triggers (USACE 2025b).

8.2 RBC Drought Response

8.2.1 Roles and Responsibilities

Under the Planning Framework, the RBC will support drought response, collect drought information, and coordinate drought response activities. With the support of SCDNR and SCDES, the RBC will:

- Collect and evaluate local hydrologic information for drought assessment
- Provide local drought information and recommendations to the DRC regarding drought declarations
- Communicate drought conditions and declarations to the rest of the RBC, stakeholders, and the public

- Advocate for a coordinated, basinwide response by entities with drought management responsibilities (e.g., water utilities, reservoir operators, large water users)
- Coordinate with other drought management groups in the basin as needed

8.2.2 Recommendations

Through consideration and discussion, the Upper Savannah RBC developed the following consensus-based recommendations related to drought planning and response. The steps to implement these recommendations, where applicable, are detailed in the 5-year and long-range implementation plans in Chapter 10.

1. The RBC recommends that the DMAs be replaced by the eight river basins and that a diverse set of stakeholder representatives from the RBCs serve on the DRC to help inform the DRC and SCO of conditions in each river basin. It was acknowledged that this would require a change to the SC Drought Response Act and supporting Regulations. The recommendation would:

- Support consistent and full representation on the DRC. Historically, there have been numerous vacancies on the DRC from each DMA because appointment by the Governor is required. Assuming the RBCs continue to meet, they would be responsible for providing a diverse mix of representatives to serve on the DRC, subject to SCDNR and/or SCDES approval.
- Further empower the RBCs, which have been charged with developing and implementing river basin plans and communicating with stakeholders during droughts, to maintain an active role in the management of the state's water resources.
- Allow for representation that aligns with the state's eight major river basins. Currently, the West and Central DMAs extend from the Upstate all the way to the Coast, crossing through the Blue Ridge, Piedmont, and Coastal Plain Provinces where climatic and hydrologic conditions can vary significantly.

2. The RBC recommends that water utilities review and update their drought management plan and response ordinance every 5 years or more frequently if conditions change. Once updated, the plans should be submitted to the SCO for review. Changing conditions that could merit an update might include:

- Change in the source(s) of water
- Significant increase in water demand (such as the addition of a new, large wholesale customer)
- New interbasin transfers
- Significant change in the proportion of water used by one sector compared to another (e.g., residential versus commercial use)
- Addition (or loss) of another user relying on the same source of water
- New water supply agreement with a neighboring utility

3. The RBC recommends that water utilities, when updating their drought management plan and response ordinance, look for opportunities to develop response actions that are consistent with those of neighboring utilities. While triggers are likely to be unique to each water utility based on their source(s) of water, coordination of response actions identified in their ordinance, to the extent practical, supports consistent messaging through the basin, and helps avoid confusion between customers.

4. The RBC recommends that water utilities coordinate, to the extent practical, their drought response messaging. Drought messaging refers to both the content and the method or mechanism to deliver the message. Consistent and coordinated drought response messaging can be important, especially when there are drought conditions impacting the entire basin and possibly neighboring basins. Consistent and coordinated messaging can help to avoid confusion and provide efficiency. However, the RBC recognizes that coordinated and consistent messaging may not be possible when drought conditions are appreciably different across the basin, when utilities are in different stages of drought response, or when utilities' response strategies are different.

5. The RBC encourages water utilities in the basin to consider drought surcharges on water use during severe and/or extreme drought phases. Drought surcharges, when used, are typically only implemented if voluntary reductions are not successful in achieving the desired reduction in water use. In the Upper Savannah River basin, several water utilities have already built into their response ordinance the ability to implement drought surcharges during the severe and/or extreme drought phases. One example is Greenville Water which withdraws water from Lake Keowee in the Savannah River basin, and the Table Rock Reservoir and the Poinsett (North Saluda) Reservoir in the adjacent Saluda River basin. In the event of an extreme drought-related water shortage, Greenville Water and the Commissioners of Public Works will monitor water use and limit households to 5,000 gallons per household per month. Water use above this limit will be subject to 3 times the regular water rate for 5,000 to 7,500 gallons per month, 4 times the regular rate for 7,500 to 10,000 gallons per month, and 5 times the regular rate for 10,000 gallons per month and greater.

6. The RBC discourages the use of decreasing block rate structures by water providers. Under a decreasing block rate structure, water customers pay a lower per unit rate as their water use increases. This type of rate structure discourages water conservation, and may lead to higher water use during drought, especially by residential customers. In North Carolina, the use of decreasing block rate structures are prohibited for local governments and large community water systems applying for state funds for extending water lines or expanding water treatment capacity (State Water Infrastructure Commission 2010).

7. The RBC encourages water users and those with water interests to submit drought impact observations through the Condition Monitoring Observer Reports (CMOR). The CMOR system, maintained by the National Drought Mitigation Center (NDMC), provides supporting evidence in the form of on-the-ground information to help the authors of the U.S. Drought Monitor better understand local conditions. The USDA uses the Drought Monitor to trigger disaster declarations and determine eligibility for low-interest loans and some assistance programs. The SCO also reviews and uses the CMOR system in a variety of ways. CMORs can be submitted by clicking the "Submit a Report" button at the NDMC's Drought Impacts Toolkit website. The RBC also recommends that:

a. The SCO conduct outreach to make more stakeholders aware of the CMOR system and encourage its use to report drought conditions.
b. The NRCS promote the use of the CMOR system.
c. The South Carolina Adopt-a-Stream program promote use of the CMOR by its participants so that hydrologic conditions prior to and during drought may be documented.

8.2.3 Communication Plan

The Upper Savannah RBC's recommendation to replace the DMAs with the river basins and assign RBC representatives from each river basin to serve on the DRC would impact how the RBC communicates to the DRC. For the time being, and assuming that the proposed recommendation does not trigger a change to the SC Drought Response Act, the RBC will communicate drought conditions as outlined below. Furthermore, the RBC encourages that the State Climate Office and Governor consider appointing more RBC members to the DRC, as representatives from each DMA.

The Upper Savannah RBC will communicate drought conditions and responses within the basin through a designated RBC Liaison. The RBC Liaison may be the Chair, Vice Chair, or other RBC member. At the time of this Plan's development, five Upper Savannah RBC members serve as DRC representatives, including four from the West DMA and one from the Central DMA. As such, any of those members may serve as the designated Liaison.

If any part of the basin is in a declared drought as determined by the DRC, the Liaison will solicit input from RBC members and other water managers and users regarding drought conditions and responses in their respective locations or interests. The Liaison is then responsible for communicating updates on drought conditions and responses within the basin to the DRC and/or the SCO. The DRC has existing mechanisms to communicate and coordinate drought response with stakeholders and the public. Under Section 49-23-70 of the Drought Response Act, SCDNR is responsible for disseminating public information concerning all aspects of the drought.

Chapter 9
Policy, Legislative, Regulatory, Technical, and Planning Process Recommendations

During the fourth and final phase of the planning process, the Upper Savannah RBC identified and discussed recommendations related to the river basin planning process; technical and program considerations; and policy, legislative, or regulatory considerations. Various recommendations were proposed by RBC members and discussed over the span of several meetings. They received broad RBC support and are to be taken as having consensus as defined by the River Basin Council Bylaws (SCDNR 2019a). Under these bylaws, consensus is achieved when all members can “live with” a decision, although some members may strongly endorse a solution while others may only accept it as a workable agreement.

The planning process recommendations are summarized in Chapter 9.1; the technical and program recommendations are summarized in Chapter 9.2; and the policy, legislative, and regulatory recommendations are summarized in Chapter 9.3.

9.1 River Basin Planning Process Recommendations

The following planning process recommendations should be taken as considerations for future phases of the river basin planning process. To implement these recommendations, the Upper Savannah RBC will need support from SCDES, other RBCs, technical experts, the South Carolina Legislature, and other organizations.

The Upper Savannah RBC proposed the following recommendations to improve communication among RBCs and other groups:

- **SCDES should develop a strategy for maintaining membership and sustaining the RBCs. Elected officials should be invited and considered to participate on the RBCs as part of the Local Government water interest category**. Adequate representation of all water use groups may require intentional, targeted outreach to encourage potential members to apply to the RBC. Manufacturing is an interest category that is not well represented but is important. Membership should also be reviewed when any member resigns from the council to ensure there is still sufficient representation of that member’s water interest category. Recognizing that RBC members invest significant time over the planning process in understanding the water resources of the river basin and the variety of issues, any appointments of RBC members after the river basin planning process is underway would need to be considered on a case-by-case basis. Appointments would be at the discretion of SCDES and would consider feedback from the RBC. In such instances, orientation would be necessary to bring new members up to speed.

- **During 2025, the RBCs should initiate and coordinate discussions with SCDES to begin the process of updating the State Water Plan**. The RBCs can help identify objectives of the Plan update process and formalize how the RBCs can participate in and meaningfully contribute to development of the Plan.

- **Future water planning efforts should consider increased collaboration between all of South Carolina's RBCs**. At least one or two statewide RBC meetings should be held annually. Consideration should also be given to annual meetings between North Carolina, South Carolina, and Georgia regional water planning groups.

- **As part of future water planning efforts, the RBC should attempt to increase engagement with USACE, and specifically with the Planning and Operations Divisions**. The USACE is responsible for management of the Savannah River Basin. Increased engagement with the USACE's Planning and Operations Division may help with implementation of the RBC's recommendations.

Members of the Upper Savannah RBC proposed the following recommendations for funding needs related to ongoing water planning and sources of funding:

- **Following development of the initial River Basin Plans, the RBCs should work with SCDES to identify the scope of future RBC activities and help develop funding needs and requests.** Continued and consistent planning is critical to the effective management of water resources. The South Carolina Water Planning Framework envisioned a continuous, long-term process in which the River Basin Plans will be updated approximately every five years as new information is gathered and new issues arise.

- **The South Carolina Legislature should authorize recurring funding for state water planning activities, including river basin planning.** Currently, nearly all the funding for the river basin planning process has come from the legislature. Matching or supplemental funding opportunities may come from the USACE through its Planning Assistance to States program, environmental and conservation organizations like The Nature Conservancy, water utilities, local governments, or other entities with interest in preserving, protecting, and managing water resources.

The Upper Savannah RBC proposed the following recommendations to promote findings and coordinate implementation of the River Basin Plan:

- **RBCs should develop and implement an engagement plan to improve awareness and build support for the recommendations, actions, and strategies identified in the River Basin Plan.** The RBC will meet quarterly as needed following publishing of the River Basin Plan. Initial meetings should focus on implementation and the development of a communication and engagement plan. The RBC may consider the formation of subcommittees to lead the implementation of the engagement plan. The engagement plan should:

- Identify target audiences. Early engagement with elected officials is important. Engagement with groups outside of the "water" space should also be considered. The Association of Counties and South Carolina Manufacturers Alliance may be a worthwhile target audience.

- Identify the means and methods for engagement. For example, digital methods including social media may be especially effective with certain audiences.
- Leverage existing mechanisms like the joint South Carolina American Water Works Association / Water Environment Association of South Carolina Public Information Officers Committee and other water advocacy groups to help with messaging.

- **When conducting education and outreach, the Upper Savannah RBC should coordinate with groups that have existing education and outreach efforts focused on water conservation such as Clemson, Lake Keowee Source Water Protection Team, Lake Hartwell Partners for Clean Water, and Anderson Pickens Stormwater Partners.** Existing groups have the experience and resources to help promote the water conservation ethic strategies and recommended in this River Basin Plan.

9.2 Technical and Program Recommendations

The RBC may make technical and program recommendations to address any data gaps or information needs identified during the river basin planning process. The following recommendations should be taken as considerations for future phases of the river basin planning process. To implement these recommendations, the Upper Savannah RBC will need support from SCDES and other technical experts.

The Upper Savannah RBC identified the following needs for more data:

- **Compile the data obtained from established credible systems in alignment with RBC goals for utilization across the State before creating new systems, databases, or monitoring stations.** Data specific to RBC goals could include rain gage data or stream gage data. Historic data, and new data when developed, needs to be publicly accessible and in a consistent, standardized, format that supports public comprehension.

- **Fund and establish of a mesoscale network of weather and climate monitoring stations.** Establishing a mesoscale network of weather and climate monitoring stations, known as a Mesonet, provides near real-time data at the local level to improve situational awareness and preparedness and support decision-makers and stakeholders, such as emergency management agencies, water resources managers, agricultural interests, transportation officials, and energy providers. Currently, South Carolina is only one of 12 states without a Mesonet. A network of 46 weather stations (one per county) will provide an essential public service to the citizens of South Carolina.

- **Fund all existing and future state agency recommended streamflow gage locations.** The RBC recognizes that comprehensive, reliable, and long-term hydrologic data is critical to water planning and management. Additional partners and sponsors should be identified to help fund and maintain streamflow gages.

The Upper Savannah RBC developed the following recommendations for technical studies to improve knowledge of specific issues:

- While the RBC should maintain its focus on the assessment of water quantity, no recommendations about bacterial issues are included in this plan; however **future planning efforts should include evaluation of surface water quality, including bacteria, nutrient loading and sedimentation,** which is important to maintaining affordable public water supplies and the ecological health of the streams, rivers, and lakes. Earlier chapters of this plan reference the impacts of e coli bacterial contamination on recreational activities in lakes. As part of future study and planning, the RBC could make recommendations to other planning bodies or departments of water quality parameters or stream segments requiring further study and impairment mitigation. Similarly, the RBC should be educated on other on-going water quality efforts such as §303(d) listings, watershed planning programs, and TMDL development. The RBC also recommends a **study on the impacts of drought on fishkills due to dissolved oxygen.**

- **Study the impacts of changing land use on streamflow characteristics including the magnitude of flows, timing of flows, and flashiness.** The RBC recognizes that, while water resources of the basin were simulated to meet projected demands under the 2070 High Demand Scenario, the SWAM model does not account for potential changes in land use that might impact the magnitude, timing, and frequency of flows. The recent climatic trend of more frequent and higher intensity rainfall events, coupled with development-driven increases in impervious surface and a reduction in recharge areas may result in shorter duration, higher flows. This not only effects the timing of flow but can exacerbate streambank scour and increase sediment transport and sediment loading to reservoirs. Models that simulate changes to rainfall, land use, and runoff can be used to evaluate this issue.

- **Identify and prioritize properties for conservation to protect quantity and quality of water. Once properties are identified and prioritized, the RBC recommends that the state and local governments develop and fund county conservation and mitigation banks and collaborate with South Carolina Conservation Bank and Land Trusts to conserve priority properties.** The rainfall runoff models referenced in the previous recommendation which are capable of simulating changes to rainfall, land use, and runoff can be used to help prioritize areas for conservation.

- **Continue discussion of data needs for flow-ecology relationships.** Work with the Saluda RBC to continue discussions with the USGS and Clemson University about the need for additional data in the Blue Ridge. The application of ecological flow standards is a relatively new process in South Carolina which will continue to be modified and improved throughout the water planning process.

- **The state should request for and cost-share in the completion of Phase 2 of the USACE Comprehensive Study and Drought Plan Update**. As discussed in Chapter 8, the USACE was requested to examine The Drought Contingency Plan as part of the second interim of the Savannah River Basin Comprehensive Study. The Comprehensive Study ended in 2020 due to inadequate analysis, a lack of full partnership concurrence on the recommendation, and insufficient funding. The cost share for the Comprehensive Study has been 50 percent Federal and 50 percent non-Federal (cash or work-in-kind). SCDNR, the Georgia Department of Natural Resources, and the Nature Conservancy all contributed to the non-Federal cost of the Comprehensive Study. The RBC also encourages USACE to be more proactive and incorporate forecasting into drought decision-making.

With regard to drought impacts on lake levels, those were modeled during the RBC's planning process and compared to ramp and access level requirements for recreational activities. Modeling demonstrated what has been observed during past droughts, which is that recreational access impacts will occur during severe and extreme drought conditions; however, the RBC did not identify any recommendations to mitigate those potential impacts.

- **In future planning phases, the RBC recommends a study be performed to understand the extent and potential impacts of private and community/commercial wells, and to what extent they may reduce surface water availability, especially during droughts.** In the crystalline fractured rock aquifer system of the Piedmont, groundwater withdrawals may reduce baseflow in streams and lower surface water availability for both in-stream and off-stream uses. This study could also examine availability of groundwater for these users.

The Upper Savannah RBC developed the following recommendations protecting the water resources of the basin:

- Sedimentation has been identified as a threat to the basin's water resources. The USACE estimated that Lake Hartwell, Lake Russell and Lake Thurmond have lost 14, 10 and 7 percent of their storage (to the top of the conservation pool) respectively, since their construction. Sediment loading to reservoirs not only reduces storage capacity but impacts water quality. As such, **the RBC encourages local governments and land managers to act to reduce sediment loading to reservoirs through:**
    - **The implementation of infiltration, riparian buffers, land use planning, setbacks, minimizing streambank erosion, scour, and sources of sedimentation to reservoirs.**
    - **Studies to better identify sources of sediment load to reservoirs.**
    - **Further incentivize the establishment of riparian buffers, streambank restoration, and other practices that reduce sediment load to streams and reservoirs.**
    - **Develop and incentivize green infrastructure/stormwater ordinances.**
    - **Strengthen penalties for non-compliance of stormwater ordinances.**
    - **Advocate for the development of local ordinances such as riparian buffers and tree ordinances for new development.**
- **The RBC recommends that the financial impacts of increased sedimentation on reservoirs and water resources be identified, and the results be communicated to local governments to demonstrate the value of riparian buffers, sedimentation and erosion control measures, and other policies and controls that reduce sediment generation and transport.** Convincing local governments and property owners that sedimentation is a problem may require demonstrating the long-term financial impacts of sedimentation associated with loss of water supply storage, increased cost of water treatment, loss of property and property values, and impacts to the local economy due to loss or degradation of recreation opportunities.

- **Encourage the building permitting process where applicable to require developers work with water/wastewater utilities to ensure adequate availability/capacity**. Recognizing this may already happen in some parts of the basin, the RBC encourages the practice be adopted broadly. The RBC also encourages local governments, developers, and others to use this River Basin Plan as a guide to help inform decisions on growth and development, based on water resource availability.

9.3 Policy, Legislative, or Regulatory Recommendations

The Upper Savannah RBC engaged in discussion about issues and concerns with the existing policies, laws, and regulations governing water withdrawals and water use. Current (as of December 2024) regulations regarding surface water and groundwater withdrawals are summarized in Table 9-1 located at the end of this chapter. The Upper Savannah RBC developed the following recommendations for modifications to existing state or local laws, regulations, or ordinances:

- **The South Carolina Surface Water Withdrawal, Permitting, Use, and Reporting Act should allow for reasonable use criteria to be applied to all new surface water withdrawals, like those that currently exist for groundwater withdrawals.** Under current regulation, for surface water withdrawals, reasonable use criteria vary depending on the water use category and the time of permit application (pre- or post-2011, when SCDHEC's regulation, 61-119 Surface Water Withdrawal, Permitting, Use and Reporting, came into effect), as summarized below.

  - Existing (pre-2011) non-agricultural surface water withdrawers do not need to meet reasonable use criteria. The permitted withdrawal is based on the largest volume as determined by previously documented use, current treatment capacity, or designed capacity of the intake structure.
  - New (post-2011) or expanding non-agricultural surface water withdrawers must demonstrate that the requested water withdrawal amount meets the criteria for reasonable use.
  - Agricultural surface water withdrawals, all of which do not require a permit where there is remaining safe yield in a basin, do not need to satisfy reasonableness criteria for the requested withdrawal amount.

  Comparatively, under SCDHEC's regulation 61-113 Groundwater Use and Reporting, permittees of any use category seeking to withdraw greater than 3 million gallons in any month from groundwater must demonstrate to SCDHEC's satisfaction that groundwater withdrawal is reasonable and necessary and there are no unreasonable adverse effects on other water users.

  In parts of the Edisto and Pee Dee River basins, the absence of reasonable use as a criterion for issuing surface water registrations has resulted in large registrations being granted which have used up the remaining safe yield. Farmers seeking new registrations in these fully allocated portions of the Edisto and Pee Dee River basins must therefore apply for a permit and abide by permit conditions.

- **Improve the current laws that allow for regulation of water use so that they are enforceable and effective. The current water law, which grandfathers most water users, needs to be improved to support effective management of the state's water resources.** One approach to improve the effectiveness of the Act in ensuring wise use of water resources is to require sector-specific strategies to improve water use efficiency. The Act should also allow for the reallocation of water resources to where they are needed to support well-planned growth and development. This may require re-evaluation of existing users' permit limits, but only after carefully considering their long-term growth projections, water needs, and planned infrastructure investment.

- **The RBC recommends that the Legislature approve and adopt the State Water Plan.** This recommendation assumes that the River Basin Plans will be included as appendices to the State Water Plan, and therefore they be similarly adopted. Legislative approval and adoption of the State Water Plan would not only recognize that significant time and money invested in water planning over the past decade but signal the importance of effective and continuous stakeholder-driven water planning that balances the state's economic and environmental interests and ensures the long-term protection of its water resources.

- **Increase coordination and planning with GAEPD on Savannah River water resources issues.** Through collaboration and planning, Georgia and South Carolina have generally avoided interstate water disputes with each other. Increased coordination between the Upper Savannah RBC, the Lower Savannah-Salkehatchie RBC, the Coastal Georgia Council, and the Savannah-Upper Ogeechee Council would help continue that trend and better leverage the planning and technical analyses that both states have completed over the past decade. Meetings with other planning bodies in the Savannah River basin should occur annually, at a minimum.

- **The state should support and fund water education programs that include all sectors of water use and promote the types of water management strategies recommended in the River Basin Plans.** Extension Services and others already provide education and outreach to varying levels. The RBCs can provide guidance on topics that are important.

- **The RBC recommends that as part of the comprehensive planning process that each local jurisdiction across the state consult the Resilience Plan developed by the South Carolina Office of Resilience, local Hazard Mitigation Plans, and the associated River Basin Plan(s) developed by the RBCs for inclusion within the resilience element as required by the South Carolina Local Government Comprehensive Planning Enabling Act as amended in 2020.**

- **A grant program should be established to help support the implementation of the actions and strategies identified in each RBC's River Basin Plan.** One example is Georgia's Regional Water Plan Seed Grant Program which supports and incentivizes local governments and other water users as they address implementation strategies and actions of their regional water plan.

Table 9-1. Summary of regulations related to surface water and groundwater withdrawal.

Water Source	Use Type	User Type	Process	Applicability	Withdrawal Volume	Use Criteria	Low Flow Period Requirements	Review Period	Reporting
Surface Water	Agricultural	Existing (pre Jan 1, 2011)	Registration	Users withdrawing more than 3 million gallons (MG) in a month	Highest previous water usage	No criteria	No MIF obligations	No review, in perpetuity	Annual
		New (post Jan 1, 2011) or Expanding	Registration	Users withdrawing more than 3 MG in a month	Amount of water requested by the proposed withdrawer and availability of water at the point of withdrawal based on Safe Yield calculations.	Subject to safe yield assessment	No MIF obligations	No review, in perpetuity	Annual
	Hydropower	All	Exempt (non-consumptive use)						Annual
	All Other Use Types	Existing (pre Jan 1, 2011)	Permit	Users withdrawing more than 3 MG in a month	Largest volume as determined by previously documented use, current treatment capacity, or designed capacity of the intake structure	No criteria	Must address "appropriate industry standards for water conservation." Not subject to enforcement for MIF.	30 to 50 years[1]	Annual
		New (post Jan 1, 2011) or Expanding	Permit	Users withdrawing more than 3 MG in a month	Based on reasonableness, availability of water at point of withdrawal based on Safe Yield calculations.	Reasonable use criteria	Development of Contingency Plan for low flow periods, enforceable. Public water suppliers not subject to MIF[2]	20 to 50 years[1]	Annual

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Table 9-1. Summary of regulations related to surface water and groundwater withdrawal. (Continued)

Water Source	Use Type	User Type	Process	Applicability	Withdrawal Volume	Use Criteria	Low Flow Period Requirements	Review Period	Reporting
Ground water	All Use Types	Withdrawals in Capacity Use Areas	Permit	Users withdrawing more than 3 MG in a month	Permit withdrawals based on reasonable use guidelines, which vary by water use sector.	Reasonable use criteria	Requires development of Best Management Plan that identifies water conservation measures, alternate sources of water, justification of water use, and description of beneficial use	Every 5 years	Annual
	All Use Types	Withdrawals Outside of Capacity Use Areas	Registration	Users withdrawing more than 3 MG in a month	Registrations do not have limits but require reporting.	No criteria	No MIF obligations	No review, in perpetuity	Annual

[1] New surface water permitees may receive permits of 20 years or up to 40 years as determined by department review.
Existing surface water permittees may receive permits of 30 years or up to 40 years as determined by department review.
Municipal or governmental bodies may receive permits of up to 50 years to retire a bond it issues to finance the construction of waterworks (SECTION 49-4-100).

[2] Public water suppliers not subject to MIF but are required to implement their contingency plan in accordance with drought declarations 49-4-150 6.

Chapter 10
River Basin Plan Implementation

10.1 Recommended Five-Year Implementation Plan

10.1.1 Implementation Objectives

The Upper Savannah RBC identified six implementation objectives for the Upper Savannah River Basin Plan. These six objectives were developed based on themes that emerged from the recommendations made in previous chapters. The objectives are as follows:

- Objective 1. Improve water use efficiency to conserve water resources
- Objective 2. Communicate, coordinate, and promote findings and recommendations from the River Basin Plan
- Objective 3. Improve technical understanding of water resource management issues
- Objective 4. Protect water resources
- Objective 5. Improve drought management
- Objective 6. Promote engagement in water planning process

Objective 1, improve water use efficiency to conserve water resources, corresponds to the demand side management strategies presented in Chapters 6.1.1 and 6.1.2 and recommended in Chapter 7.1. Objective 5, improve drought management, corresponds to the drought management recommendations made in Chapter 8.2.3. Objectives 2, 3, 4, and 6, regarding RBC communication, technical recommendations, protection of water resources, and engagement in water planning, respectively, were developed based on the RBC recommendations presented in Chapter 9. Although the Planning Framework affords the RBC the opportunity to prioritize the objectives, the Upper Savannah RBC decided not to prioritize implementation objectives and rather prioritize the strategies under each objective to guide implementation.

The strategies and corresponding actions to achieve each objective are presented in Table 10-1. Where applicable, each strategy under an objective was listed by its priority for implementation. Table 10-1 also includes an outline of 5-year actions, responsible parties, budget, and potential funding sources to achieve each objective. The funding sources are further described in Chapter 10.1.2.

Table 10-1. Implementation plan.

<table>
<tr><th colspan="2">Strategy</th><th>Strategy Priority</th><th>5-Year Actions</th><th>Responsible Parties</th><th>Budget</th><th>Funding Sources[1]</th></tr>
<tr><td colspan="7">Objective 1. Reduce demand to conserve water resources</td></tr>
<tr><td rowspan="8">A. Municipal Conservation</td><td>Public Education of Water Conservation</td><td>1</td><td rowspan="8">1. Identify funding opportunities and technical assistance (yrs 1-5)
2. Establish a baseline of residential per capita water use by system (yr 1)
3. Survey to understand the extent of AMI/AMR use amongst utilities (yrs 1-2)
4. Encourage water utilities to conduct a water loss/leak detection audit using AWWA M36 Method, establish a baseline, and continue to measure every 2-3 years (yrs 1-5)
5. Work with water utilities to determine how water is being used and understand where conservation measures may have the most impact (yrs 2-3)
6. Implement outreach and education program about recommended water management practices and funding opportunities (yrs 1-5)
7. Individual water users to implement conservation practices (yrs 3-5)
8. Develop survey of practices implemented, funding issues, and funding sources utilized (beginning in yr 5 as part of 5-year Plan update)
9. Review and analyze per capita water usage to improve understanding of water savings of strategies (beginning in yr 5 as part of 5-year Plan update)</td><td rowspan="8">RBC with support of SCDES and contractors - Identify funding opportunities and develop information to distribute. Conduct surveys and analyze results.
Municipal Withdrawers - Implement appropriate strategies and seek funding from recommended sources as necessary.</td><td rowspan="8">Costs of implementation will vary by municipality according to current program capabilities and financial means. See Chapter 6.1.6 for discussion of cost-benefit of individual strategies.
Cost of RBC support activities are included in on-going RBC meeting budgets.</td><td rowspan="8">Individual strategies to be funded using outside funding opportunities or by evaluating existing rate structure. Possible outside funding sources include: Fed-1, 2, 5, 6, 7, 8 and USDA-8 and 9</td></tr>
<tr><td>Conservation Pricing Structures</td><td rowspan="2">2</td></tr>
<tr><td>Leak Detection and Water Loss Control Program</td></tr>
<tr><td>Reclaimed Water Programs</td><td rowspan="5">Toolbox of strategies. Applicability and priority will vary by utility.</td></tr>
<tr><td>Residential Water Audits</td></tr>
<tr><td>Landscape Irrigation Program and Codes</td></tr>
<tr><td>Water Efficiency Standards for New Construction</td></tr>
<tr><td>Time-of-Day Watering Limit</td></tr>
</table>

[1] See Tables 10-2 and 10-2 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 1. Reduce demand to conserve water resources					
B. Agriculture water BMPs, which may include center-pivot sprinkler water audits and nozzle retrofits, irrigation scheduling, soil management, and irrigation equipment changes.	Toolbox of strategies. Applicability and priority will vary by operation.	1. Identify funding opportunities (yrs 1-5) 2. Implement outreach and education program about recommended water management practices and funding opportunities (yrs 1-5) 3. Individual water users to implement conservation practices (yrs 3-5) 4. Develop survey of practices implemented, funding issues, and funding sources utilized (beginning in yr 5 as part of 5-year Plan update)	RBC with support of SCDES and contractors - Identify funding opportunities and develop and implement outreach program. Conduct surveys and analyze results. Farmers - Implement appropriate strategies and seek funding from recommended sources as necessary.	Costs of implementation will vary by agricultural operation according to size of operation, crops grown, current irrigation practices, and financial means. See Chapter 6.1.6 for discussion of cost-benefit of individual strategies. Cost of RBC activities are included in on-going RBC meeting budgets.	Possible funding sources include: USDA-7
Objective 2. Communicate, coordinate, and promote findings and recommendations from the River Basin Plan					
A. RBCs should develop and implement an engagement plan to improve awareness and build support for the recommendations, actions, and strategies identified in the River Basin Plan	1	1. RBC to meet quarterly as needed following publishing of River Basin Plan. Meetings will focus on implementation and developing a communication and engagement plan (yr 1) 2. RBC to consider the formation of subcommittees to lead engagement (yr 1) 3. Implement engagement plan (yrs 1-5)	RBC Members to develop and implement outreach plan. RBC to seek support and collaborate with other entities as needed.	Cost of RBC activities are included in on-going RBC meeting and support budgets.	No direct cost
B. Following development of the initial River Basin Plans, the RBCs should work with SCDES to identify the scope of future RBC activities and help develop funding needs and requests. The South Carolina Legislature should authorize recurring funding for state water planning activities, including river basin planning.	2	1. RBC to work with SCDES to identify scope (yr 1) 2. SCDES to identify funding needs and communicate with Legislature (yr 2-5)	SCDES to identify the scope. Legislature to approve the funding	Existing SCDES budget to develop scope. Budget for on-going planning to be determined.	Existing SCDES budget to develop scope. Water planning budget to be determined with SCDES and Legislature approval

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 2. Communicate, coordinate, and promote findings and recommendations from the River Basin Plan					
C. A grant program should be established to help support the implementation of the actions and strategies identified in each RBC's River Basin Plan.	3	1. SCDES to identify funding needs and communicate with Legislature (yr 1-5)	SCDES to identify the scope. Legislature to approve the funding	Existing SCDES budget to develop scope. Budget for implementation to be determined.	Existing SCDES budget to develop scope. Water planning budget to be determined with SCDES and Legislature approval
D. The RBC recommends that as part of the comprehensive planning process each local government consults the Resilience Plan developed by the South Carolina Office of Resilience, local Hazard Mitigation Plans, and the associated River Basin Plan(s) developed by the RBCs for inclusion within the resilience element as required by the South Carolina Local Government Comprehensive Planning Enabling Act as amended in 2020. Encourage land use regulations and corresponding ordinances be adjusted to support the resilience element.	4	1. RBC to develop and conduct outreach to local governments with information about Resilience Plan and associated River Basin Plans (yrs 1-2)	Upper Savannah RBC with support from SCDES and contractors	Cost of RBC activities are included in on-going RBC meeting and support budgets.	No direct cost

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 3. Improve technical understanding of water resource management issues					
A. Future planning efforts should include evaluation of surface water quality and trends, including bacteria, nutrient loading, and sedimentation. Study impacts of drought on fishkills due to dissolved oxygen.	1	1. RBC to first identify specific water quality and quantity issues and concerns in the basin (yr 1) 2. RBC to determine if there are data gaps and recommend data collection to fill gaps (yrs 2-5) 3. RBC to develop approach to further address identified water quality issues and concerns, including the need for development of a watershed plan under SCDES Watershed Program (yrs 2-5)	Upper Savannah RBC with support from SCDES and contractors	Cost of RBC activities are included in on-going RBC meeting and support budgets. Development of watershed plans would come from SCDES's existing Watershed Program budget.	No direct cost
B. The Upper Savannah RBC, with support from technical experts, should evaluate the impact of future land use changes on water resources quantity and streamflow characteristics. Identify and prioritize properties for conservation to protect quantity and quality of water.	2	1. RBC to invite RTI and/or others to educate the RBC on the CWWMG's land conservation modeling or listen to recording from Broad implementation meeting in November 2024 (yr 1-2) 2. RBC to consider performing similar land conservation modeling to identify how land use changes may impact water resources (yrs 3-5). 3. RBC to identify funding opportunities for conservation and mitigation banks (yrs 3-5). 4. Conserve identified properties (yr 5)	Upper Savannah RBC with support from SCDES and contractors	Potential modeling to be conducted under SCDES existing budget. Outside funding source needed for conservation.	Modeling funded by SCDES budget as available. Other funding sources to be determined.
C. Identify the financial impacts of increased sedimentation on reservoirs and water resources and communicate the results to local governments to demonstrate the value of riparian buffers, sedimentation and erosion control measures, and other policies and controls that reduce sediment generation and transport.	3	1. RBC to work with utilities and other impacted parties to identify funding that could be used to estimate the financial impact of increased sedimentation on reservoirs and water resources (yr 1) 2. RBC to communicate findings to local government to demonstrate the value of riparian buffers, sedimentation and erosion control measures (yr 2-5)	Upper Savannah RBC with support from SCDES and contractors	Costs of performing analysis of financial impacts will vary with the availability of data and the level of detail and could range between \$50,000 to \$100,000.	Funded by SCDES budget as available

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 3. Improve technical understanding of water resource management issues					
D. Fund all existing and future state agency recommended streamflow gage locations.	4	1. Develop communication strategy for speaking with USGS and other entities funding stream gages (yr 1-2) 2. Outreach to USGS and current funding entities on the importance of streamflow data to the river basin planning process. RBC to support search for additional funding sources as needed (yr 3-5)	Upper Savannah RBC with support from SCDES and contractors	Costs of monitoring and processing data for existing streamflow gages are included in USGS existing budget. Some gages are maintained by other entities. A stream gauge suitable for inclusion in the USGS system cost between $20,000 and $35,000 to install, depending on the site, and $16,000 a year to operate (Gardner-Smith 2021).	USGS, SCDES, and co-sponsors
E. Continue discussion of data needs for flow-ecology relationships	5	1. Work with Saluda RBC to continue discussions with USGS and Clemson about the need for additional data in the Blue Ridge. (yr 1-2)	Upper Savannah and Saluda RBCs with support from USGS, Clemson, The Natural Conservancy (TNC), SCDES, and contractors.	Aquatic data collection funded through on-going SCDES programs. Additional funding may be needed to continue developing ecological flow relationships.	Existing SCDES budgets with TNC, USGS, Clemson contributions.

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 4. Protect water resources					
A. The RBC supports reducing sediment loading to reservoirs through: 1. The implementation of infiltration, riparian buffers, land use planning, setbacks, minimizing streambank erosion, scour, and sources of sedimentation to reservoirs. 2. Studies to better identify sources of sediment load to reservoirs 3. Further incentivize the establishment of riparian buffers, streambank restoration, and other practices that reduce sediment load to streams and reservoirs. 4. Develop and incentivize green infrastructure/stormwater ordinances 5. Strengthen penalties for non-compliance of stormwater ordinances 6. Advocate for the development of local ordinances such as riparian buffers and tree ordinances for new development.	1	1. Work with local governments and Councils of Government (COGs) to incorporate strategies into land use, planning, zoning, permitting processes (yrs 1-5)	Upper Savannah RBC with support of SCDES to perform outreach. Local governments and COGs to enact amendments.	Cost of RBC activities are included in on-going RBC meeting budgets.	No direct cost
B. Encourage the building permitting process where applicable to require developers work with water/wastewater utilities to ensure adequate availability/capacity.	2	1. RBC to develop communication materials and strategy to promote recommendations to county and municipal officials (yr 1) 2. Counties and municipalities to consider amendments to permitting process (yrs 2-5) 3. RBC to track adoption of recommendation (yrs 2-5)	Upper Savannah RBC with support of SCDES to perform outreach. Municipal or county officials to enact amendments.	Cost of RBC activities are included in on-going RBC meeting budgets.	No direct cost

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 5. Improve drought management					
A. The RBC recommends that water utilities review and update their drought management plan and response ordinance every 5 years or more frequently if conditions change. Once updated, the plans should be submitted to the SCO for review.	1	1. Public suppliers on the RBC to review and update their drought management plans and send them to the SCO (yrs 1-5) 2. Public suppliers on the RBC to consider ways to incorporate RBC drought management recommendations into their drought plans (yrs 1-5) 3. Updates to drought management plans should be shared with the SCO (e-mailed to drought@dnr.sc.gov)	Public suppliers in the Upper Savannah RBC.	Drought planning activities to occur within public suppliers' annual budgets.	Fed-6
B. State to request for and cost-share in the completion of Phase 2 of the USACE Comprehensive Study and Drought Plan Update. RBC encourages USACE to be more proactive and incorporate forecasting into drought decision-making.	2	1. RBC to conduct outreach to State and USACE to communicate recommendations (yr 1) 2. In collaboration with the LSS RBC, develop outreach materials to educate the area about the Savannah River system (yrs 2-3) 3. USACE to complete Study (yrs 3-5)	RBC to conduct outreach. USACE to complete study	To be determined in consultation with USACE and partners	USACE, South Carolina, Georgia, and potential other partners

[1] See Tables 10-2 and 10-3 for funding source references.

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Table 10-1. Implementation plan. (Continued)

Strategy		Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 5. Improve drought management						
C. Develop materials and outreach strategy to public suppliers in the basin to implement the RBC's drought management recommendations (see Chapter 8.2.3)	1. The RBC recommends that water utilities, when updating their drought management plan and response ordinance, look for opportunities to develop response actions that are consistent with those of neighboring utilities. 2. The RBC recommends that water utilities coordinate, to the extent practical, their drought response messaging. 3. The RBC encourages water utilities in the basin to consider drought surcharges on water use during severe and/or extreme drought phases. 4. The RBC encourages water users and those with water interests to submit drought impact observations through the Condition Monitoring Observer Reports (CMOR).	3	1. Develop materials on benefits and implementation of RBC drought management recommendations (yr 1) 2. Develop outreach strategy to communicate with public suppliers and distribute materials (yr 2) 3. Execute outreach strategy and update materials as necessary (yrs 3-5) 4. Develop approach to track updates to drought management plans in the basin (yrs 3-5)	RBC with support of SCDES and contractors.	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting budgets.	Fed-6

Table 10-1. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 6. Promote engagement in the water planning process					
A. SCDES, the RBC Planning Teams, and the RBCs should develop a strategy for maintaining a diverse and representative membership and sustaining the RBCs. During 2025, the RBCs should initiate and coordinate discussions with SCDES to begin the process of updating the State Water Plan.	1	1. SCDES, RBC Planning Team, and RBC to conduct review of membership every 6 months (yrs 1-5) 2. SCDES and RBCs to invite elected officials of local governments and COGs to join the RBC (yr 1-5) 3. RBC to coordinate with SCDES on the role of RBCs in updating the State Water Plan (yr 1) 4. SCDES and RBC to conduct outreach to promote membership for under-represented groups as necessary (yrs 1-5)	SCDES, RBC Planning Team, and RBC	Cost of RBC activities are included in on-going RBC meeting budgets.	No direct cost
B. The Upper Savannah RBC will coordinate with groups that have existing education and outreach efforts focused on water conservation, including Clemson, Lake Keowee Source Water Protection Team, Lake Hartwell Partners for Clean Water, and Anderson Pickens Stormwater Partners.	2	1. RBC to provide outreach to group representatives and assess value in having them join an RBC meeting (virtually) to discuss on-going activities and opportunities for collaboration (yr 1) 2. RBC to develop and implement coordinated education and outreach plan (yrs 2-5)	Upper Savannah RBC to conduct outreach and coordination with SCDES and contractor support as needed	Cost of RBC activities are included in on-going RBC meeting budgets.	No direct cost
C. Future water planning efforts should consider increased collaboration between all of South Carolina's RBCs, adjoining states, and the USACE.	3	1. SCDES to gauge interest in joint RBC meetings from all active RBCs (yr 1) 2. SCDES and RBCs to work with GAEPD and their Regional Water Councils to have annual meeting, and/or otherwise participate in each other's meetings (yrs 1-2) 3. SCDES to plan first annual meeting location, agenda, and invitees. Identify costs and identify funding source (yrs 1-2) 4. Execute annual meeting (yrs 3-5)	SCDES to lead effort. RBC members to attend.	If contractor led, RBC meetings may range between $5,000 and $15,000 per meeting, depending on effort needed to prepare for, conduct, and document each meeting.	Funded by SC Legislature and Fed-8

[1] See Tables 10-2 and 10-3 for funding source references.

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10.1.2 Funding Opportunities

Existing external funding sources may be leveraged to promote implementation of the objectives outlined in Chapter 10.1.1. For example, EPA's Water Infrastructure Finance and Information Act program offers funding to support eligible water and wastewater infrastructure projects including those related to drought prevention, reduction, and mitigation. Other funding to support drought mitigation efforts may be available through the Federal Emergency Management Agency's (FEMA's) Hazard Mitigation Grant Program (HMGP) or Building Resilient Infrastructure and Communities (BRIC) programs. Table 10-2 summarizes existing federal funding sources for public suppliers.

Although agricultural water use in the Upper Savannah River basin is limited and expected to already be efficient, funding opportunities related to agricultural programs are also included in this section for reference. The USDA offers numerous programs for farmers and ranchers to reduce risk from drought or to restore land impacted by drought. The Farm Bill has authorized several programs to provide relief to farms and ranches experiencing drought, including the Federal Crop Insurance Program; the Emergency Conservation Program; the Pasture, Rangeland, and Forage Program; and the Livestock Forage Disaster Program. In addition, the Environmental Quality Incentives Program (EQIP) provides assistance to farm operations to conserve water and for other conservation measures. Some EQIP assistance is targeted toward water-conserving efforts in drought-prone regions through the WaterSMART Initiative, a collaboration between the USDA and the U.S. Department of the Interior's Bureau of Reclamation. Table 10-3 summarizes these and other existing USDA funding sources.

In 2022 Congress passed the Inflation Reduction Act (IRA), which may provide additional funding to programs related to agricultural conservation for fiscal years 2023 through 2026. For example, of the $20 billion allotted to the USDA, Section 21001 of the IRA assigned $8.5 billion in addition to amounts otherwise available to an existing USDA program, EQIP. EQIP pays for ecosystem restoration and emissions reduction projects on farmland and may be used for activities such as the purchase of cover crops (one of the agricultural conservation strategies discussed in this plan). Annual obligations from the EQIP program have been approximately $1.8 to $1.9 billion from 2018 through 2021, with between $36 to $45 million allotted for projects in South Carolina in these years. Additionally, $3.25 billion was allotted to the federal Conservation Stewardship Program, $1.4 million to the Agricultural Conservation Easement Program, and $4.95 billion to the Regional Conservation Partnership Program. The IRA indicates that activities funded by these programs must "directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide, methane, or nitrous oxide emissions, associated with agricultural production" (IRA 2022). Projects that provide water efficiency benefits in addition to these climate benefits may be eligible for funding under these programs. Section 30002 of the IRA also designated $837.5 million in funding to the Secretary of Housing and Urban Affairs for projects that improve energy or water efficiency for affordable housing (IRA 2022). On January 20, 2025, an Executive Order was issued requiring all agencies to immediately pause the disbursement of funds appropriated through the IRA and for agency heads to review the IRA to enhance their alignment with the administration's new policies. At the time this Plan was prepared, it is unknown if the IRA funding described above will be continued or eliminated

In September 2022, $70 million in USDA "Partnerships for Climate-Smart Commodities" funding was invested in South Carolina's two land-grant universities, Clemson University and South Carolina State University, to promote "climate-smart" agricultural practices in South Carolina. The project will utilize a coalition of 27 entities to promote the program to farmers, with a focus on peanuts, leafy greens, beef cattle, and forestry. Most of the funding will go directly to growers to offset the costs of implementing conservation practices. There may be opportunities to leverage this new funding source to implement the agricultural conservation strategies recommended in this plan. Although enrollment is currently closed as of the drafting of this plan in January 2025, interested parties are encouraged to sign up to learn about future opportunities.

Table 10-2. Federal funding sources.

Funding Source Index[1]	Program	Agency	Grant/Loan Funds Available	Description
Fed-1	U.S. Economic Development Administration (EDA) Grants	EDA	No limit (subject to federal appropriation)	EDA's Public Works Program and Economic Adjustment Assistance Program aids distressed communities by providing funding for existing physical infrastructure improvements and expansions.
Fed-2	Water Infrastructure Finance and Information Act	U.S. EPA	Up to 49 percent of eligible project costs (minimum project size is $20 million for large communities and $5 million for small communities)	A federal credit program administered by EPA for eligible water and wastewater infrastructure projects, including drought prevention, reduction, and mitigation.
Fed-3	Section 502 Direct Loan Program	USDA Rural Development	Loans based on individual county mortgage limits	Loans are available for wells and water connections in rural communities. Availability is based on community income.
Fed-4	National Rural Water Association Revolving Loan Fund	USDA Rural Utilities Service	$100,000 or 75% of the total project	Provides loans for predevelopment costs associated with water and wastewater projects and for existing systems in need of small-scale capital improvements.
Fed-5	Emergency Community Water Assistance Grants	USDA Rural Development	Up to $100,000 or $1,000,000 depending on the type of project	Offers grants to rural areas and towns with populations of 10,000 or less to construct waterline extensions; repair breaks or leaks; address maintenance necessary to replenish the water supply; or construct a water source, intake, or treatment facility.
Fed-6	HMGP	FEMA	Variable	Provides funds to states, territories, tribal governments, and communities for hazard mitigation planning and the implementation of mitigation projects following a presidentially declared disaster event
Fed-7	Building Resilient Infrastructure and Communities	FEMA	Variable	Building Resilient Infrastructure and Communities will support states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards

[1] As referenced in the "Funding Sources" column of Table 10-1.

Table 10-2. Federal funding sources. (Continued)

Funding Source Index[1]	Program	Agency	Grant/Loan Funds Available	Description
Fed-8	Planning Assistance to States	USACE	Variable – funding is 50% federal and 50% nonfederal	USACE can provide states, local governments, and other nonfederal entities assistance in the development of comprehensive plans for the development, use, and conservation of water resources.
Fed-9	Drinking Water State Revolving Fund	SCDES and SC Rural Infrastructure Authority	Congress appropriates funding for the Drinking Water State Revolving Fund that is then awarded to states by EPA based on results of the most recent Drinking Water Infrastructure Needs Survey and Assessment.	This program is a federal-state partnership aimed at ensuring that communities have safe drinking water by providing low-interest loans and grants to eligible recipients for drinking water infrastructure projects.

[1] As referenced in the "Funding Sources" column of Table 10-1.

Table 10-3. USDA disaster assistance programs.

Funding Source Index[1]	Program	Agency	Description
USDA-1	Crop Insurance	Risk Management Agency (RMA)	Provides indemnity payments to growers who purchased crop insurance for production and quality losses related to drought, including losses from an inability to plant caused by an insured cause of loss.
USDA-2	Conservation Reserve Program Haying and Grazing	Farm Service Agency (FSA)	Provides for emergency haying and grazing on certain Conservation Reserve Program practices in a county designated as D2 or higher on the United States Drought Monitor, or in a county where there is at least a 40% loss in forage production.
USDA-3	Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program	FSA	Provides assistance to eligible owners of livestock and producers of honeybees and farm-raised fish for losses.
USDA-4	Emergency Conservation Program	FSA	Provides funding and technical assistance for farmers and ranchers to restore farmland damaged by natural disasters and for emergency water conservation measures in severe droughts.
USDA-5	Emergency Forest Restoration Program	FSA	Provides funding to restore privately owned forests damaged by natural disasters. Assistance helps landowners carry out emergency measures to restore forest health on land damaged by drought disasters.
USDA-6	Farm Loans	FSA	Provides emergency and operating loans to help producers recover from production and physical losses due to natural disasters and can pay for farm operating and family living expenses.

[1] As referenced in the "Funding Sources" column of Table 10-1.

Table 10-3. USDA disaster assistance programs. (Continued)

Funding Source Index[1]	Program	Agency	Description
USDA-7	Environmental Quality Incentives Program	FSA	Provides agricultural producers with financial resources and assistance to plan and implement improvements on the land in support of disaster recovery and repair and can help mitigate loss from future natural disasters. Assistance may also be available for emergency animal mortality disposal from natural disasters.
USDA-8	Emergency Watershed Program (Recovery)	NRCS	Offers vital recovery options for local communities to help people reduce hazards to life and property caused by droughts.
USDA-9	Emergency Community Water Assistance Grants	Rural Development	Offers grants to rural areas and towns with populations of 10,000 or less to construct waterline extensions; repair breaks or leaks; address maintenance necessary to replenish the water supply; or construct a water source, intake, or treatment facility.
USDA-10	Pasture, Rangeland, and Forage Program	RMA	Offers farmers and ranchers financial support to replace lost income due to forage losses caused by lower than average rainfall.
USDA-11	Livestock Forage Disaster Program	FSA	Offers financial support to livestock producers who experience grazing losses due to qualifying drought conditions or fire on federally managed lands. Payments compensate for lost grazing opportunities and additional feed costs incurred due to the disaster.

[1] As referenced in the "Funding Sources" column of Table 10-1.

10.1.3 Implementation Considerations

The Upper Savannah RBC may encounter challenges in the implementation of the identified strategies. One such challenge is the identification of sufficient funding. For the implementation of Objective 1, water withdrawers may have limited financial capacity to pursue the recommended water management strategies. A municipal water utility's budget is limited by its customer base and rate structure. The increases to water rates necessary to fund implementation of the actions associated with these objectives may not be feasible for some communities. Agricultural water withdrawers may have limited financial resources to invest in new and potentially expensive water conservation or augmentation strategies. Although some outside funding sources exist, applications for such programs may present a technical or resource barrier to many water withdrawers. Any new funding sources pursued by the RBC with SCDES support may take time to develop, leading to delays in implementation. The identification of immediately available funding opportunities, the provision of support in funding applications, and the investigation of new funding sources are vital to implementation of the recommended strategies under Objective 1. The Upper Savannah RBC included a recommendation of establishing a grant program to support implementation of River Basin Plan recommendations. This strategy is included under Objective 2, communicate, coordinate, and promote findings and recommendations from the River Basin Plan.

Another challenge in the implementation of the River Basin Plan is stakeholder acceptance. The RBC itself has no authority to enforce recommendations in the basin. Therefore, implementation of these strategies is dependent upon effective communication of RBC findings and recommendations to stakeholders. For example, stakeholder acceptance is vital for achieving Objectives 1 and 5, as these strategies rely on individual water withdrawers reducing their demands or modifying their drought management plans. To gain acceptance, water withdrawers must understand the need for and goals of the recommended strategies as well as have assurance that they are viable and effective in improving equitable access to the basin's water resources. Stakeholder acceptance is also vital to achieving Objective 4, protect water resources, which requires other entities to take action to reduce sediment loading or revise permitting processes. Strategies that require coordination with another entity or require another entity to take action include outreach components as part of their 5-year actions in the implementation table. Outreach may include the development of print or online materials to describe potential water management strategies, benefits, and funding sources and to describe how these strategies relate to findings from the planning process. Recognizing the importance of stakeholder acceptance, the RBC has included the development and implementation of an engagement plan as a strategy under Objective 2.

To effectively implement the recommended strategies of the River Basin Plan, the RBC must continue to meet as a planning body. The Planning Framework states that the River Basin Plan should not be perceived as a static document and the RBC should not be a stagnant planning body between successive updates. Rather, the RBC is to be "actively engaged in promoting the implementation of the recommendations proposed" and "will continue to meet on a periodic basis to pursue River Basin Plan implementation activities as needed" (SCDNR 2019a, p. 90). The Upper Savannah RBC has identified quarterly meetings as desirable in the first year after publication of the River Basin Plan to pursue funding and implementation. After the first year, meetings may be held less frequently as needed, but at least once per year. The RBC included a recommendation to continue funding of the planning process under Objective 2 and recommendations to sustain the RBC and promote coordination with other RBCs and groups under Objective 6. Additional RBCs, including the Broad RBC and Saluda RBC, have recommended joint meetings of multiple RBCs, suggesting there is broad support for this recommendation.

As the RBC makes decisions related to implementation, the RBC should aim to build consensus where possible and consider documenting alternative points of view when consensus is not possible. Documenting alternative points of view can be equally valuable to officials who have a role implementing water management strategies and/or recommendations made by a portion of the RBC. Full consensus on every issue is an unrealistic goal, but the RBC should continue to discuss, revisit, and document issues from this and later planning phases that are marked by alternative or opposing points of view.

10.2 Long-term Planning Objectives

The Upper Savannah RBC's objectives described in Chapter 10.1 represent both short-term and long-term objectives. For each objective, short-term strategies are discussed in Chapter 10.1 and long-term strategies are presented below in Table 10-4.

Table 10-4. Long-term planning objectives.

Objective and Strategy	Long-Term Strategy
Objective 1. Improve water use efficiency to conserve water resources	
A. Municipal Conservation	Continue short term goals. Adjust recommended actions based on water savings realized. Seek additional funding sources.
B. Agricultural Conservation	Continue short term goals. Adjust recommended actions based on water savings realized. Seek additional funding sources. Explore new technologies and incorporate into recommendations as appropriate.
Objective 2. Communicate, coordinate, and promote findings and recommendations from the River Basin Plan	
A. RBCs should develop and implement an engagement plan to improve awareness and build support for the recommendations, actions, and strategies identified in the River Basin Plan	Continue outreach during implementation
B. Following development of the initial River Basin Plans, the RBCs should work with SCDES to identify the scope of future RBC activities and help develop funding needs and requests. The South Carolina Legislature should authorize recurring funding for state water planning activities, including river basin planning.	Continue funding of river basin and state water planning activities
C. A grant program should be established to help support the implementation of the actions and strategies identified in each RBC's River Basin Plan.	Develop funding to support implementation of river basin and state water planning activities
D. The RBC recommends that as part of the comprehensive planning process each local government consults the Resilience Plan developed by the South Carolina Office of Resilience, local Hazard Mitigation Plans, and the associated River Basin Plan(s) developed by the RBCs for inclusion within the resilience element as required by the South Carolina Local Government Comprehensive Planning Enabling Act as amended in 2020. Encourage land use regulations and corresponding ordinances be adjusted to support the resilience element.	Continue outreach with each 5-year update of the Plan and with development of State Water Plan
Objective 3. Improve technical understanding of water resource management issues	
A. Future planning efforts should include evaluation of surface water quality and trends, including bacteria, nutrient loading, and sedimentation. Study impacts of drought on fishkills due to dissolved oxygen.	Consider findings of analysis and include recommendations in next 5-yr Plan update.
B. The Upper Savannah RBC, with support from technical experts, should evaluate the impact of future land use changes on water resources quantity and streamflow characteristics. Identify and prioritize properties for conservation to protect quantity and quality of water.	Understand impacts of land use changes and conserve priority properties.
C. Identify the financial impacts of increased sedimentation on reservoirs and water resources and communicate the results to local governments to demonstrate the value of riparian buffers, sedimentation and erosion control measures, and other policies and controls that reduce sediment generation and transport.	Demonstrate the financial benefits of erosion and sedimentation control measures

Table 10-4. Long-term planning objectives. (Continued)

Objective and Strategy	Long-Term Strategy
Objective 3. Improve technical understanding of water resource management issues	
D. Fund all existing and future state agency recommended streamflow gage locations.	Continue short-term goals. Monitor number of active gages in the basin.
E. Continue discussion of data needs for flow-ecology relationships	Consider findings of analysis in next 5-yr Plan update. Support continued collection of fish and invertebrate data.
Objective 4. Protect water resources	
A. The RBC supports reducing sediment loading to reservoirs through: 1. The implementation of infiltration, riparian buffers, land use planning, setbacks, minimizing streambank erosion, scour, and sources of sedimentation to reservoirs. 2. Studies to better identify sources of sediment load to reservoirs 3. Further incentivize the establishment of riparian buffers, streambank restoration, and other practices that reduce sediment load to streams and reservoirs. 4. Develop and incentivize green infrastructure/stormwater ordinances 5. Strengthen penalties for non-compliance of stormwater ordinances 6. Advocate for the development of local ordinances such as riparian buffers and tree ordinances for new development.	Encourage best practices to reduce sediment loading to water bodies.
B. Encourage the building permitting process where applicable to require developers work with water/wastewater utilities to ensure adequate availability/capacity.	Encourage development in portions of the basin with sufficient and/or abundant water resources.
Objective 5. Improve drought management	
A. The RBC recommends that water utilities review and update their drought management plan and response ordinance every 5 years or more frequently if conditions change. Once updated, the plans should be submitted to the SCO for review.	Public suppliers maintain up-to-date drought management plans that are consistent (where possible) with the recommendations of the RBC. Incorporate updated drought management plans into modeling, to test effectiveness.
B. State to request for and cost-share in the completion of Phase 2 of the USACE Comprehensive Study and Drought Plan Update. RBC encourages USACE to be more proactive and incorporate forecasting into drought decision-making.	Encourage drought forecasting in future planning efforts and decisions

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Table 10-4. Long-term planning objectives. (Continued)

Objective and Strategy		Long-Term Strategy
Objective 5. Improve drought management		
C. Develop materials and outreach strategy to public suppliers in the basin to implement the RBC's drought management recommendations (see Chapter 8.2.3)	1. The RBC recommends that water utilities, when updating their drought management plan and response ordinance, look for opportunities to develop response actions that are consistent with those of neighboring utilities.	Continue short-term goals. Monitor progress towards increasing the number of up-to-date (within last 5 years) drought management plans in the basin.
	2. The RBC recommends that water utilities coordinate, to the extent practical, their drought response messaging.	
	3. The RBC encourages water utilities in the basin to consider drought surcharges on water use during severe and/or extreme drought phases.	
	4. The RBC encourages water users and those with water interests to submit drought impact observations through the CMORs.	
Objective 6. Promote engagement in the water planning process		
A. SCDES, the RBC Planning Teams, and the RBCs should develop a strategy for maintaining a diverse and representative membership and sustaining the RBCs. During 2025, the RBCs should initiate and coordinate discussions with SCDES to begin the process of updating the State Water Plan.		Maintain RBC membership and engagement in water planning processes in the state.
B. The Upper Savannah RBC will coordinate with groups that have existing education and outreach efforts focused on water conservation, including Clemson, Lake Keowee Source Water Protection Team, Lake Hartwell Partners for Clean Water, and Anderson Pickens Stormwater Partners.		Coordinate efforts related to education and outreach with other groups' existing efforts
C. Future water planning efforts should consider increased collaboration between all of South Carolina's RBCs, adjoining states, and the USACE.		Coordinate efforts and recommendations among RBCs.

10.3 Progress on River Basin Plan Implementation

To assess the performance of and quality of actions taken by the RBC, the Framework proposes the development of progress metrics. A progress metric is a "*benchmark used to monitor the success or failure of an action taken by an RBC*" (SCDNR 2009). Noting that the ultimate value and impact of the river basin planning process is the dissemination of its findings and implementation of its recommendations, the Upper Savannah RBC developed progress metrics around each of the six implementation objectives defined at the beginning of this chapter. The progress metrics are:

1. Improve water use efficiency to conserve water resources
    a. Metric 1a: Water utilities establish a baseline water loss/leak detection measure and improvement is seen over 5 years in subsequent surveys.
    b. Metric 1b: Funding opportunities are identified and used to implement conservation strategies.
2. Communicate, coordinate, and promote fundings and recommendations from the River Basin Plan
    a. Metric 2a: The RBC has developed an engagement plan within one year following completion of the River Basin Plan.
    b. Metric 2b: Outreach leads to local, legislative or federal actions, decisions, and funding that support implementation strategies and actions.
3. Improve technical understanding of water resources management issues
    a. Metric 3a: Water quality issues and concerns in the basin are identified and a strategy to study approaches to address them is developed.
    b. Metric 3b: The impact of potential, future land use changes on water resources quantity and streamflow characteristics is determined, and a method for prioritizing areas for land conservation is developed and applied.
    c. Metric 3c: The financial impacts of sedimentation on reservoirs and water resources is identified. Results are communicated to local governments.
    d. Metric 3d: USGS streamflow gages in the basin are maintained and increased, if SCDES recommends as such.
    e. Metric 3e: All data necessary to support implementation actions and future areas of study is accessible and made available to the RBC and public.
4. Protect water resources
    a. Metric 4a: The primary sources of sediment loading to reservoirs are identified.
    b. Metric 4b: Measures are put in place by local governments to prevent sediment loading to reservoirs.
5. Improve drought management
    a. Metric 5a: One hundred percent of public water supplier’s drought management plans are updated within the last 5 years and submitted to the SCO for review.

   b. Metric 5b: State funding is designated to complete Phase 2 of the USACE Comprehensive Study and Drought Plan Update.

6. Promote engagement in the water planning process

   a. Metric 6a: The RBCs continue beyond 2025 with a diverse, active and representative membership with 90 percent of seats filled.

   b. Metric 6b: Coordination occurs with groups that have existing education and outreach efforts focused on water conservation.

   c. Metric 6c: Collaboration has occurred with other RBCs, Georgia, the Georgia Regional Water Planning Councils, and the USACE. At least one meeting with each entity has occurred annually.

This 2025 publication is the first Upper Savannah River Basin Plan publication. Future 5-year updates will evaluate the Upper Savannah RBC's performance relative to the progress metrics.

As noted throughout this plan, communication and the development of stakeholder buy-in is key to successful plan implementation. To develop stakeholder acceptance, RBC members, who are the ambassadors of the River Basin Plan, must have confidence in the planning process and outcomes. A key responsibility of RBC members, as defined in the Framework, is to regularly communicate with stakeholders to maintain a current understanding of RBC activities, the River Basin Plan, and emerging issues. To assess each RBC member's confidence in the plan, the plan approval process dictates that there will first be a test for consensus on the Draft Upper Savannah River Basin Plan. For the test of consensus, each member rates their concurrence with the plan using a five-point scale, as shown below:

1. Full Endorsement (i.e., member likes it).

2. Endorsement but with minor points of contention (i.e., basically member likes it).

3. Endorsement but with major points of contention (i.e., member can live with it).

4. Stand aside with major reservations (i.e., member cannot live with it in its current state and can only support it if changes are made).

5. Withdraw - Member will not support the draft River Basin Plan. The Planning Framework indicates that if a member votes 5 they will not continue working within the RBC's process and will leave the RBC. In practice, if a member votes 5 but wishes to remain engaged in future work of the RBC, the RBC has the discretion to vote on whether the member may remain on the RBC.

- For the Final River Basin Plan, each RBC member votes simply to support or not support the plan. By indicating support, the member would be acknowledging his/her concurrence with the Final River Basin Plan and their commitment to support implementation of the plan. The results of the test for consensus on the Draft River Basin Plan and the RBC's votes on the Final River Basin Plan are shown in Table 10-5. The full results are included in Appendix C.

Table 10-5. Test of consensus results.

Test of Consensus Result	Number of RBC Members[1]
Draft River Basin Plan	
1. Full Endorsement (i.e., Member likes it).	**13**
2. Endorsement but with Minor Points of Contention (i.e., basically Member likes it).	**6**
3. Endorsement but with Major Points of Contention (i.e., Member can live with it).	**0**
4. Stand aside with Major Reservations (i.e., Member cannot live with it in its current state and can only support it if changes are made).	**0**
5. Withdraw – Member will not support the Draft River Basin Plan and will not continue working within the RBC's process. Member has decided to leave the RBC.	**0**
Final River Basin Plan	
Support	
Does Not Support	

[1] One member was not present during the test of consensus and did not provide an indication of their level of endorsement prior to publication of the Draft River Basin Plan.

Chapter 11 References

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Appendix A
Demand Projections for Individual Water Users

Table A-1. Current Water Demands, Consumptive Use, and Returns.

User	Use Category	Source	Withdrawal (MGD)	Consumptive Use (%)	Consumptive Use (MGD)	Return (MGD)
Abbeville	Public Supply	Surface Water	2.05	35%	0.72	1.32
ARJWS	Manufacturing	Surface Water	5.13	28%	1.44	3.69
ARJWS	Public Supply	Surface Water	18.42	42%	7.74	10.68
BASF	Manufacturing	Surface Water	0.18	54%	0.10	0.08
Calyx	Agriculture	Surface Water	0.01	100%	0.01	0.00
Clemson Energy	Manufacturing	Surface Water	1.30	0%	0.00	1.30
Easley Central WD	Public Supply	Surface Water	1.21	99%	1.20	0.01
Greenville	Public Supply	Surface Water	23.15	42%	9.72	13.43
Gurosik Farm	Agriculture	Surface Water	0.10	100%	0.10	0.00
Hanson Aggregates	Mining	Surface Water	0.27	14%	0.04	0.24
Head Lee Nursery	Agriculture	Surface Water	0.10	100%	0.10	0.00
Hickory Knob	Golf Course	Surface Water	0.07	100%	0.07	0.00
Holcombe Farm	Agriculture	Surface Water	0.00	100%	0.00	0.00
Keowee Falls	Golf Course	Surface Water	0.14	100%	0.14	0.00
Keowee Key	Golf Course	Surface Water	0.05	100%	0.05	0.00
Keowee Springs	Golf Course	Surface Water	0.09	100%	0.09	0.00
Keowee Vineyards	Golf Course	Surface Water	0.07	100%	0.07	0.00
McCormick	Public Supply	Surface Water	1.00	28%	0.28	0.72
Milliken	Manufacturing	Surface Water	1.24	5%	0.07	1.18
Mt Vernon Mills	Manufacturing	Surface Water	0.00	21%	0.00	0.00
Oconee	Thermoelectric	Surface Water	2846.49	1%	28.46	2818.03
Pickens	Public Supply	Surface Water	1.37	78%	1.07	0.30
Pioneer	Public Supply	Surface Water	1.59	52%	0.82	0.77
Reserve at Keowee	Golf Course	Surface Water	0.17	100%	0.17	0.00
Savannah Lakes	Golf Course	Surface Water	0.12	100%	0.12	0.00
SC Rainey Station	Thermoelectric	Surface Water	2.05	90%	1.85	0.20

User	Use Category	Source	Withdrawal (MGD)	Consumptive Use (%)	Consumptive Use (MGD)	Return (MGD)
Seneca	Public Supply	Surface Water	6.63	64%	4.28	2.35
Vulcan	Manufacturing	Surface Water	0.10	90%	0.09	0.01
Walhalla	Public Supply	Surface Water	2.05	75%	1.53	0.52
Walker	Golf Course	Surface Water	0.12	100%	0.12	0.00
Westminster	Public Supply	Surface Water	1.73	87%	1.51	0.22
WG Smith	Agriculture	Surface Water	0.00	100%	0.00	0.00
Blue Granite Water Company/PURDY SHORE S/D	Public Supply	Groundwater	0.00	100%	0.00	0.00
Layman Wholesale Nursery Inc	Agriculture	Groundwater	0.08	100%	0.08	0.00
Michelin NA/US 10	Manufacturing	Groundwater	0.00	100%	0.00	0.00
MT VINTAGE GOLF CLUB	Golf Course	Groundwater	0.23	100%	0.23	0.00
SALEM TOWN OF	Public Supply	Groundwater	0.09	100%	0.09	0.00

Table A-2. Permit and Registration Amounts for Current Water Users.

User	Use Category	Water Source	Permit or Registration	Permit or Registration Amount (MGD)	Permit or Registration Amount (MGM)	Permit or Registration Amount (MGY)
Abbeville	Public Supply	Surface Water	Permit	10.4	316.3	3796
ARJWS	Manufacturing	Surface Water	Permit	26.5	806.0	9672.5
ARJWS	Public Supply	Surface Water	Permit	61.2	1861.0	22332.2
BASF	Manufacturing	Surface Water	Permit	3.4	103.4	1241
Calyx	Agriculture	Surface Water	Registration	0	0.0	0
Clemson Energy	Manufacturing	Surface Water	Permit	18.5	562.7	6752.5
Easley Central WD	Public Supply	Surface Water	Permit	3.1	94.3	1131.5
Greenville	Public Supply	Surface Water	Permit	153	4653.8	55845
Gurosik Farm	Agriculture	Surface Water	Registration	0	0.0	0
Hanson Aggregates	Mining	Surface Water	Permit	1	30.4	365
Head Lee Nursery	Agriculture	Surface Water	Registration	0.1	3.0	36.5
Hickory Knob	Golf Course	Surface Water	Permit	0.8	24.3	292
Holcombe Farm	Agriculture	Surface Water	Registration	0	0.0	0
Keowee Falls	Golf Course	Surface Water	Permit	1	30.4	365
Keowee Key	Golf Course	Surface Water	Permit	1.5	45.6	547.5
Keowee Springs	Golf Course	Surface Water	Permit	0.6	18.3	219
Keowee Vineyards	Golf Course	Surface Water	Permit	0.6	18.3	219
McCormick	Public Supply	Surface Water	Permit	2.9	88.2	1058.5
Milliken	Manufacturing	Surface Water	Permit	2.6	79.1	949
Mt Vernon Mills	Manufacturing	Surface Water	Permit	0.7	21.3	255.5
Oconee	Thermoelectric	Surface Water	Permit	3121.2	94936.5	1139238
Pickens	Public Supply	Surface Water	Permit	7.2	219.0	2628
Pioneer	Public Supply	Surface Water	Permit	7.6	231.2	2774
Reserve at Keowee	Golf Course	Surface Water	Permit	2	60.8	730
Savannah Lakes	Golf Course	Surface Water	Permit	3.5	106.5	1277.5

User	Use Category	Water Source	Permit or Registration	Permit or Registration Amount (MGD)	Permit or Registration Amount (MGM)	Permit or Registration Amount (MGY)
SC Rainey Station	Thermoelectric	Surface Water	Permit	16.7	508.0	6095.5
Seneca	Public Supply	Surface Water	Permit	30.6	930.8	11169
Vulcan	Manufacturing	Surface Water	Permit	2.1	63.9	766.5
Walhalla	Public Supply	Surface Water	Permit	6.7	203.8	2445.5
Walker	Golf Course	Surface Water	Permit	1.6	48.7	584
Westminster	Public Supply	Surface Water	Permit	4.1	124.7	1496.5
Blue Granite Water Company/PURDY SHORE S/D	Public Supply	Groundwater	Registration	0.0	0.0	0
Layman Wholesale Nursery Inc	Agriculture	Groundwater	Registration	0.1	0.1	28.6
Michelin NA/US 10	Industrial	Groundwater	Registration	0.0	0.0	0
MT VINTAGE GOLF CLUB	Golf Course	Groundwater	Registration	0.2	0.2	83.3
SALEM TOWN OF	Public Supply	Groundwater	Registration	0.1	0.1	32.5

Table A-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Abbeville	Surface Water	WS	Moderate	2025	2.02
Abbeville	Surface Water	WS	Moderate	2030	2.11
Abbeville	Surface Water	WS	Moderate	2035	2.19
Abbeville	Surface Water	WS	Moderate	2040	2.28
Abbeville	Surface Water	WS	Moderate	2050	2.47
Abbeville	Surface Water	WS	Moderate	2060	2.66
Abbeville	Surface Water	WS	Moderate	2070	2.85
Agriculture Distributed Growth	Surface Water	IR	Moderate	2025	0.00
Agriculture Distributed Growth	Surface Water	IR	Moderate	2030	0.01
Agriculture Distributed Growth	Surface Water	IR	Moderate	2035	0.02
Agriculture Distributed Growth	Surface Water	IR	Moderate	2040	0.02
Agriculture Distributed Growth	Surface Water	IR	Moderate	2050	0.04
Agriculture Distributed Growth	Surface Water	IR	Moderate	2060	0.05
Agriculture Distributed Growth	Surface Water	IR	Moderate	2070	0.06
ARJWS	Surface Water	IN	Moderate	2025	5.25
ARJWS	Surface Water	IN	Moderate	2030	5.48
ARJWS	Surface Water	IN	Moderate	2035	5.69
ARJWS	Surface Water	IN	Moderate	2040	5.92
ARJWS	Surface Water	IN	Moderate	2050	6.41
ARJWS	Surface Water	IN	Moderate	2060	6.90
ARJWS	Surface Water	IN	Moderate	2070	7.39
ARJWS	Surface Water	WS	Moderate	2025	19.20
ARJWS	Surface Water	WS	Moderate	2030	20.04
ARJWS	Surface Water	WS	Moderate	2035	20.83
ARJWS	Surface Water	WS	Moderate	2040	21.65
ARJWS	Surface Water	WS	Moderate	2050	23.45
ARJWS	Surface Water	WS	Moderate	2060	25.24
ARJWS	Surface Water	WS	Moderate	2070	27.04
BASF	Surface Water	IN	Moderate	2025	0.17
BASF	Surface Water	IN	Moderate	2030	0.19
BASF	Surface Water	IN	Moderate	2035	0.20
BASF	Surface Water	IN	Moderate	2040	0.23
BASF	Surface Water	IN	Moderate	2050	0.31

User	Water Source	Use Category	Projection	Year	Demand (MGD)
BASF	Surface Water	IN	Moderate	2060	0.38
BASF	Surface Water	IN	Moderate	2070	0.47
Calyx	Surface Water	IR	Moderate	2025	0.00
Calyx	Surface Water	IR	Moderate	2030	0.00
Calyx	Surface Water	IR	Moderate	2035	0.00
Calyx	Surface Water	IR	Moderate	2040	0.00
Calyx	Surface Water	IR	Moderate	2050	0.00
Calyx	Surface Water	IR	Moderate	2060	0.00
Calyx	Surface Water	IR	Moderate	2070	0.00
Clemson Energy	Surface Water	IN	Moderate	2025	0.66
Clemson Energy	Surface Water	IN	Moderate	2030	0.66
Clemson Energy	Surface Water	IN	Moderate	2035	0.66
Clemson Energy	Surface Water	IN	Moderate	2040	0.66
Clemson Energy	Surface Water	IN	Moderate	2050	0.66
Clemson Energy	Surface Water	IN	Moderate	2060	0.66
Clemson Energy	Surface Water	IN	Moderate	2070	0.66
Easley Central WD	Surface Water	WS	Moderate	2025	1.08
Easley Central WD	Surface Water	WS	Moderate	2030	1.12
Easley Central WD	Surface Water	WS	Moderate	2035	1.17
Easley Central WD	Surface Water	WS	Moderate	2040	1.21
Easley Central WD	Surface Water	WS	Moderate	2050	1.31
Easley Central WD	Surface Water	WS	Moderate	2060	1.41
Easley Central WD	Surface Water	WS	Moderate	2070	1.51
Greenville	Surface Water	WS	Moderate	2025	23.15
Greenville	Surface Water	WS	Moderate	2030	28.62
Greenville	Surface Water	WS	Moderate	2035	34.09
Greenville	Surface Water	WS	Moderate	2040	39.56
Greenville	Surface Water	WS	Moderate	2050	50.50
Greenville	Surface Water	WS	Moderate	2060	61.45
Greenville	Surface Water	WS	Moderate	2070	72.39
Gurosik Farm	Surface Water	IR	Moderate	2025	0.09
Gurosik Farm	Surface Water	IR	Moderate	2030	0.09
Gurosik Farm	Surface Water	IR	Moderate	2035	0.09
Gurosik Farm	Surface Water	IR	Moderate	2040	0.09

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Gurosik Farm	Surface Water	IR	Moderate	2050	0.09
Gurosik Farm	Surface Water	IR	Moderate	2060	0.09
Gurosik Farm	Surface Water	IR	Moderate	2070	0.09
Hanson Aggregates	Surface Water	MI	Moderate	2025	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2030	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2035	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2040	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2050	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2060	0.16
Hanson Aggregates	Surface Water	MI	Moderate	2070	0.16
Head Lee Nursery	Surface Water	IR	Moderate	2025	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2030	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2035	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2040	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2050	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2060	0.08
Head Lee Nursery	Surface Water	IR	Moderate	2070	0.08
Hickory Knob	Surface Water	GC	Moderate	2025	0.06
Hickory Knob	Surface Water	GC	Moderate	2030	0.06
Hickory Knob	Surface Water	GC	Moderate	2035	0.06
Hickory Knob	Surface Water	GC	Moderate	2040	0.06
Hickory Knob	Surface Water	GC	Moderate	2050	0.06
Hickory Knob	Surface Water	GC	Moderate	2060	0.06
Hickory Knob	Surface Water	GC	Moderate	2070	0.06
Keowee Falls	Surface Water	GC	Moderate	2025	0.12
Keowee Falls	Surface Water	GC	Moderate	2030	0.12
Keowee Falls	Surface Water	GC	Moderate	2035	0.12
Keowee Falls	Surface Water	GC	Moderate	2040	0.12
Keowee Falls	Surface Water	GC	Moderate	2050	0.12
Keowee Falls	Surface Water	GC	Moderate	2060	0.12
Keowee Falls	Surface Water	GC	Moderate	2070	0.12
Keowee Key	Surface Water	GC	Moderate	2025	0.05
Keowee Key	Surface Water	GC	Moderate	2030	0.05
Keowee Key	Surface Water	GC	Moderate	2035	0.05

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Keowee Key	Surface Water	GC	Moderate	2040	0.05
Keowee Key	Surface Water	GC	Moderate	2050	0.05
Keowee Key	Surface Water	GC	Moderate	2060	0.05
Keowee Key	Surface Water	GC	Moderate	2070	0.05
Keowee Springs	Surface Water	GC	Moderate	2025	0.07
Keowee Springs	Surface Water	GC	Moderate	2030	0.07
Keowee Springs	Surface Water	GC	Moderate	2035	0.07
Keowee Springs	Surface Water	GC	Moderate	2040	0.07
Keowee Springs	Surface Water	GC	Moderate	2050	0.07
Keowee Springs	Surface Water	GC	Moderate	2060	0.07
Keowee Springs	Surface Water	GC	Moderate	2070	0.07
Keowee Vineyards	Surface Water	GC	Moderate	2025	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2030	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2035	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2040	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2050	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2060	0.05
Keowee Vineyards	Surface Water	GC	Moderate	2070	0.05
McCormick	Surface Water	WS	Moderate	2025	0.88
McCormick	Surface Water	WS	Moderate	2030	0.75
McCormick	Surface Water	WS	Moderate	2035	0.63
McCormick	Surface Water	WS	Moderate	2040	0.58
McCormick	Surface Water	WS	Moderate	2050	0.58
McCormick	Surface Water	WS	Moderate	2060	0.58
McCormick	Surface Water	WS	Moderate	2070	0.58
Milliken	Surface Water	IN	Moderate	2025	1.13
Milliken	Surface Water	IN	Moderate	2030	1.26
Milliken	Surface Water	IN	Moderate	2035	1.38
Milliken	Surface Water	IN	Moderate	2040	1.48
Milliken	Surface Water	IN	Moderate	2050	1.72
Milliken	Surface Water	IN	Moderate	2060	1.93
Milliken	Surface Water	IN	Moderate	2070	2.18
Oconee	Surface Water	PN	Moderate	2025	2607.16
Oconee	Surface Water	PN	Moderate	2030	2607.16

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Oconee	Surface Water	PN	Moderate	2035	2607.16
Oconee	Surface Water	PN	Moderate	2040	2601.75
Oconee	Surface Water	PN	Moderate	2050	2607.16
Oconee	Surface Water	PN	Moderate	2060	2601.75
Oconee	Surface Water	PN	Moderate	2070	2607.16
Pickens	Surface Water	WS	Moderate	2025	1.40
Pickens	Surface Water	WS	Moderate	2030	1.48
Pickens	Surface Water	WS	Moderate	2035	1.56
Pickens	Surface Water	WS	Moderate	2040	1.65
Pickens	Surface Water	WS	Moderate	2050	1.81
Pickens	Surface Water	WS	Moderate	2060	1.98
Pickens	Surface Water	WS	Moderate	2070	2.14
Pioneer	Surface Water	WS	Moderate	2025	1.56
Pioneer	Surface Water	WS	Moderate	2030	1.60
Pioneer	Surface Water	WS	Moderate	2035	1.63
Pioneer	Surface Water	WS	Moderate	2040	1.66
Pioneer	Surface Water	WS	Moderate	2050	1.73
Pioneer	Surface Water	WS	Moderate	2060	1.80
Pioneer	Surface Water	WS	Moderate	2070	1.87
Reserve at Keowee	Surface Water	GC	Moderate	2025	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2030	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2035	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2040	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2050	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2060	0.13
Reserve at Keowee	Surface Water	GC	Moderate	2070	0.13
Savannah Lakes	Surface Water	GC	Moderate	2025	0.11
Savannah Lakes	Surface Water	GC	Moderate	2030	0.11
Savannah Lakes	Surface Water	GC	Moderate	2035	0.11
Savannah Lakes	Surface Water	GC	Moderate	2040	0.11
Savannah Lakes	Surface Water	GC	Moderate	2050	0.11
Savannah Lakes	Surface Water	GC	Moderate	2060	0.11
Savannah Lakes	Surface Water	GC	Moderate	2070	0.11
SC Rainey Station	Surface Water	PT	Moderate	2025	2.14

User	Water Source	Use Category	Projection	Year	Demand (MGD)
SC Rainey Station	Surface Water	PT	Moderate	2030	2.14
SC Rainey Station	Surface Water	PT	Moderate	2035	2.14
SC Rainey Station	Surface Water	PT	Moderate	2040	2.13
SC Rainey Station	Surface Water	PT	Moderate	2050	2.14
SC Rainey Station	Surface Water	PT	Moderate	2060	2.13
SC Rainey Station	Surface Water	PT	Moderate	2070	2.14
Seneca	Surface Water	WS	Moderate	2025	5.65
Seneca	Surface Water	WS	Moderate	2030	5.79
Seneca	Surface Water	WS	Moderate	2035	5.90
Seneca	Surface Water	WS	Moderate	2040	5.99
Seneca	Surface Water	WS	Moderate	2050	6.25
Seneca	Surface Water	WS	Moderate	2060	6.51
Seneca	Surface Water	WS	Moderate	2070	6.76
Vulcan	Surface Water	IN	Moderate	2025	0.05
Vulcan	Surface Water	IN	Moderate	2030	0.05
Vulcan	Surface Water	IN	Moderate	2035	0.05
Vulcan	Surface Water	IN	Moderate	2040	0.06
Vulcan	Surface Water	IN	Moderate	2050	0.06
Vulcan	Surface Water	IN	Moderate	2060	0.07
Vulcan	Surface Water	IN	Moderate	2070	0.07
Walhalla	Surface Water	WS	Moderate	2025	1.53
Walhalla	Surface Water	WS	Moderate	2030	1.57
Walhalla	Surface Water	WS	Moderate	2035	1.60
Walhalla	Surface Water	WS	Moderate	2040	1.62
Walhalla	Surface Water	WS	Moderate	2050	1.69
Walhalla	Surface Water	WS	Moderate	2060	1.76
Walhalla	Surface Water	WS	Moderate	2070	1.83
Walker	Surface Water	GC	Moderate	2025	0.10
Walker	Surface Water	GC	Moderate	2030	0.10
Walker	Surface Water	GC	Moderate	2035	0.10
Walker	Surface Water	GC	Moderate	2040	0.10
Walker	Surface Water	GC	Moderate	2050	0.10
Walker	Surface Water	GC	Moderate	2060	0.10
Walker	Surface Water	GC	Moderate	2070	0.10

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Westminster	Surface Water	WS	Moderate	2025	1.22
Westminster	Surface Water	WS	Moderate	2030	1.26
Westminster	Surface Water	WS	Moderate	2035	1.28
Westminster	Surface Water	WS	Moderate	2040	1.30
Westminster	Surface Water	WS	Moderate	2050	1.36
Westminster	Surface Water	WS	Moderate	2060	1.41
Westminster	Surface Water	WS	Moderate	2070	1.47
WG Smith	Surface Water	IR	Moderate	2025	0.00
WG Smith	Surface Water	IR	Moderate	2030	0.00
WG Smith	Surface Water	IR	Moderate	2035	0.00
WG Smith	Surface Water	IR	Moderate	2040	0.00
WG Smith	Surface Water	IR	Moderate	2050	0.00
WG Smith	Surface Water	IR	Moderate	2060	0.00
WG Smith	Surface Water	IR	Moderate	2070	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2025	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2030	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2035	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2040	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2050	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2060	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	Moderate	2070	0.00
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2025	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2030	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2035	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2040	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2050	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2060	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	Moderate	2070	0.08
Michelin NA/US 10	Groundwater	IN	Moderate	2025	0.00
Michelin NA/US 10	Groundwater	IN	Moderate	2030	0.00

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Michelin NA/US 10	Groundwater	IN	Moderate	2035	0.00
Michelin NA/US 10	Groundwater	IN	Moderate	2040	0.00
Michelin NA/US 10	Groundwater	IN	Moderate	2050	0.00
Michelin NA/US 10	Groundwater	IN	Moderate	2060	0.00
Michelin NA/US 10	Groundwater	IN	Moderate	2070	0.00
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2025	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2030	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2035	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2040	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2050	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2060	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	Moderate	2070	0.23
SALEM TOWN OF	Groundwater	WS	Moderate	2025	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2030	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2035	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2040	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2050	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2060	0.09
SALEM TOWN OF	Groundwater	WS	Moderate	2070	0.09
Abbeville	Surface Water	WS	High Demand	2025	2.32
Abbeville	Surface Water	WS	High Demand	2030	2.45
Abbeville	Surface Water	WS	High Demand	2035	2.59
Abbeville	Surface Water	WS	High Demand	2040	2.74
Abbeville	Surface Water	WS	High Demand	2050	3.05
Abbeville	Surface Water	WS	High Demand	2060	3.41
Abbeville	Surface Water	WS	High Demand	2070	3.82
Agriculture Distributed Growth	Surface Water	IR	High Demand	2025	0.01
Agriculture Distributed Growth	Surface Water	IR	High Demand	2030	0.02
Agriculture Distributed Growth	Surface Water	IR	High Demand	2035	0.03
Agriculture Distributed Growth	Surface Water	IR	High Demand	2040	0.05
Agriculture Distributed Growth	Surface Water	IR	High Demand	2050	0.07
Agriculture Distributed Growth	Surface Water	IR	High Demand	2060	0.10
Agriculture Distributed Growth	Surface Water	IR	High Demand	2070	0.14
ARJWS	Surface Water	IN	High Demand	2025	6.03

User	Water Source	Use Category	Projection	Year	Demand (MGD)
ARJWS	Surface Water	IN	High Demand	2030	6.37
ARJWS	Surface Water	IN	High Demand	2035	6.73
ARJWS	Surface Water	IN	High Demand	2040	7.11
ARJWS	Surface Water	IN	High Demand	2050	7.93
ARJWS	Surface Water	IN	High Demand	2060	8.86
ARJWS	Surface Water	IN	High Demand	2070	9.91
ARJWS	Surface Water	WS	High Demand	2025	22.08
ARJWS	Surface Water	WS	High Demand	2030	23.31
ARJWS	Surface Water	WS	High Demand	2035	24.62
ARJWS	Surface Water	WS	High Demand	2040	26.00
ARJWS	Surface Water	WS	High Demand	2050	29.03
ARJWS	Surface Water	WS	High Demand	2060	32.43
ARJWS	Surface Water	IN	High Demand	2070	36.27
BASF	Surface Water	IN	High Demand	2025	0.32
BASF	Surface Water	IN	High Demand	2030	0.35
BASF	Surface Water	IN	High Demand	2035	0.39
BASF	Surface Water	IN	High Demand	2040	0.43
BASF	Surface Water	IN	High Demand	2050	0.53
BASF	Surface Water	IN	High Demand	2060	0.65
BASF	Surface Water	IN	High Demand	2070	0.81
Calyx	Surface Water	IR	High Demand	2025	0.05
Calyx	Surface Water	IR	High Demand	2030	0.05
Calyx	Surface Water	IR	High Demand	2035	0.05
Calyx	Surface Water	IR	High Demand	2040	0.05
Calyx	Surface Water	IR	High Demand	2050	0.05
Calyx	Surface Water	IR	High Demand	2060	0.05
Calyx	Surface Water	IR	High Demand	2070	0.05
Clemson Energy	Surface Water	IN	High Demand	2025	4.20
Clemson Energy	Surface Water	IN	High Demand	2030	4.20
Clemson Energy	Surface Water	IN	High Demand	2035	4.20
Clemson Energy	Surface Water	IN	High Demand	2040	4.20
Clemson Energy	Surface Water	IN	High Demand	2050	4.20
Clemson Energy	Surface Water	IN	High Demand	2060	4.20
Clemson Energy	Surface Water	IN	High Demand	2070	4.20

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Easley Central WD	Surface Water	WS	High Demand	2025	1.24
Easley Central WD	Surface Water	WS	High Demand	2030	1.31
Easley Central WD	Surface Water	WS	High Demand	2035	1.38
Easley Central WD	Surface Water	WS	High Demand	2040	1.46
Easley Central WD	Surface Water	WS	High Demand	2050	1.63
Easley Central WD	Surface Water	WS	High Demand	2060	1.82
Easley Central WD	Surface Water	WS	High Demand	2070	2.03
Greenville	Surface Water	WS	High Demand	2025	23.15
Greenville	Surface Water	WS	High Demand	2030	32.30
Greenville	Surface Water	WS	High Demand	2035	41.46
Greenville	Surface Water	WS	High Demand	2040	50.61
Greenville	Surface Water	WS	High Demand	2050	68.92
Greenville	Surface Water	WS	High Demand	2060	87.23
Greenville	Surface Water	WS	High Demand	2070	105.54
Gurosik Farm	Surface Water	IR	High Demand	2025	0.14
Gurosik Farm	Surface Water	IR	High Demand	2030	0.14
Gurosik Farm	Surface Water	IR	High Demand	2035	0.14
Gurosik Farm	Surface Water	IR	High Demand	2040	0.14
Gurosik Farm	Surface Water	IR	High Demand	2050	0.14
Gurosik Farm	Surface Water	IR	High Demand	2060	0.14
Gurosik Farm	Surface Water	IR	High Demand	2070	0.14
Hanson Aggregates	Surface Water	MI	High Demand	2025	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2030	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2035	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2040	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2050	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2060	0.50
Hanson Aggregates	Surface Water	MI	High Demand	2070	0.50
Head Lee Nursery	Surface Water	IR	High Demand	2025	0.13
Head Lee Nursery	Surface Water	IR	High Demand	2030	0.13
Head Lee Nursery	Surface Water	IR	High Demand	2035	0.13
Head Lee Nursery	Surface Water	IR	High Demand	2040	0.13
Head Lee Nursery	Surface Water	IR	High Demand	2050	0.13
Head Lee Nursery	Surface Water	IR	High Demand	2060	0.13

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Head Lee Nursery	Surface Water	IR	High Demand	2070	0.13
Hickory Knob	Surface Water	GC	High Demand	2025	0.14
Hickory Knob	Surface Water	GC	High Demand	2030	0.14
Hickory Knob	Surface Water	GC	High Demand	2035	0.14
Hickory Knob	Surface Water	GC	High Demand	2040	0.14
Hickory Knob	Surface Water	GC	High Demand	2050	0.14
Hickory Knob	Surface Water	GC	High Demand	2060	0.14
Hickory Knob	Surface Water	GC	High Demand	2070	0.14
Keowee Falls	Surface Water	GC	High Demand	2025	0.26
Keowee Falls	Surface Water	GC	High Demand	2030	0.26
Keowee Falls	Surface Water	GC	High Demand	2035	0.26
Keowee Falls	Surface Water	GC	High Demand	2040	0.26
Keowee Falls	Surface Water	GC	High Demand	2050	0.26
Keowee Falls	Surface Water	GC	High Demand	2060	0.26
Keowee Falls	Surface Water	GC	High Demand	2070	0.26
Keowee Key	Surface Water	GC	High Demand	2025	0.13
Keowee Key	Surface Water	GC	High Demand	2030	0.13
Keowee Key	Surface Water	GC	High Demand	2035	0.13
Keowee Key	Surface Water	GC	High Demand	2040	0.13
Keowee Key	Surface Water	GC	High Demand	2050	0.13
Keowee Key	Surface Water	GC	High Demand	2060	0.13
Keowee Key	Surface Water	GC	High Demand	2070	0.13
Keowee Springs	Surface Water	GC	High Demand	2025	0.19
Keowee Springs	Surface Water	GC	High Demand	2030	0.19
Keowee Springs	Surface Water	GC	High Demand	2035	0.19
Keowee Springs	Surface Water	GC	High Demand	2040	0.19
Keowee Springs	Surface Water	GC	High Demand	2050	0.19
Keowee Springs	Surface Water	GC	High Demand	2060	0.19
Keowee Springs	Surface Water	GC	High Demand	2070	0.19
Keowee Vineyards	Surface Water	GC	High Demand	2025	0.11
Keowee Vineyards	Surface Water	GC	High Demand	2030	0.11
Keowee Vineyards	Surface Water	GC	High Demand	2035	0.11
Keowee Vineyards	Surface Water	GC	High Demand	2040	0.11
Keowee Vineyards	Surface Water	GC	High Demand	2050	0.11

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Keowee Vineyards	Surface Water	GC	High Demand	2060	0.11
Keowee Vineyards	Surface Water	GC	High Demand	2070	0.11
McCormick	Surface Water	WS	High Demand	2025	1.29
McCormick	Surface Water	WS	High Demand	2030	1.35
McCormick	Surface Water	WS	High Demand	2035	1.41
McCormick	Surface Water	WS	High Demand	2040	1.48
McCormick	Surface Water	WS	High Demand	2050	1.62
McCormick	Surface Water	WS	High Demand	2060	1.78
McCormick	Surface Water	WS	High Demand	2070	1.95
Milliken	Surface Water	IN	High Demand	2025	1.59
Milliken	Surface Water	IN	High Demand	2030	1.76
Milliken	Surface Water	IN	High Demand	2035	1.95
Milliken	Surface Water	IN	High Demand	2040	2.16
Milliken	Surface Water	IN	High Demand	2050	2.67
Milliken	Surface Water	IN	High Demand	2060	3.28
Milliken	Surface Water	IN	High Demand	2070	4.04
Oconee	Surface Water	PN	High Demand	2025	2846.49
Oconee	Surface Water	PN	High Demand	2030	2846.49
Oconee	Surface Water	PN	High Demand	2035	2846.49
Oconee	Surface Water	PN	High Demand	2040	2839.53
Oconee	Surface Water	PN	High Demand	2050	2846.49
Oconee	Surface Water	PN	High Demand	2060	2839.53
Oconee	Surface Water	PN	High Demand	2070	2846.49
Pickens	Surface Water	WS	High Demand	2025	1.57
Pickens	Surface Water	WS	High Demand	2030	1.67
Pickens	Surface Water	WS	High Demand	2035	1.78
Pickens	Surface Water	WS	High Demand	2040	1.90
Pickens	Surface Water	WS	High Demand	2050	2.17
Pickens	Surface Water	WS	High Demand	2060	2.48
Pickens	Surface Water	WS	High Demand	2070	2.83
Pioneer	Surface Water	WS	High Demand	2025	1.78
Pioneer	Surface Water	WS	High Demand	2030	1.86
Pioneer	Surface Water	WS	High Demand	2035	1.95
Pioneer	Surface Water	WS	High Demand	2040	2.04

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Pioneer	Surface Water	WS	High Demand	2050	2.23
Pioneer	Surface Water	WS	High Demand	2060	2.44
Pioneer	Surface Water	WS	High Demand	2070	2.68
Reserve at Keowee	Surface Water	GC	High Demand	2025	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2030	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2035	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2040	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2050	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2060	0.22
Reserve at Keowee	Surface Water	GC	High Demand	2070	0.22
Savannah Lakes	Surface Water	GC	High Demand	2025	0.24
Savannah Lakes	Surface Water	GC	High Demand	2030	0.24
Savannah Lakes	Surface Water	GC	High Demand	2035	0.24
Savannah Lakes	Surface Water	GC	High Demand	2040	0.24
Savannah Lakes	Surface Water	GC	High Demand	2050	0.24
Savannah Lakes	Surface Water	GC	High Demand	2060	0.24
Savannah Lakes	Surface Water	GC	High Demand	2070	0.24
SC Rainey Station	Surface Water	PT	High Demand	2025	2.48
SC Rainey Station	Surface Water	PT	High Demand	2030	2.48
SC Rainey Station	Surface Water	PT	High Demand	2035	2.48
SC Rainey Station	Surface Water	PT	High Demand	2040	2.47
SC Rainey Station	Surface Water	PT	High Demand	2050	2.48
SC Rainey Station	Surface Water	PT	High Demand	2060	2.47
SC Rainey Station	Surface Water	PT	High Demand	2070	2.48
Seneca	Surface Water	WS	High Demand	2025	6.41
Seneca	Surface Water	WS	High Demand	2030	6.71
Seneca	Surface Water	WS	High Demand	2035	7.02
Seneca	Surface Water	WS	High Demand	2040	7.35
Seneca	Surface Water	WS	High Demand	2050	8.05
Seneca	Surface Water	WS	High Demand	2060	8.82
Seneca	Surface Water	WS	High Demand	2070	9.66
Vulcan	Surface Water	IN	High Demand	2025	0.55
Vulcan	Surface Water	IN	High Demand	2030	0.61
Vulcan	Surface Water	IN	High Demand	2035	0.68

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Vulcan	Surface Water	IN	High Demand	2040	0.75
Vulcan	Surface Water	IN	High Demand	2050	0.93
Vulcan	Surface Water	IN	High Demand	2060	1.14
Vulcan	Surface Water	IN	High Demand	2070	1.40
Walhalla	Surface Water	WS	High Demand	2025	1.74
Walhalla	Surface Water	WS	High Demand	2030	1.82
Walhalla	Surface Water	WS	High Demand	2035	1.90
Walhalla	Surface Water	WS	High Demand	2040	1.99
Walhalla	Surface Water	WS	High Demand	2050	2.18
Walhalla	Surface Water	WS	High Demand	2060	2.39
Walhalla	Surface Water	WS	High Demand	2070	2.61
Walker	Surface Water	GC	High Demand	2025	0.24
Walker	Surface Water	GC	High Demand	2030	0.24
Walker	Surface Water	GC	High Demand	2035	0.24
Walker	Surface Water	GC	High Demand	2040	0.24
Walker	Surface Water	GC	High Demand	2050	0.24
Walker	Surface Water	GC	High Demand	2060	0.24
Walker	Surface Water	GC	High Demand	2070	0.24
Westminster	Surface Water	WS	High Demand	2025	1.39
Westminster	Surface Water	WS	High Demand	2030	1.45
Westminster	Surface Water	WS	High Demand	2035	1.52
Westminster	Surface Water	WS	High Demand	2040	1.59
Westminster	Surface Water	WS	High Demand	2050	1.75
Westminster	Surface Water	WS	High Demand	2060	1.91
Westminster	Surface Water	WS	High Demand	2070	2.09
WG Smith	Surface Water	IR	High Demand	2025	0.00
WG Smith	Surface Water	IR	High Demand	2030	0.00
WG Smith	Surface Water	IR	High Demand	2035	0.00
WG Smith	Surface Water	IR	High Demand	2040	0.00
WG Smith	Surface Water	IR	High Demand	2050	0.00
WG Smith	Surface Water	IR	High Demand	2060	0.00
WG Smith	Surface Water	IR	High Demand	2070	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2025	0.00

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2030	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2035	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2040	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2050	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2060	0.00
Blue Granite Water Company/PURDY SHORE S/D	Groundwater	WS	High Demand	2070	0.00
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2025	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2030	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2035	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2040	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2050	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2060	0.08
Layman Wholesale Nursery Inc	Groundwater	IR	High Demand	2070	0.08
Michelin NA/US 10	Groundwater	IN	High Demand	2025	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2030	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2035	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2040	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2050	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2060	0.00
Michelin NA/US 10	Groundwater	IN	High Demand	2070	0.00
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2025	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2030	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2035	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2040	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2050	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2060	0.23
MT VINTAGE GOLF CLUB	Groundwater	GC	High Demand	2070	0.23
SALEM TOWN OF	Groundwater	WS	High Demand	2025	0.09
SALEM TOWN OF	Groundwater	WS	High Demand	2030	0.09
SALEM TOWN OF	Groundwater	WS	High Demand	2035	0.09

User	Water Source	Use Category	Projection	Year	Demand (MGD)
SALEM TOWN OF	Groundwater	WS	High Demand	2040	0.09
SALEM TOWN OF	Groundwater	WS	High Demand	2050	0.09
SALEM TOWN OF	Groundwater	WS	High Demand	2060	0.09
SALEM TOWN OF	Groundwater	WS	High Demand	2070	0.09

Appendix B
Flow-Ecology Relationships in the Upper Savannah River Basin

08/30/2024

Flow-Ecology Relationships in the Upper Savannah River Basin

With Applications for Flow Performance Measures in SWAM

DRAFT

DISCLAIMER

The following peer-reviewed scientific publications contain detailed information on data sources, flow metric calculations, statistical analyses relating flow to aquatic organisms, etc.:

- Bower, L. M., Peoples, B. K., Eddy, M. C., & Scott, M. C. (2022). Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina. Science of the Total Environment, 802, 149721. URL: https://www.sciencedirect.com/science/article/pii/S0048969721047963
- Eddy, M. C., Lord, B., Perrot, D., Bower, L. M., & Peoples, B. K. (2022). Predictability of flow metrics calculated using a distributed hydrologic model across ecoregions and stream classes: Implications for developing flow–ecology relationships. Ecohydrology, 15(2), e2387. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/eco.2387

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The Nature Conservancy

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John Boyer

US Forest Service

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Weyerhaeuser Corporation

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EXECUTIVE SUMMARY

Responses of organisms to stream flow change have long been recognized in scientific literature. The evolution of methods, large data sets, and statistical improvements over the last 20 years have advanced our ability to characterize these responses. If the necessary data is available, it is now possible to understand these responses to a specificity, making them useful for water resource management.

We identified a wide variety of flow–biological relationships to derive a set of recommended performance measures and predict changes in biological metrics in response to changes in flow for the upper Savannah River basin. These relationships:

1) are highly relevant to drought management and water withdrawal,

2) are the strongest relationships between flow and river health, and

3) capture the greatest number of flow regime components of the streams and rivers of the upper Savannah River Basin.

We found statistically significant effects of flow on fish and invertebrates for all attributes of the natural flow regime, including magnitude, duration, frequency, timing, or rate of change. For this recommendation, only measures that are relevant to the upper Savannah River, can be calculated in SWAM, and meet the three principles cited above were used.

Priority Flow Characteristics

A flow metric emerged as having the greatest impact on instream health in the Basin. It was:

1. *Mean Daily Flow*: The mean daily flow is the mean of daily flows over the period of record.

Results Summary:

Overall, SWAM estimated no significant change in mean daily flow (MA1) for all scenarios and at all strategic nodes. The largest change in mean daily flow was predicted by SWAM at Twelvemile Creek, showing a 4.4% reduction in mean daily flow full allocation water use scenario with an estimated change in the number of fish species and Shannon's diversity of fishes by 4% and 3%, respectively. Based on the SWAM models, mean daily flow is not expected to be strongly altered by water use across all scenarios and strategic nodes. Therefore, we predict little change in the biological metrics based on these SWAM scenarios.

INTRODUCTION

South Carolina is home to a rich diversity of freshwater organisms, including a variety of fishes and invertebrates. These organisms have unique traits that make them especially adapted for life in rivers. Many species have traits that make them *sensitive* to environmental change. Some of these traits include spawning or living in gravel habitats, or specialized body shapes for living in high-flow conditions. Likewise, other species have traits that make them *tolerant* to environmental change, such as the ability to spawn in a variety of habitats or tolerate a wide range of temperatures.

Over 50 years of research supports the fact that aquatic organisms respond readily to changes in their environment. It is well known that key *biological metrics* such as the total number of species in a location and the representation of species with similar traits are directly indicative of *aquatic ecosystem health*. As ecosystems become less healthy, sensitive species are removed and replaced by tolerant species. Scientists use these biological metrics to assess aquatic ecosystem health to (a) identify high quality ecosystems to maintain and (b) identify ecosystems in poor health for remediation.

Aquatic ecosystem health is influenced strongly by instream flow. Sensitive species are especially adapted to the *natural flow regime*. The natural flow regime is described by five aspects of flow events that culminate to describe the overall flow conditions in a stream or river. These include:

-*Magnitude*: The size of high- and low-flow events

-*Frequency*: How often high- and low-flow events occur

-*Duration*: How long high- and low-flow events last when they do occur

-*Timing:* The time of year in which high- and low-flow events occur

-*Rate of change*: How often flows change from increasing to decreasing, or vice versa

Historically, instream flow management recommendations have focused only on maintaining minimum daily flows. However, it is becoming increasingly recognized that management for all five components of the natural flow regime is necessary for maintaining aquatic ecosystem health.

The natural flow regime is different across regions, and changes based on geology, natural vegetation, and precipitation patterns (see **upper Savannah River Stream Types** below). Humans can alter the natural flow regime by withdrawing water directly from surface water or indirectly through groundwater withdrawal. Humans can also affect flow by changing land cover. Converting natural forests, grasslands, and wetlands to intensive agriculture or urban/suburban land cover types changes natural patterns of surface runoff and groundwater recharge. These changes have direct effects on aquatic ecosystem health and are indicated by aquatic organisms.

South Carolina is a state that is rich in water resources. However, the state is experiencing a period of rapid economic growth and population expansion. As such, identifying relationships between key instream flow metrics and biological metrics (hereafter, *flow-ecology relationships*) will provide guidance for developing recommendations for instream flow management that allows for smart development while maintaining the natural flow regime for aquatic ecosystem health.

THIS STUDY

The goal of this study was to estimate flow-ecology relationships for fishes and macroinvertebrates for streams and small rivers in the upper Savannah River basin, South Carolina to provide recommendations for guiding instream flow management in the basin. The best available data sources and statistical modeling tools were used to accomplish this goal. The approach is summarized as follows:

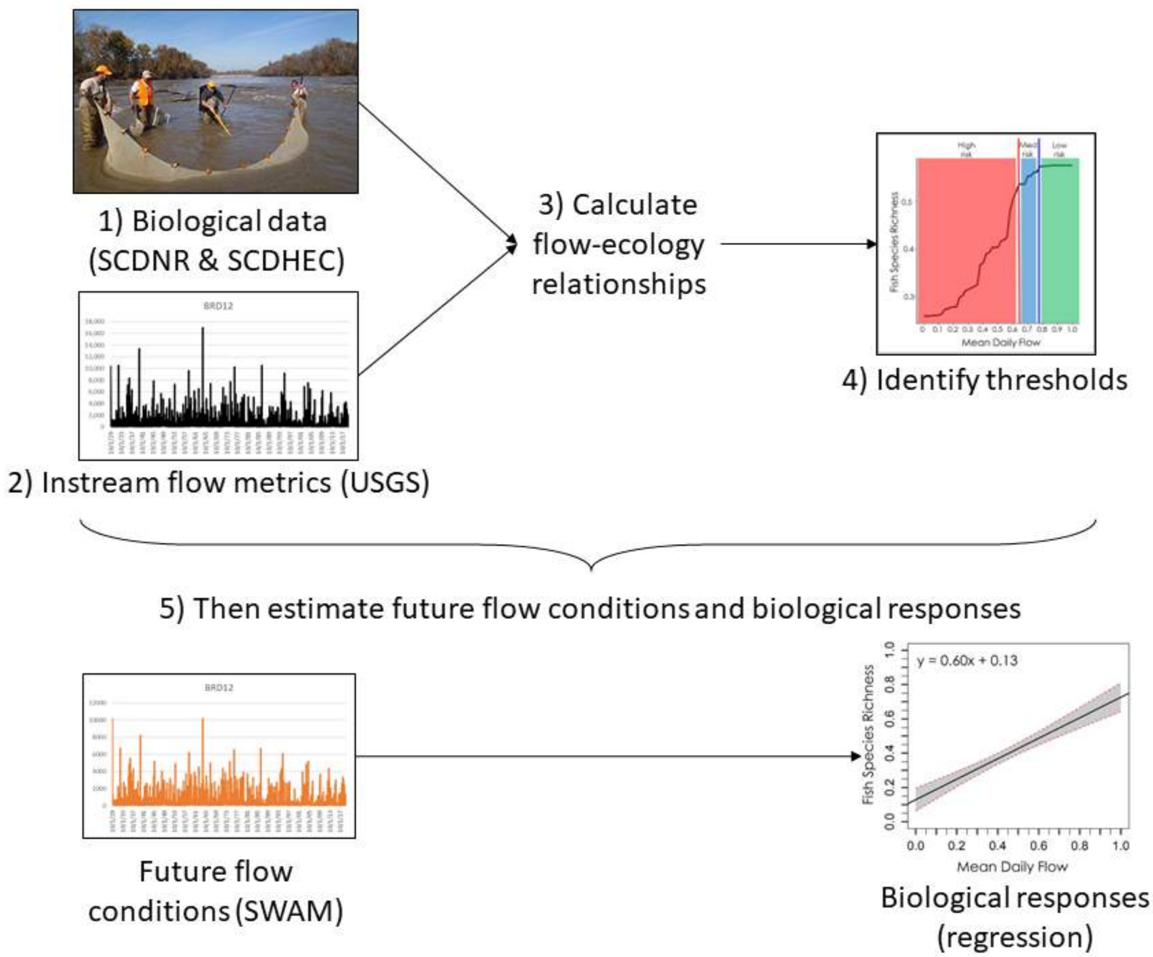


Figure 1: Flow chart of the described methods.

1. *Obtain biological data*: Fish community data is collected by the South Carolina Department of Natural Resources (SCDNR). Aquatic invertebrate community data is collected by the South Carolina Department of Health and Environmental Control (SCDHEC). In total, these include 1,022 sampling locations across the state, and about 120 in the upper Savannah River basin (Figure 2). All data are collected using standardized protocols designed to fully characterize the aquatic community for the purpose of quantifying aquatic ecosystem health. Sampling protocols can be found in Scott et al. (2009) and SCDHEC (2017). Raw fish and invertebrate community data were summarized into numerous biological metrics for each sampling site based on the number of species and proportional representation of species with similar traits. These metrics have been shown in previous studies to be directly indicative of aquatic ecosystem health. The full list of biological metrics included in this study is presented in Appendix Table 1.

2. *Estimate instream flow metrics*. The US Geological Survey maintains 2 flow gauges in the Savannah River Basin. However, biological sampling does not always occur at those locations, and

the number of gauged sites does not present sufficient sample sites for estimating flow ecology relationships. Accordingly, flow metrics were estimated for every stream/river in the Savannah River basin using the WaterFALL(™) flow allocation model. This work was accomplished by researchers from RTI International and is reported in full detail in Eddy et al. (2022). The full list of candidate flow metrics used in this study is presented in Appendix Table 2.

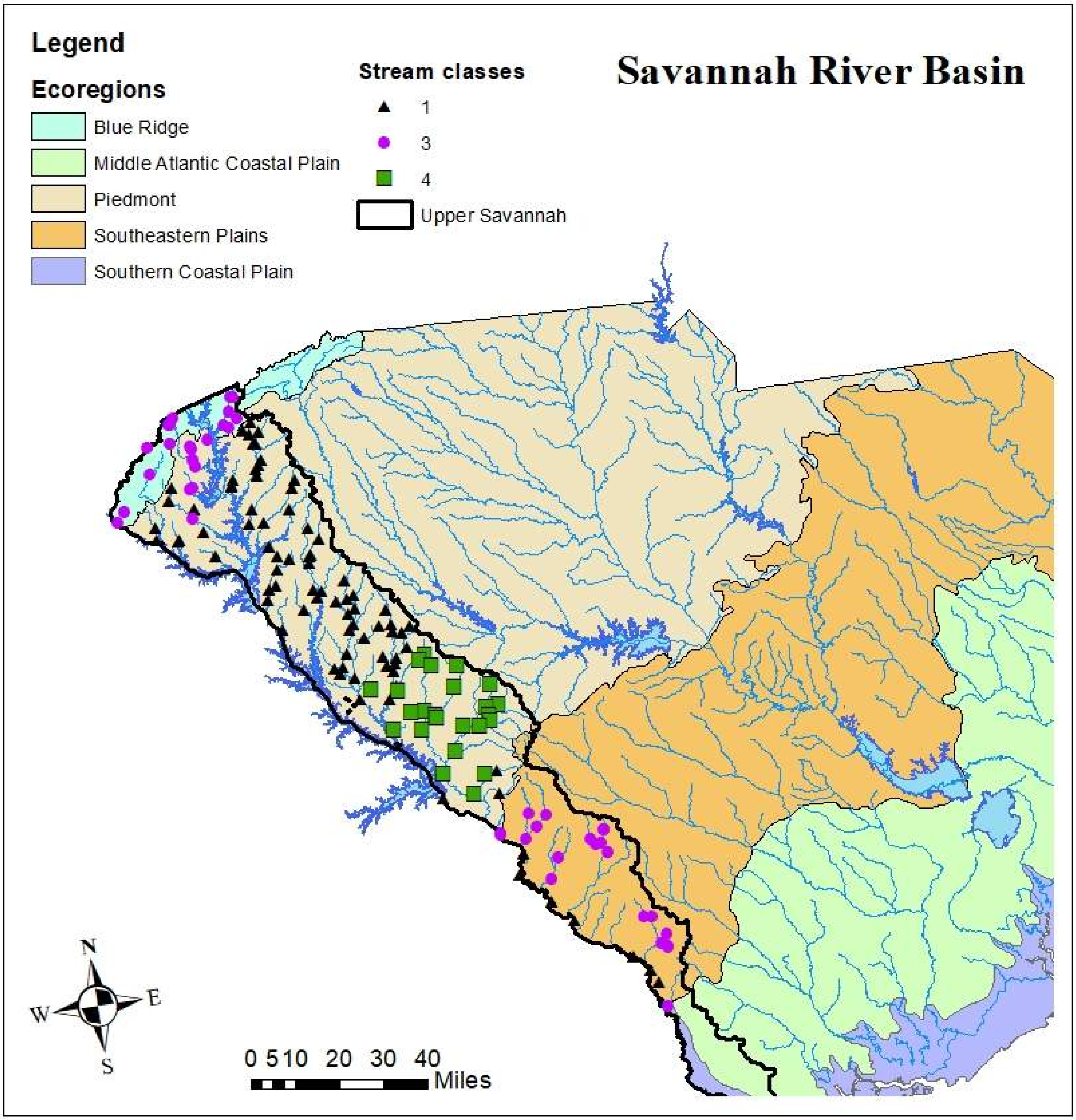


Figure 2: *Map of the upper Savannah River Basin overlain with ecoregion boundaries and stream classifications. Each point is also a biological sampling point for either fish, or aquatic invertebrates, or*

both. Stream classes are labeled as follows:1 (perennial runoff), 3 (stable base flow), and 4 (perennial flashy).

3. *Identify critical flow-ecology relationships*. The modeling approach started with 24 flow metrics and 14 biological metrics, yielding an untenable number of potential relationships. To reduce this complexity, we only analyzed flow metrics that were (a) shown to be biologically relevant (b) captured all components of the flow regime, and (c) were non-redundant (Appendix Table 2). Because many biological metrics will be weakly correlated with some flow metrics, it was critical to identify the strongest and most informative flow-ecology relationships to develop recommendations. This was accomplished using *random forests*—a type of machine learning statistical model that is ideal for identifying complex ecological relationships.

4. *Use flow-ecology relationships to identify potentially harmful/protective levels of flow change*. The most important relationships can be identified by random forest in two ways: 1) as a performance measure to determine the potential biological impact of water withdrawal, and 2) to estimate predicted change in a biological metric based on estimated change in flow due to water withdrawal. To create the performance measures, the random forest model plots were used as seen below (Figure 2). These plots are scaled to represent the estimated proportional change in the biotic metric that would result from a proportional change in the flow metric. These plots were used to identify potential flow thresholds – a point along a flow metric that corresponds to large shifts in biological health. The thresholds define the best points to set performance measures. Two distinct thresholds were identified in each relationship to produce 3 zones corresponding to high, medium, and low levels of risk to the chosen biotic metric.

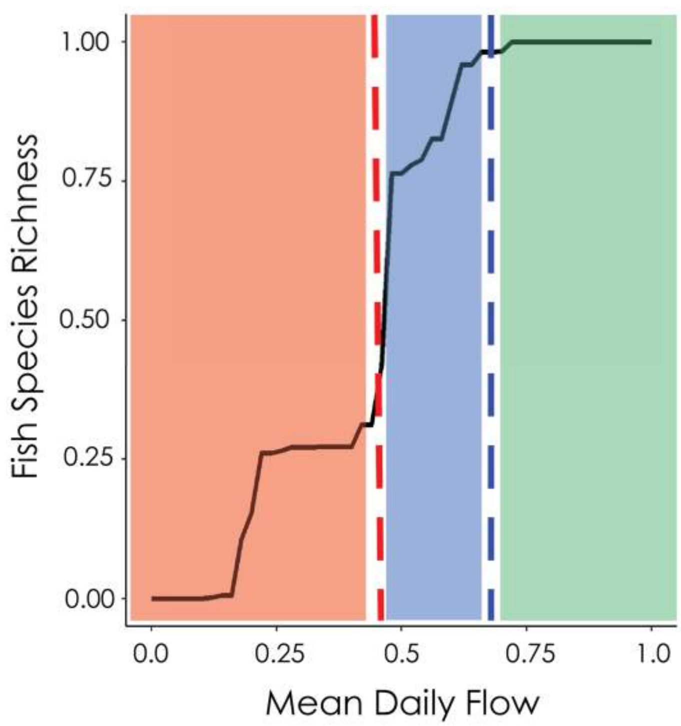


Figure 3*: Model-estimated risk ranges for the selected biota and flow metrics. in Piedmont Flashy Streams. Areas of high risk are shaded red, medium risk in blue, and low risk in green. Changes in the overall flow regime cause mean daily flow to fall between 71 and 49% of current values in Piedmont flashy perennial streams correspond to low and high risk for fish species loss, respectively. Reducing mean daily flow into the zone of 49-71% constitutes medium risk for fish species loss.*

5. *Estimate potential future flow conditions and biological response*. Researchers from CDM Smith used the Surface Water Allocation Model (SWAM) to estimate future flow conditions at *strategic nodes*–key locations in tributaries to the upper Savannah River (Figure 4). Estimates were provided for four potential future water withdrawal scenarios: (1) unimpaired flow (no water withdrawals occur in the system), (2) moderate development by 2070, (3) high development by 2070, and (4) full allocation (all permitted water withdrawals are realized) for each strategic node. Finally, potential future changes in biological metrics were estimated in each of the four future water withdrawal scenarios based on (a) model-predicted responses of biological metrics to instream flow, and (b) SWAM-based predicted flow metrics. To do this, linear relationships between each flow metric and biological metric were used for the important relationships identified by random forest models. This method provides a more precise estimate of the biological change in response to flow alteration and the error associated with this estimate (Figure 5). This process was conducted for each of three main categories of streams and rivers in the upper Savannah River basin (see below).

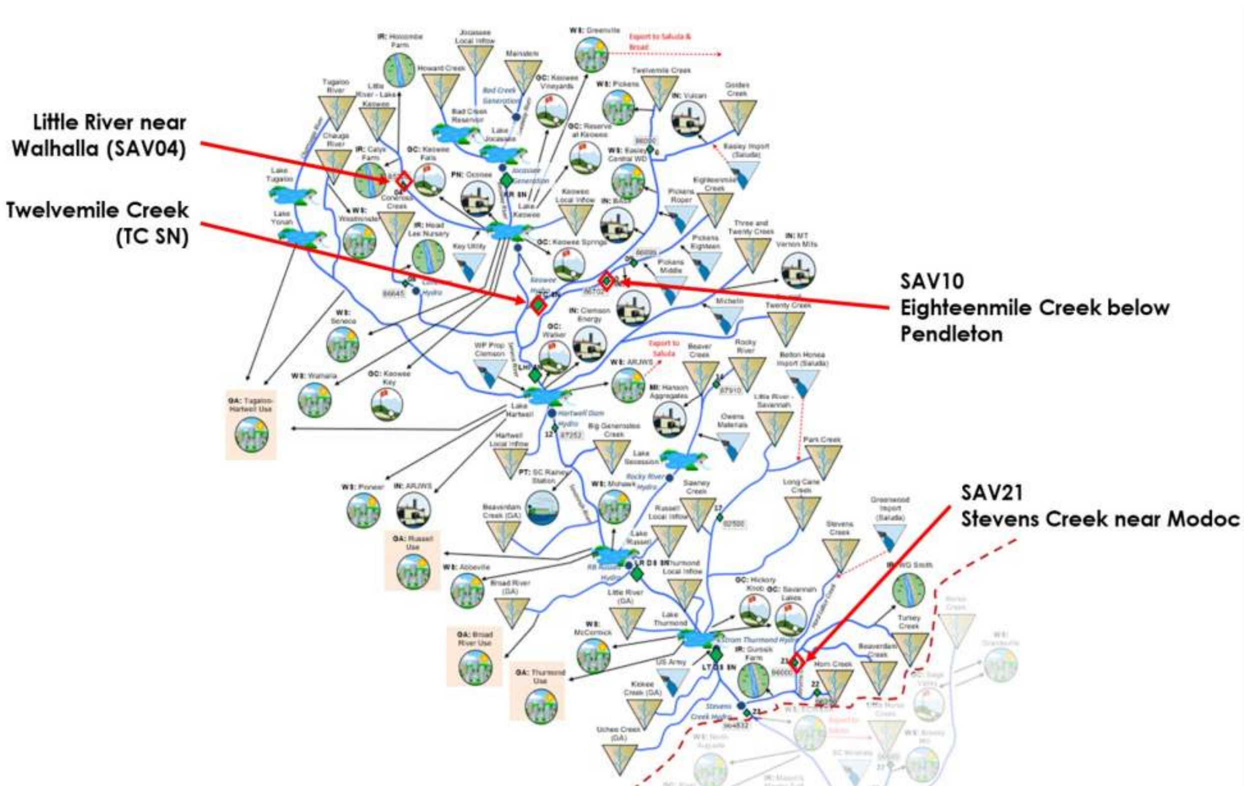


Figure 4: *Location of example strategic nodes from the upper Savannah River River Basin*

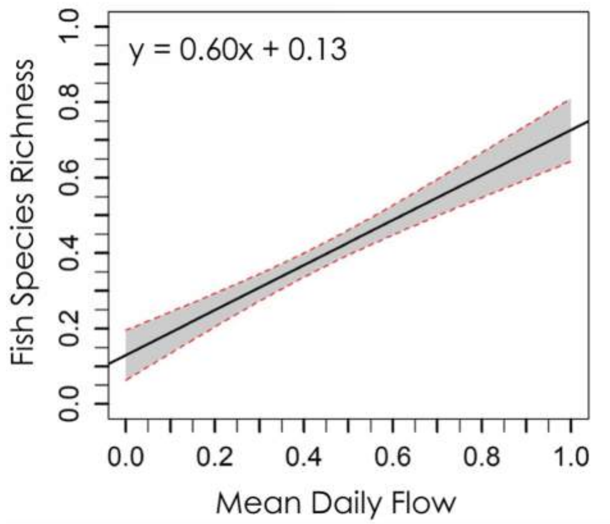


Figure 5*. Example of the linear relationship established between mean daily flow and fish species richness in Piedmont Flashy Streams. The formula,* Y = 0.60x + 0.13*, allows us to apply this relationship to the flow projection scenarios by replacing* x *with the predicted mean daily flow to derive the predicted change in fish richness, represented by* Y.

UPPER SAVANNAH RIVER STREAM TYPES

There are 5 stream types in the Upper Savannah River basin (**Figure 2**), determined by ecoregion and water source / behavior:

1. Piedmont Perennial Runoff (P1): Streams and rivers in the Piedmont ecoregion characterized by moderately stable flow and distinct seasonal extremes.

2. Piedmont Perennial Flashy (P4): Streams in the Piedmont ecoregion with moderately stable flow with high variability.

3. Blue Ridge Plains Stable Base Flow (SE3): Streams and rivers in the Blue Ridge ecoregion whose flow is composed of both high stable base flow and rainfall runoff.

However, no strategic nodes were selected in the Blue Ridge ecoregions, restricting the results to a two stream classes: Piedmont Perennial Runoff and Piedmont Perennial Flashy.

ASSUMPTIONS OF THE APPROACH

Like all model-based studies, the approach relies on a few assumptions that should be considered when interpreting the results.

First, the flow-ecology relationship analyses assume that flow metrics were estimated perfectly. This is not the case, and indeed is impossible, as described in detail in Eddy et al. (2022). However, this study relied on the most precisely estimated flow metrics estimated by Eddy et al. (2022), and omitted flow metrics with high levels of uncertainty.

Second, models are only as good as the data on which they are based. The most up-to-date sources to estimate flow metrics and their relationships with biological metrics were used. However, data are continuously being collected by USGS, SCDHEC, and SCDNR. As such, the inclusion of new data into potential future approaches could yield different results. However, the inclusion of new data would be expected to only increase the precision of the estimates.

A third assumption is that future flow-ecology relationships will exist in the same shape and magnitude as they currently do. The future flow scenarios are based solely on changes to instream flow metrics due to known surface water withdrawal demands. These scenarios assume that land cover, temperature, and precipitation, and thus instream flow, will remain the same in the future. While this may not be a reasonable assumption, incorporating these factors into more detailed estimates of future instream flow conditions is beyond the scope of the present work, but will be an important contribution to ongoing flow management efforts.

Finally, this work was developed on streams in rivers with watershed areas of 3 to 600 km^2. Streams of this size represent 87% of the surface water in South Carolina. This work did not include data from reservoirs or large rivers, and as such is not informative for making recommendations regarding flow management of any waterbody with a watershed greater than 600 km^2.

RESULTS: IDENTIFYING FLOW-ECOLOGY RELATIONSHIPS

Biotic metrics: Random Forest models allowed us to identify clear flow-ecology relationships. A single biotic metric was found to be informative of changes in instream flow in the one stream class. A list of at-risk species in the upper Savannah River Basin is provided in Appendix Table 3. This included:

- Species Richness: the number of species found at a given site
- Shannon diversity: an index of biodiversity that accounts for both species richness and proportional representation of each species

Flow metrics: Statistically significant effects of flow on fish and invertebrates were found for all attributes of the natural flow regime, including magnitude, duration, frequency, timing, or rate of change. However, for this recommendation, we are only bringing forward measures that are relevant to the one stream class within upper Savannah River basin, can be calculated in SWAM, and meet the three principles cited above. One flow metric emerged as having the greatest impact on aquatic ecosystem health in the upper Savannah River Basin:

1. <u>Mean Daily Flow</u>: The mean of all daily flows over the period of record.

RECOMMENDED PERFORMANCE MEASURES

Based on the flow-ecology relationships identified above, we suggest the following performance measures (Table 1). The recommended measures reflect the variability of biological responses in different ecoregions and stream types while producing a manageable set of responses to consider.

Table 1: The risk ranges for the most informative flow and biological metric for each stream class in the upper Savannah River basin. The biological metric is given in brackets. The risk ranges are colored as green (low risk), yellow (medium risk), and red (high risk).

	Performance Recommendations and Risk Ranges					
Stream Type:	**Piedmont Perennial**			**Piedmont Flashy**		
	Low	**Med**	**High**	**Low**	**Med**	**High**
Flow Metric						
Mean Daily Flow (FR)	>0.66	0.42-0.66	<0.42	>0.71	0.49-0.71	<0.49
Mean Daily Flow (FS)	>0.78	0.46-0.78	<0.46			
FR=Fish Species Richness: The number of fish species found in a stream or river reach						
FS=Fish Species Shannon's diversity: The evenness of fish species found in a stream or river reach						

APPLICATION: EVALUATING WATER USE SCENARIOS IN SWAM

SWAM was used to create four flow scenarios based on water withdrawals:

1. Unimpaired flow (no water withdrawals occur in the system)
2. Moderate development by 2070
3. High development by 2070
4. Full allocation (all permitted water withdrawals are realized) for each strategic node.

We used the flow–biological relationships in conjunction with SWAM results to estimate the responses of the organisms to these various water withdrawal scenarios at each strategic node. The performance measures can be used in an intuitive graphic approach to quickly compare the scenario performance and identify patterns. The performance measures can be used to

1) analyze the impacts or benefits of flow changes within a SWAM scenario
2) to compare impacts or benefits across multiple SWAM scenarios
3) to compare the benefits of water management strategies to a SWAM scenario(s)

Performance measure plots provide a visual way to compare the water withdrawal scenarios with respect to aquatic ecosystem health. This feature can also be informative when water management strategies are applied to the scenarios, revealing which strategies best protect stream health while still meeting essential water needs. Figure 6 shows an example of the performance measure plots.

Linear relationships were used to estimate the change in a biological metric from current flows for each SWAM scenario, producing color-coded output with the specific percentage change of the biological metric and its associated estimate error. Figure 7 shows an example of the linear relationship output.

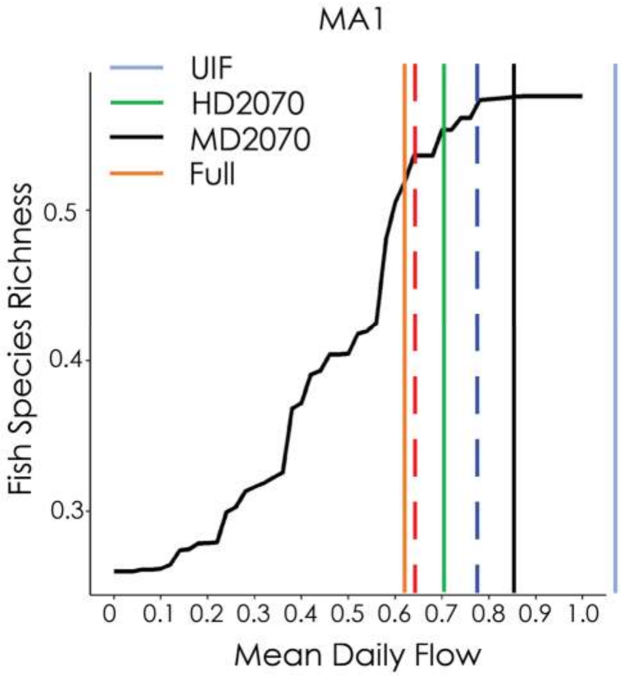


Figure 6: In this example (Mean daily flow at Middle Tyger River in the Broad River Basin), the predicted change in mean daily flow was plotted for the four SWAM scenarios along the X axis, allowing for quick determination of risk to the biologic metric. In this example, the full allocation model (orange) had a 37.3% reduction in flow, meaning only 62.7% of current flows remain, which is considered 'high risk' to the biotic metric, fish species richness. Alternatively, the medium development scenario (vertical black line), predicted only a 14% reduction in flow, which was considered 'low risk'.

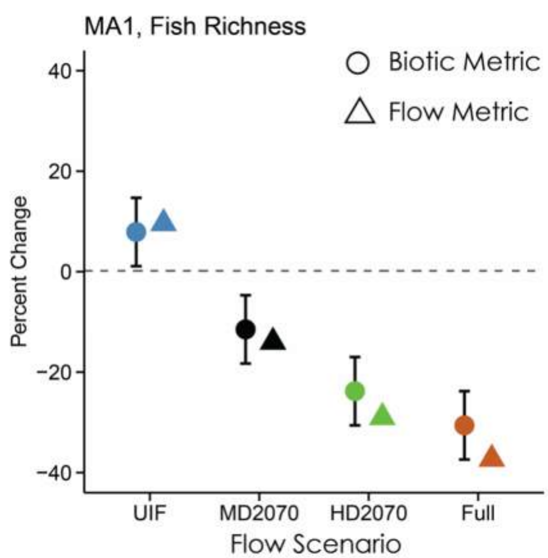


Figure 7: In this figure, the four SWAM scenarios are plotted along the X axis, and percent change for each scenario is plotted along the Y axis. The horizontal dashed line indicates the current conditions. Predicted flow metrics (triangles) were derived from the SWAM model, whereas predicted biotic metrics (circles) were derived from linear regression (Figure 5). Error bars on the biotic metrics represent the standard error or the uncertainty in the predictions.

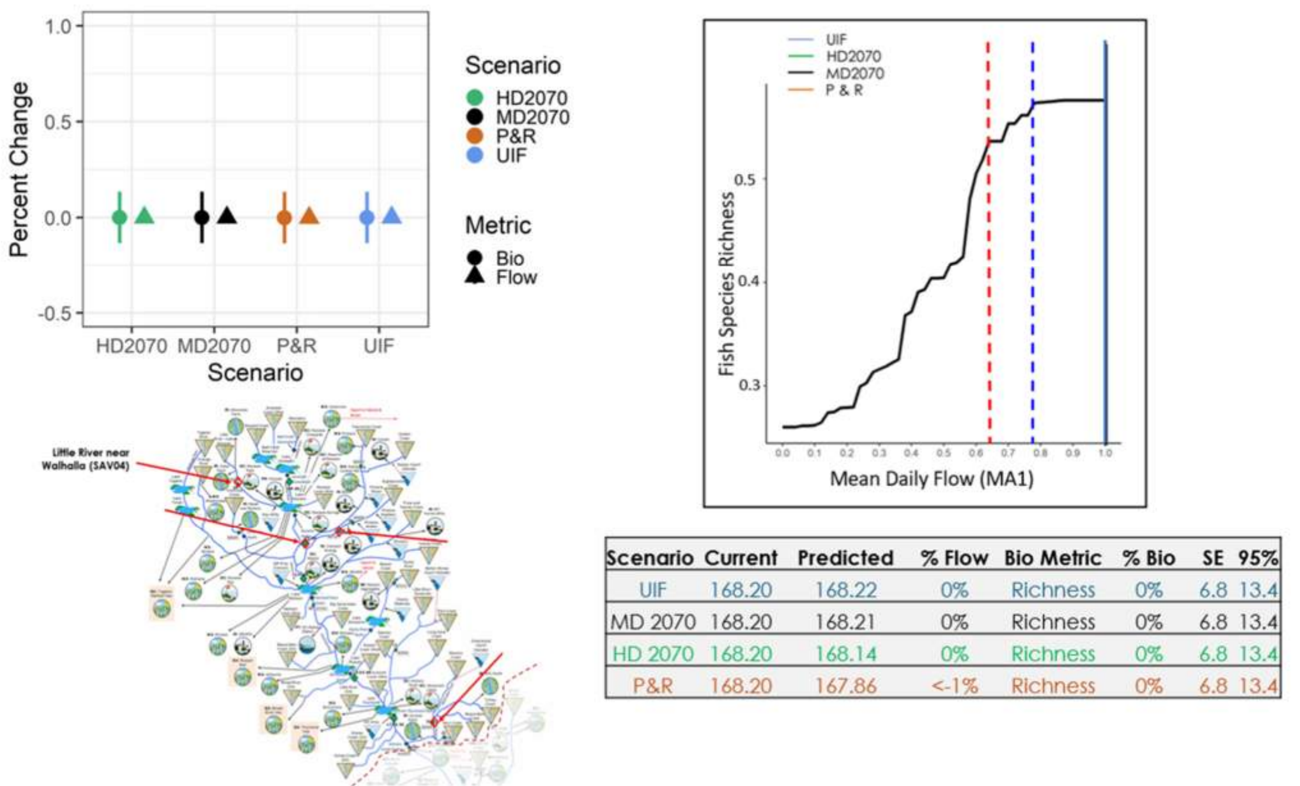
<u>*SWAM results summary.*</u>

Overall, SWAM estimated no significant change in mean daily flow (MA1) for all scenarios and at all strategic nodes (Figure 8-14). The largest change in mean daily flow was predicted at Twelvemile Creek, showing a 4.4% reduction in mean daily flow full allocation water use scenario (Figures 10-11). The linear relationships predicted a reduction in the number of species and Shannon's diversity by 4% and 3%, respectively. All other SWAM scenarios predicted small changes in mean daily flow between <1% to 1.1% resulting in low reductions in the number of fish species and Shannon's diversity predicted by linear models (Figure 8-14). The standard error associated with these estimates is important to consider because it provides a range associated with each prediction.

The performance measures showed all SWAM scenarios as remaining in low-risk zone at all strategic nodes for species richness as well as Shannon's diversity (Figures 8-14).

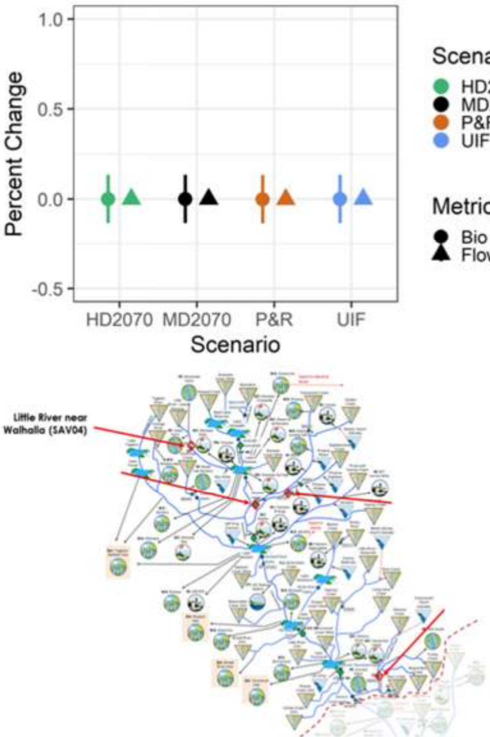
CONCLUSIONS

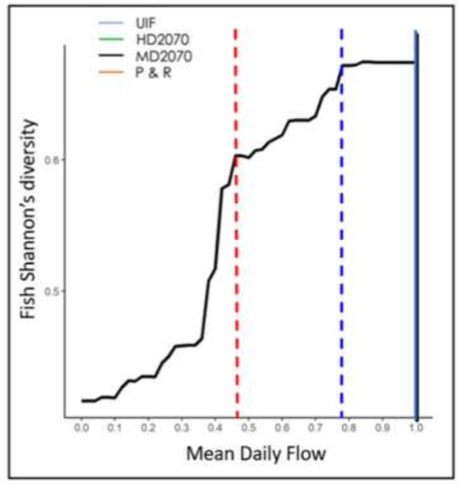
Based on the SWAM model, mean daily flow is not expected to be strongly impacted more by water use across all SWAM scenarios and strategic nodes. The linear relationships and performance measures suggest a low risk of fish species loss due to water use. However, these findings do not rule out all potential risks to ecological integrity or aquatic biodiversity related to other metrics or flow alterations.



Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	168.20	168.22	0%	Richness	0%	6.8	13.4
MD 2070	168.20	168.21	0%	Richness	0%	6.8	13.4
HD 2070	168.20	168.14	0%	Richness	0%	6.8	13.4
P&R	168.20	167.86	<-1%	Richness	0%	6.8	13.4

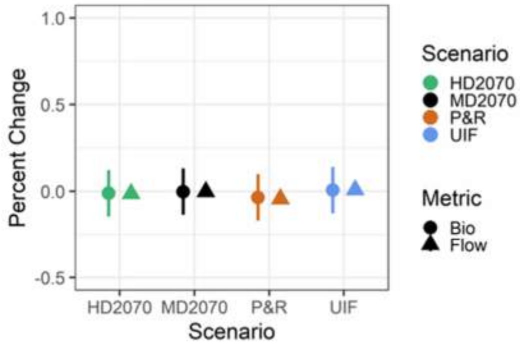
Figure 8: Mean daily flow (MA1) and fish species richness projections for Little River near Walhalla (SAV04). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.

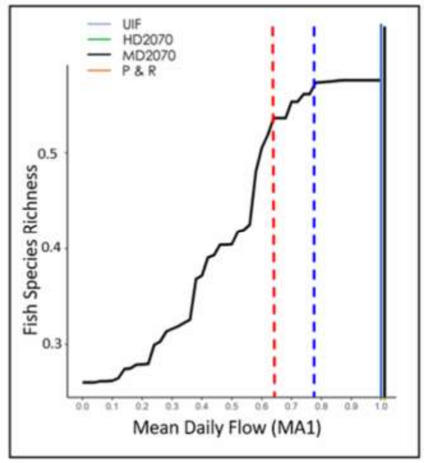


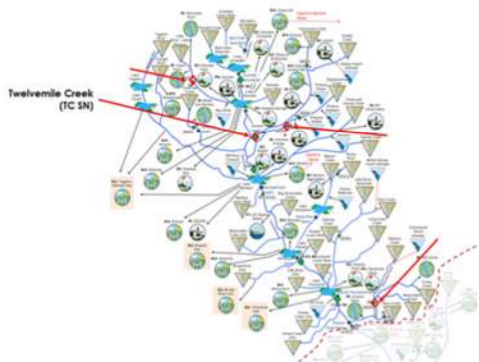


Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	168.20	168.22	0%	Shannon	0%	7.8	15.5
MD 2070	168.20	168.21	0%	Shannon	0%	7.8	15.5
HD 2070	168.20	168.14	0%	Shannon	0%	7.8	15.5
P&R	168.20	167.86	-0.2%	Shannon	0%	7.8	15.5

Figure 9: Mean daily flow (MA1) and fish Shannon's diversity projections for the Little River near Walhalla (SLD22). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.

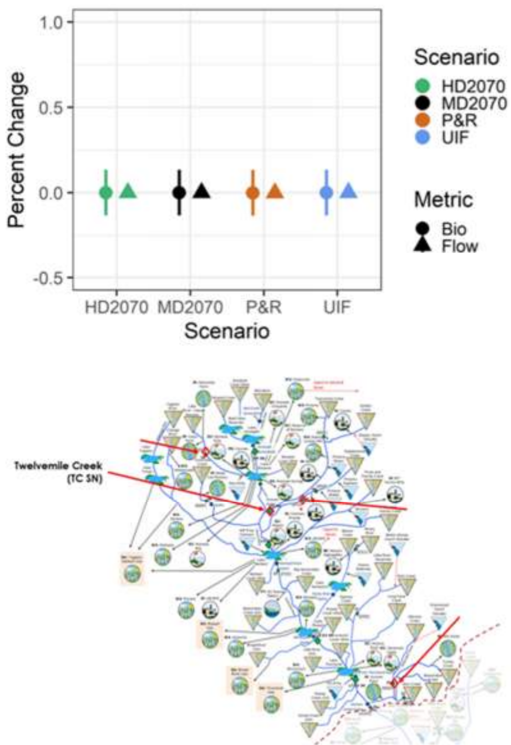


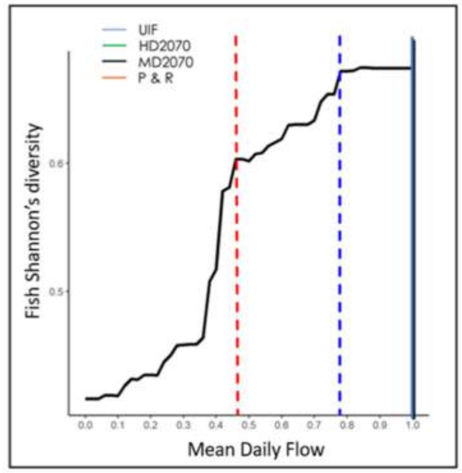




Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	263.60	265.58	<1%	Richness	<-1%	6.8	13.4
MD 2070	263.60	262.64	<-1%	Richness	0%	6.8	13.4
HD 2070	263.60	259.79	-1.1%	Richness	-1%	6.8	13.4
P&R	263.60	251.94	-4.4%	Richness	-4%	6.8	13.4

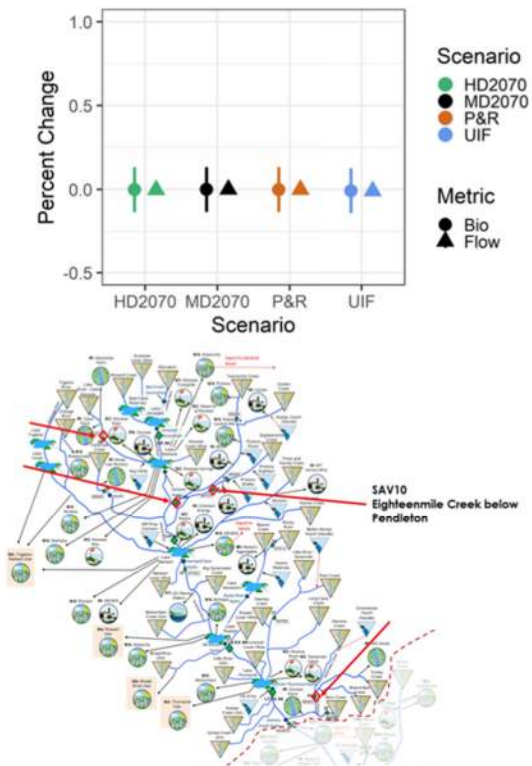
Figure 10: Mean daily flow (MA1) and fish species richness projections for Twelvemile Creek (TC SN). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.

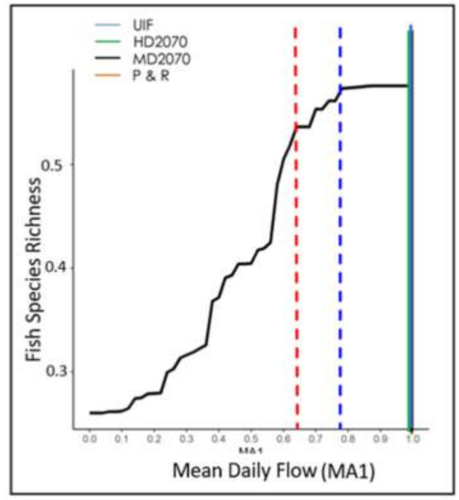




Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	263.60	265.58	<1%	Shannon	<1%	6.8	13.4
MD 2070	263.60	262.64	<-1%	Shannon	0%	6.8	13.4
HD 2070	263.60	259.79	-1.1%	Shannon	<-1%	6.8	13.4
P&R	263.60	251.94	-4.4%	Shannon	-3%	6.8	13.4

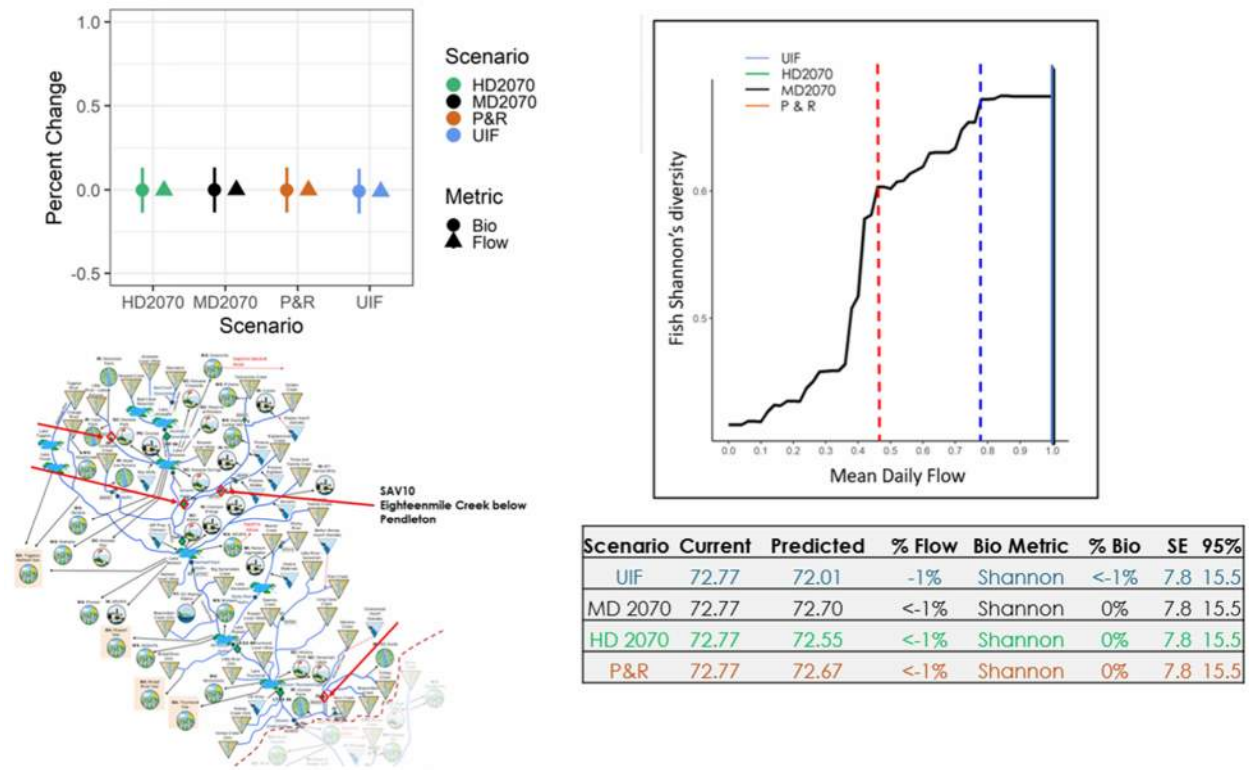
Figure 11: Mean daily flow (MA1) and fish Shannon's diversity projections for Twelvemile Creek (TC SN). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.





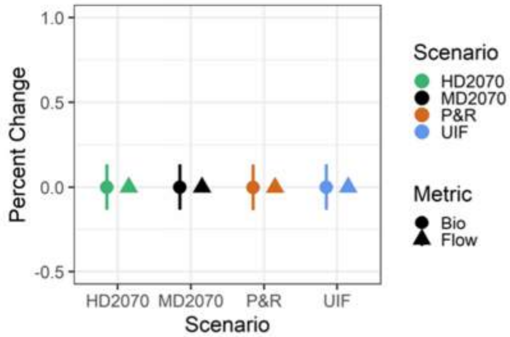
Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	72.77	72.01	<-1%	Richness	<-1%	6.8	13.4
MD 2070	72.77	72.70	<-1%	Richness	0%	6.8	13.4
HD 2070	72.77	72.55	<-1%	Richness	0%	6.8	13.4
P&R	72.77	72.67	<-1%	Richness	0%	6.8	13.4

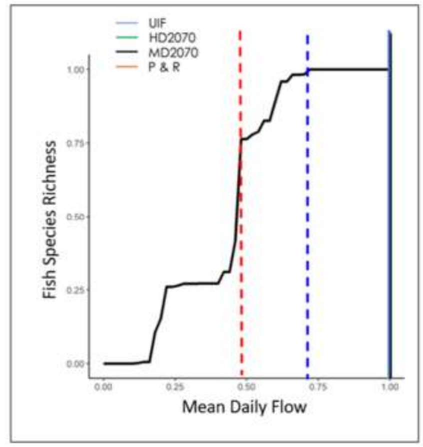
Figure 12: Mean daily flow (MA1) and fish species richness projections for the Eighteenmile Creek below Pendleton (SAV10). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.

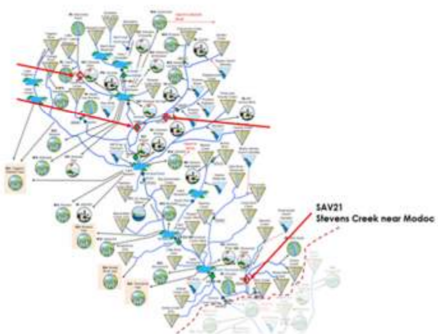


Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	72.77	72.01	-1%	Shannon	<-1%	7.8	15.5
MD 2070	72.77	72.70	<-1%	Shannon	0%	7.8	15.5
HD 2070	72.77	72.55	<-1%	Shannon	0%	7.8	15.5
P&R	72.77	72.67	<-1%	Shannon	0%	7.8	15.5

Figure 13: Mean daily flow (MA1) and fish Shannon's diversity projections for Eighteenmile Creek below Pendleton (SAV10). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.







Scenario	Current	Predicted	% Flow	Bio Metric	% Bio	SE	95%
UIF	388.34	387.81	-0.001%	Richness	0%	9	17.7
MD 2070	388.34	387.81	-0.001%	Richness	0%	9	17.7
HD 2070	388.34	389.72	0.004%	Richness	0%	9	17.7
P&R	388.34	391.79	0.009%	Richness	0%	9	17.7

Figure 14: Mean daily flow (MA1) and fish species richness projections for Stevens Creek near Modoc (SAV21). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by 95% confidence interval error bars. The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios were in the low-risk zone. The table shows the SWAM scenario, the current conditions, predicted flow metric value by SWAM, precent change in flow metric, the biological metric of interest, percent change in biological metric for given SWAM scenario, the standard error, and 95% confidence interval.

Appendix Table 1: *Abbreviation, description, and association with type of biological metrics*

Fish metrics	
Abbreviation	***Description***
Richness	*Taxa richness*
Shannon	*Shannon's diversity index*
Lepomis	*proportional representation of individuals in the genus Lepomis*
Brood Hider	*proportional representation of individuals in the brood hiding breeding strategy (Balon, 1975).*
Nest Spawner	*proportional representation of individuals in the nest spawning breeding strategy (Balon, 1975).*
Open substrate	*proportional representation of individuals an open substrate spawning breeding strategy (Balon, 1975).*
Lotic	*proportional representation of individuals that prefer lotic environments*
Tolerance	*proportional representation of tolerant individuals*
Benthic Macroinvertebrate metrics	

Abbreviation	*Description*
Richness	*Taxa richness*
Shannon	*Shannon's diversity index*
EPT	*proportional representation of individuals in*
Chronomidae	*proportional representation of individuals in Chrionomidae family*
M-O index	*Average of an index indicative of Odonata and Megaloptera taxa preference for lotic or lentic conditions*
Tolerance	*Average tolerance index for macroinvertebrate taxa*

Appendix Table 2: List of hydrologic metrics, their associated flow regime component, and description.

Code	Flow regime	Description
DL16	Duration	Low flow pulse duration. The average pulse for flow events below a threshold equal to the 25th percentile value for the entire flow record.
DL17	Duration	Coefficient of vitiation in DL16
DL18	Duration	Number of zero-flow days
DH15	Duration	High flow pulse duration. The average duration for flow events with flows above a threshold equal to the 75th percentile value for each year in the flow record.
DH16	Duration	Coefficient of vitiation in DH15
FL1	Frequency	Low flow pulse count. Average number of flow events with flows below a threshold equal to the 25th percentile value for the entire flow record
FL2	Frequency	Coefficient of vitiation in FL1
FH1	Frequency	High flow pulse count. Average pulse duration for each year for flow events below a threshold equal to the 25th percentile value for the entire flow record.
FH2	Frequency	Coefficient of vitiation in FH1
MA1	Magnitude	Mean daily flow (cfs)
MA3	Magnitude	Mean of the coefficient of vitiation (standard deviation/mean) for each year of daily flows
MA41	Magnitude	Annual runoff computed as the mean of the annual means divided by the

MA42	Magnitude	Coefficient of vitiation of MA41
ML17	Magnitude	Base flow index. The minimum of a 7-day moving average flow divided by the mean annual flow for each year.
ML18	Magnitude	Coefficient of vitiation in ML17
ML22	Magnitude	Specific mean annual minimum flow. Annual minimum flows divided by the drainage area
MH14	Magnitude	Median of annual maximum flows. The ratio of annual maximum flow to median annual flow for each year
MH20	Magnitude	Specific mean annual maximum flow. The annual maximum flows divided by the drainage area
RA8	Rate	Number of reversals. Number of days in each year when the change in flow from one day to the next changes direction
TA1	Timing	Constancy or stability of flow regime computed via the formulation of Colwell (see example in Colwell, 1974).
TL1	Timing	Julian date of annual minimum
TL2	Timing	Coefficient of vitiation in TL1
TH1	Timing	Julian date of annual maximum starting at day 100
TH2	Timing	Coefficient of vitiation in TH1

Appendix Table 3: A list of species of greatest conservation concern based on SCDNR's State Wildlife Action Plan (https://www.dnr.sc.gov/swap/index.html).

Carolina Quillback	*Carpiodes cyprinus*
Atlantic Highfin Carpsucker	*Carpiodes velifer*
Notchlip Redhorse	*Moxostoma collapsum*
V-Lip Redhorse	*Moxostoma pappillosum*
Snail Bullhead	*Ameiurus brunneus*
White Catfish	*Ameiurus catus*
Flat Bullhead	*Ameiurus platycephalus*
Stoneroller	*Campostoma anomalum*
Rosyside Dace	*Clinostomus funduloides*
Greenfin Shiner	*Cyprinella chloristia*
Thicklip Chub	*Cyprinella labrosa*
Fieryblack Shiner	*Cyprinella pyrrhomelas*
Santee Chub	*Cyprinella zanema*
Highback Chub	*Hybopsis hypsinotus*
Rosyface Chub	*Hybopsis rubrifrons*
Highfin Shiner	*Notropis altipinnis*
Swallowtail Shiner	*Notropis procne*
Sandbar Shiner	*Notropis scepticus*
Lowland Shiner	*Pteronotropis stonei*
Western Blacknose Dace	*Rhinichthys obtusus*
Striped Bass	*Morone saxatilis*
Carolina Fantail Darter	*Etheostoma brevispinum*
Carolina Darter	*Etheostoma collis*
Seagreen Darter	*Etheostoma thalassinum*
Piedmont Darter	*Percina crassa*
Southern Brook Trout	*Salvelinus fontinalis*

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Appendix C
Draft and Final Plan Survey Consensus Results

To assess each RBC member's confidence in the plan, the plan approval process dictates that there will be a test for consensus on the Draft River Basin Plan and a vote of support or disagreement on the Final River Basin Plan. For the test of consensus on the Draft Plan, each member rates their concurrence with the plan using a five-point scale, as shown below:

1. Full Endorsement (i.e., member likes it).
2. Endorsement but with minor points of contention (i.e., basically member likes it).
3. Endorsement but with major points of contention (i.e., member can live with it).
4. Stand aside with major reservations (i.e., member cannot live with it in its current state and can only support it if changes are made).
5. Withdraw - Member will not support the draft river basin plan and will not continue working within the RBC's process. Member has decided to leave the RBC.

For the Final River Basin Plan, each RBC member votes simply to support or disagree with the plan. By indicating support, the member would be acknowledging his/her concurrence with the Final River Basin Plan and their commitment to support implementation of the plan. The RBC member's votes on the Draft and Final River Basin Plans are listed below.

Table D-1. Level of consensus for the Draft and Final River Basin Plan.

RBC Member	Draft Plan Level of Endorsement	Final Plan Support or Disagree
Jon Batson	**1**	
Mack Beaty, IV	**2**	
Tonya Bonitatibus	**2**	
Cheryl Daniels	**1**	
John Hains	**1**	
Katie Hottel	**1**	
Daniel Milam	**2**	
Jill Miller	**1**	
Dan Murph	**1**	
Reagan Osbon	**1**	
Billy Owens	**1**	
Jeff Phillips	**2**	
Melisa Ramey	**2**	
Cole Rogers	**1**	
Harold Shelley	**2**	
Alan Stuart	**1**	
Mark Warner	**1**	
Scott Willett	**1**	
Will Williams	**(did not vote)**	
Tonya Winbush	**1**	

Appendix D
Public Comments and Responses