South Carolina Surface Water Quantity Modeling Project

Savannah River Basin Meeting No. 1 – Model Framework

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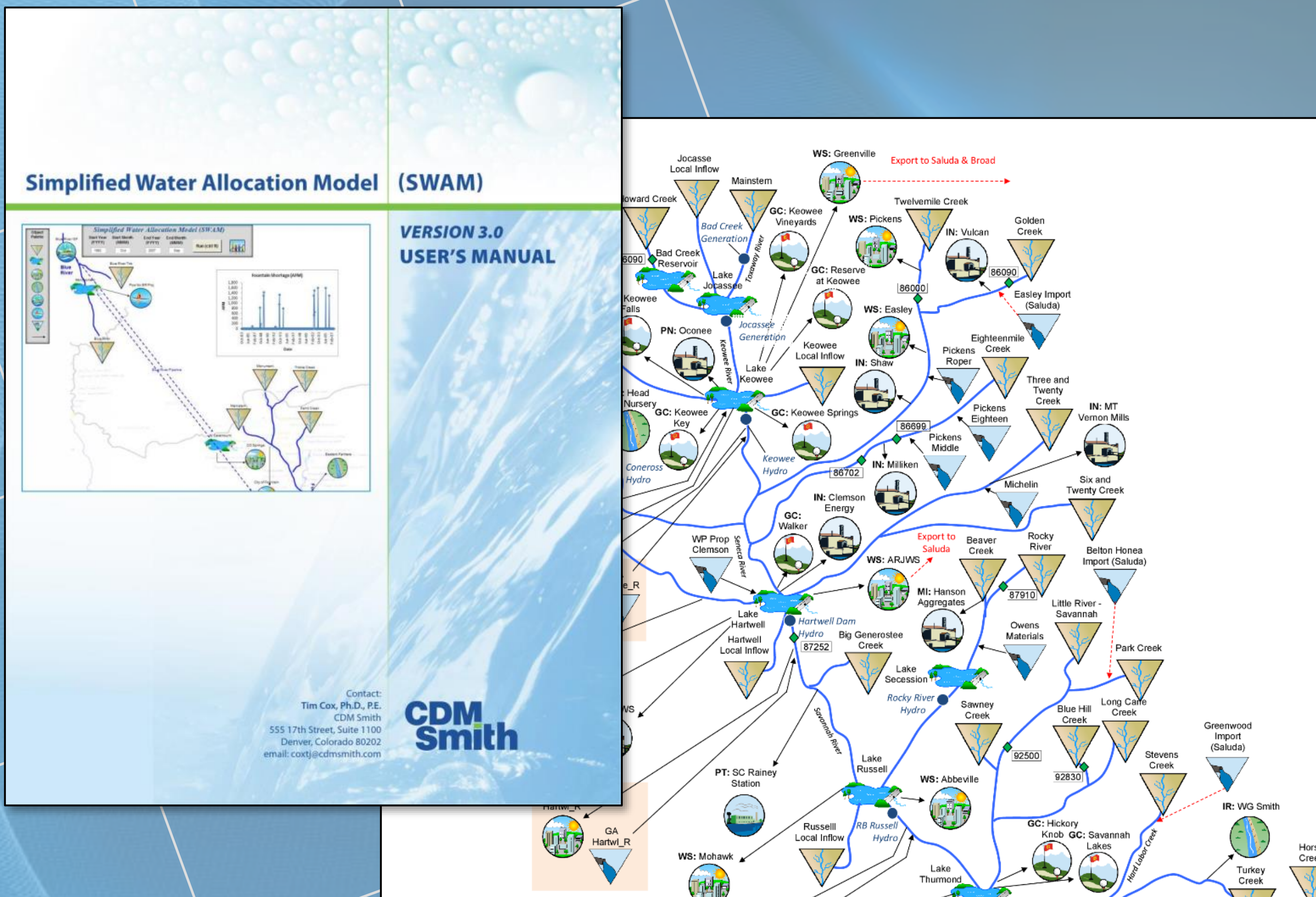
August 10, 2016



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Presentation Outline

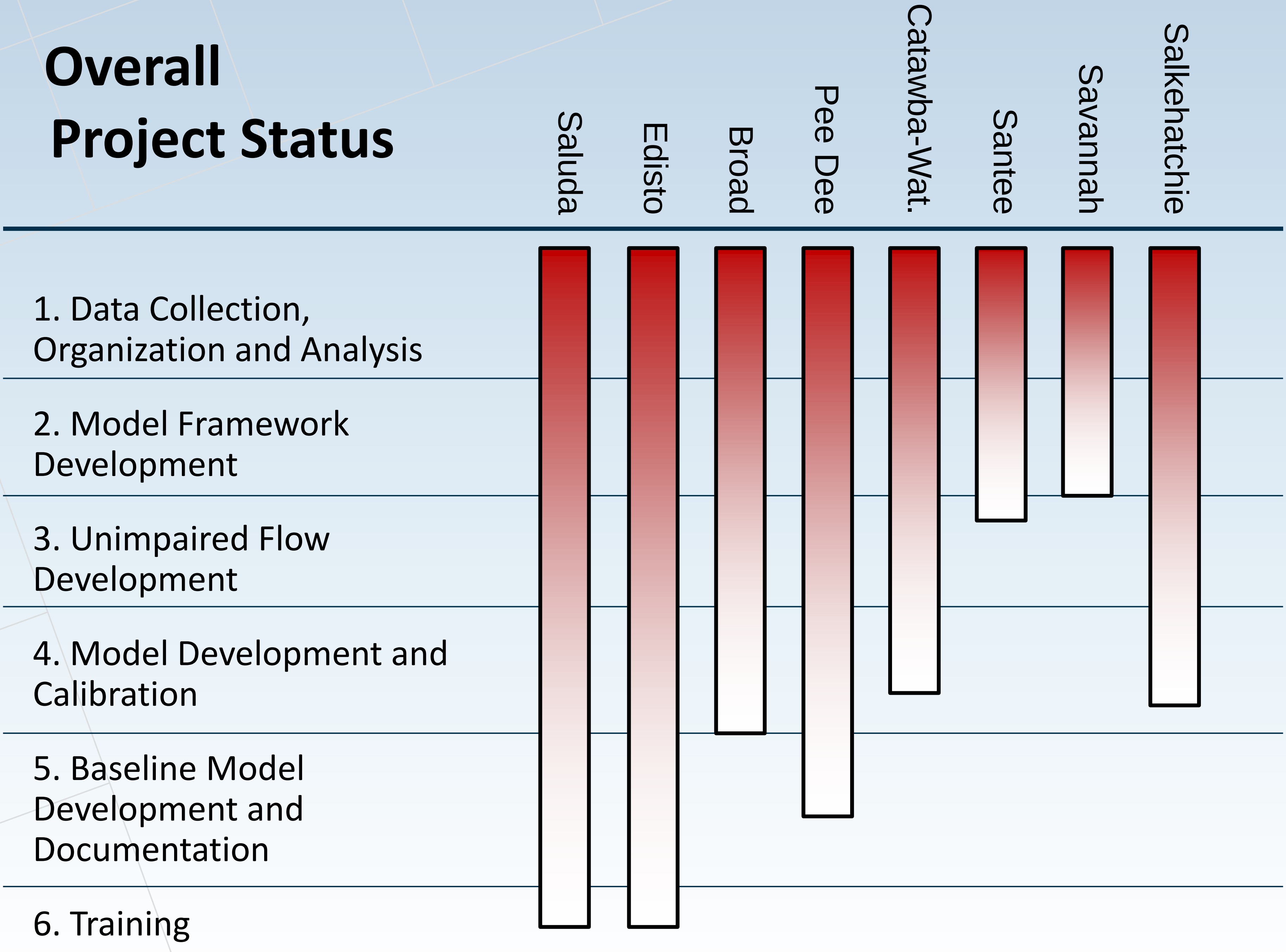
- Project purpose and status
- Introduction to SWAM
- Data requirements
- Unimpaired flows
- Overview of proposed Savannah River model framework
- Model setup
- Model calibration/validation

Project Purpose

- Build eight surface water quantity models capable of:
  - Accurately simulating streamflows and reservoir levels over the historical inflow record
  - Conducting “What if” scenarios to evaluate future water demands, management strategies and system performance.
  - Supporting future phases of the State Water Plan Update
  - Being used by regulators, water utilities, basin planning organizations and others.

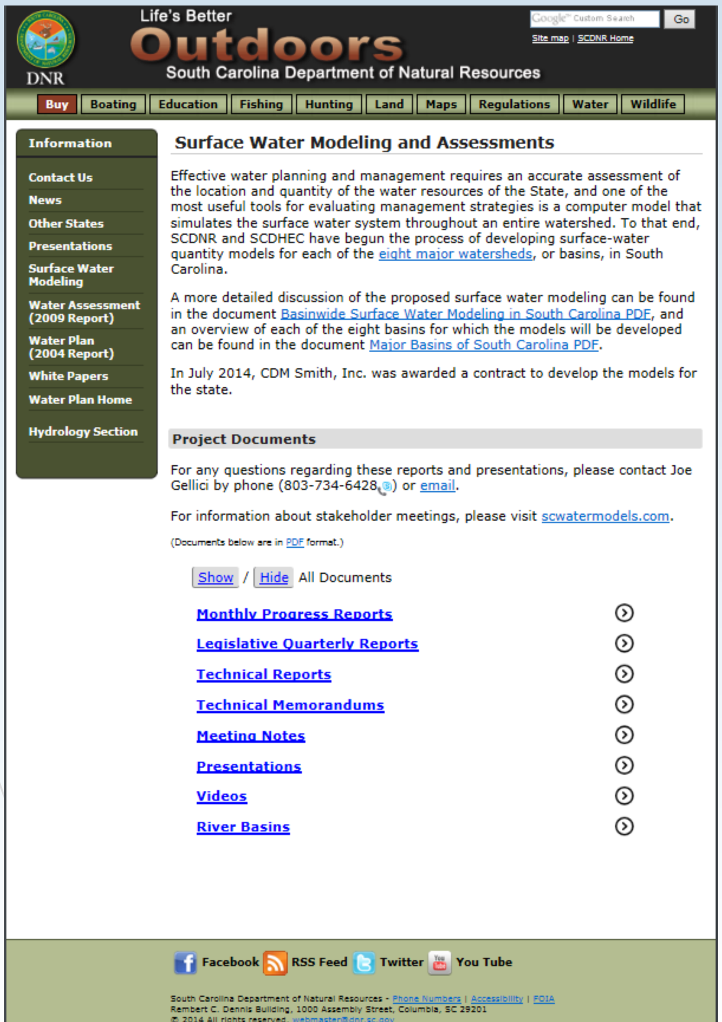


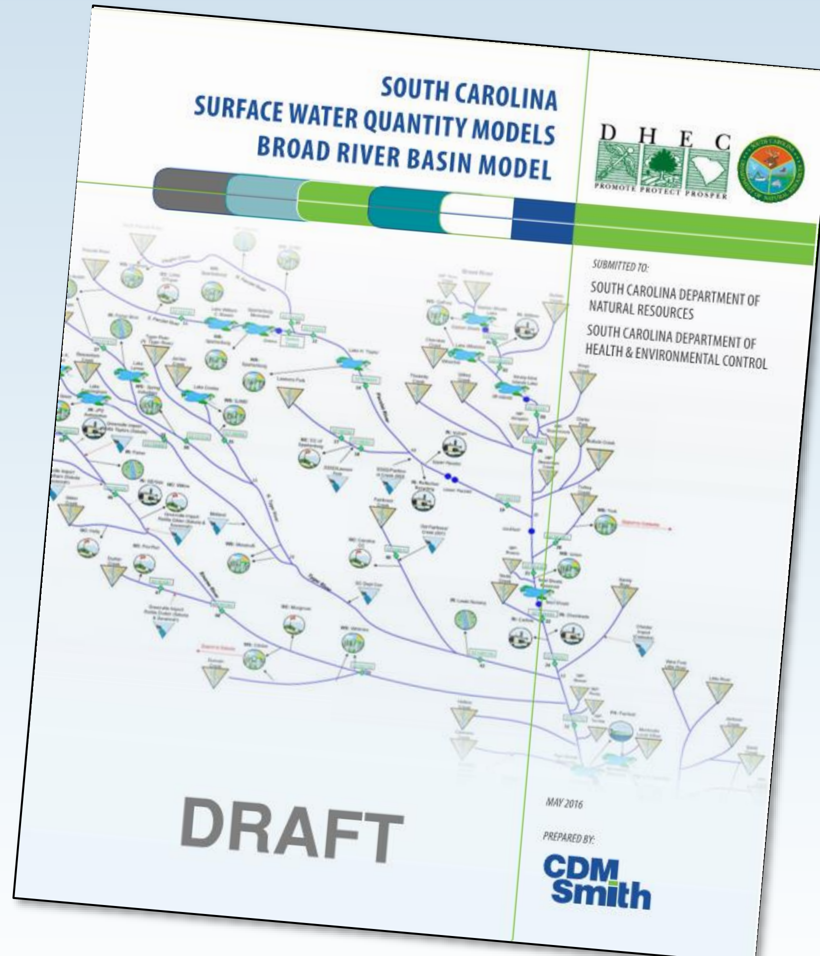
Overall Project Status



Modeling Report and Other Documents

- http://www.dnr.sc.gov/water/waterplan/surfacewater.html



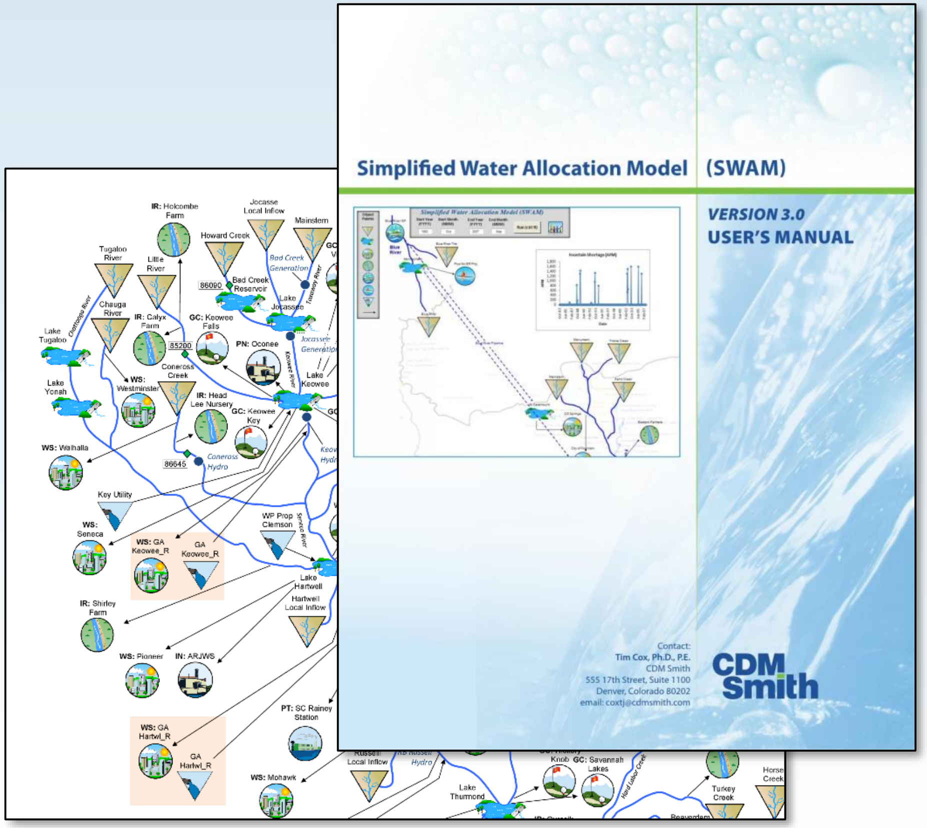


Savannah River Basin

INTRODUCTION TO SWAM

Simplified Water Allocation Model (SWAM)

- Developed in response to an increasing need for a desktop tool to facilitate regional and statewide water allocation analysis
- Calculates physically and legally available water, diversions, storage consumption and return flows at user-defined nodes
- Used to support large-scale planning studies in Colorado, Oklahoma, Arkansas and Texas



The Simplified Water Allocation Model is…

- a water accounting tool
- a WHAT-IF simulation model
- a network flow model that traces water through a natural stream network, simulating withdrawals, discharges, storage, and hydroelectric operations
- not precipitation-runoff model (e.g., HEC-HMS)
- not a hydraulic model (e.g. HEC-RAS)
- not a water quality model (e.g., QUAL2K)
- not an optimization model
- not a groundwater flow model (e.g., MODFLOW)

The Models Can Be Used To…

- Determine surface-water availability
- Predict where and when future water shortages would occur
- Test alternative water management strategies, new operating rules, and “what-if” scenarios
- Consolidate hydrologic data
- Evaluate the impacts of future withdrawals on instream flow needs
- Evaluate interbasin transfers
- Support development of Drought Management Plans
- Compare managed flows to natural flows

River Basin Flow and Operations Models

Similarities between SWAM, OASIS, CHEOPS, and RiverWare:

- Used in major river basin studies and/or statewide water plans
- Operating Rules of varying complexity
- Monthly and Daily Timesteps
- Visual Depiction of the River Network

Unique Features:

SWAM

- Familiar and adaptable environment: Visual Basic and Spreadsheets
- Built in functions for reservoirs, river operations, discharges, irrigation, return flows, etc.

OASIS

- Built in Probability Analysis for Real-Time Ops
- Optimization toward objectives in each timestep

CHEOPS

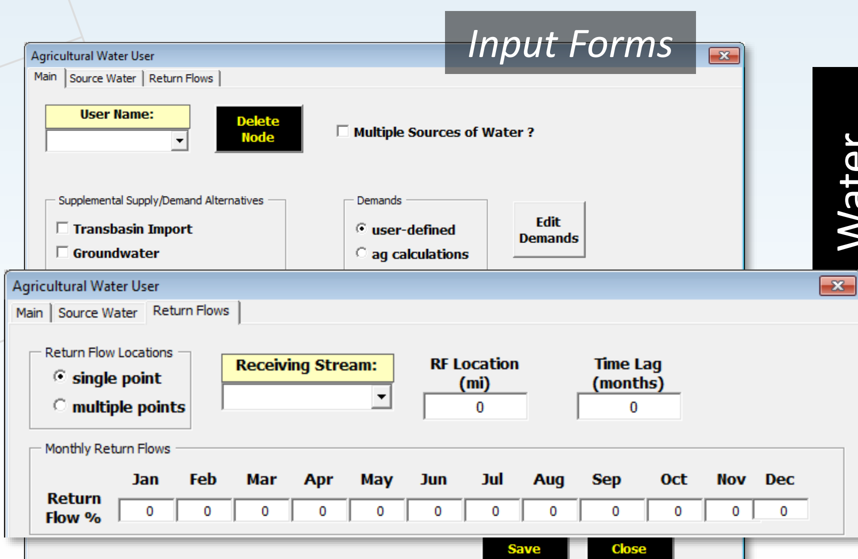
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

RiverWare

- Fully linked graphical network development
- 3 modes:
  - Pure simulation
  - Rules-based simulation
  - Optimization

Simplified Water Allocation Model (SWAM)

- Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities
- Resides within Microsoft Excel
- Point and click setup and output access

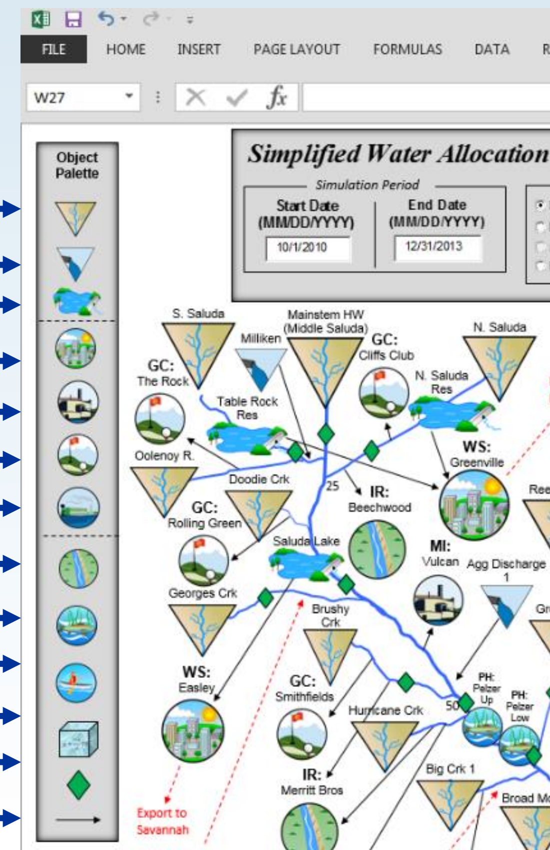


Objects

Tributaries
Discharges
Reservoirs

Water User Objects:
Municipal
Industrial
Golf Courses
Power Plants
Agriculture

Instream Flow
Recreational Pool
Aquifer
USGS Gage
Interbasin Transfer



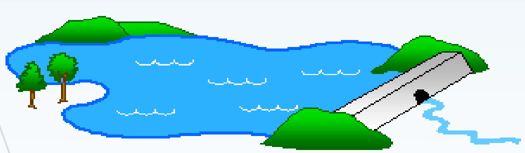
Simplified Water Allocation Model (SWAM)

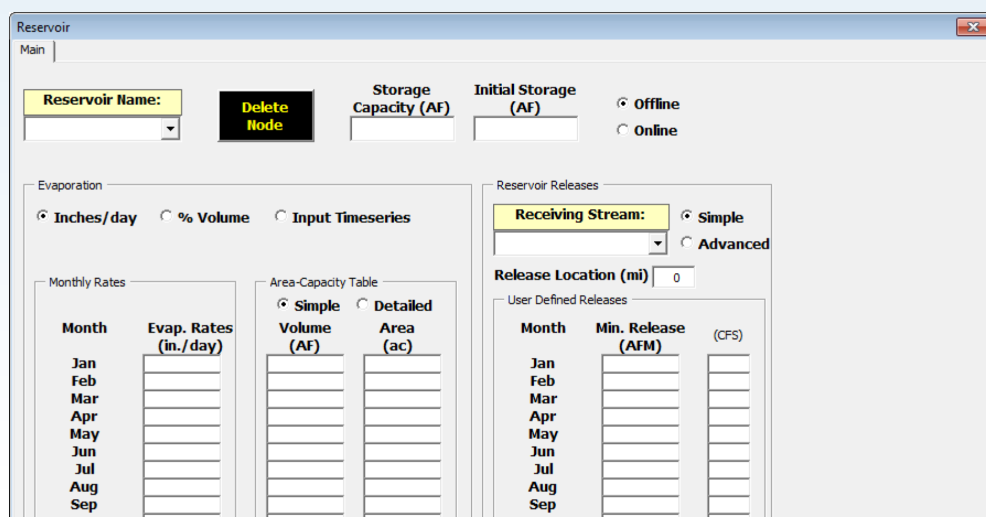
- Supports multiple layers of complexity for development of a range of systems, for example…

A Reservoir Object can include:

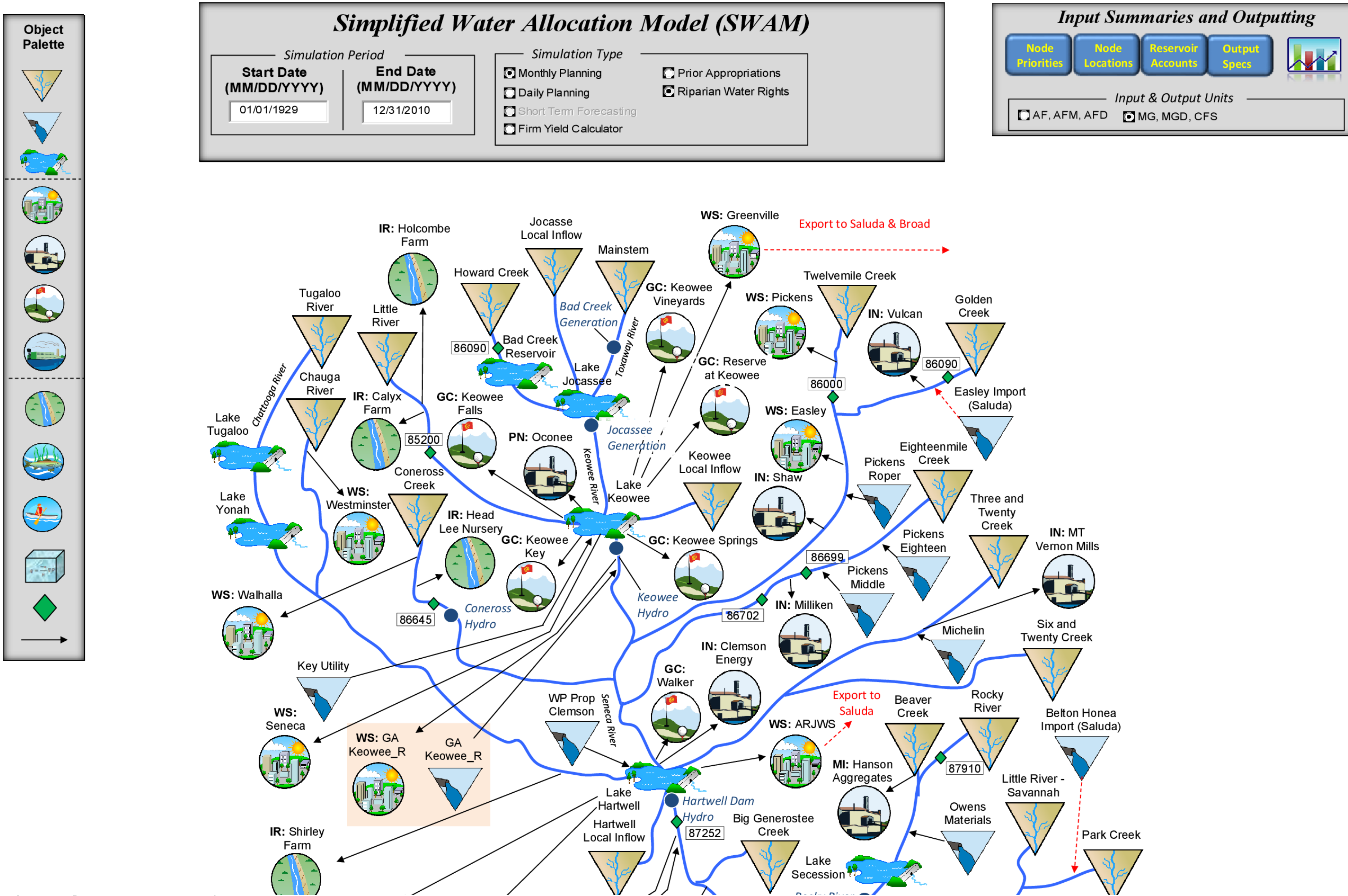
1. Basic hydrology dependent calculations
2. Operational rules of varying complexity such as prescribed releases, conditional releases, or hydrology dependent releases.

Reservoir





SWAM Model Main Screen



Savannah River Basin

MODELING DATA REQUIREMENTS

Data Collected for Model Development

- USGS daily flow records
- Historical daily rainfall and evaporation rates
- Historical Operational Data
  - Withdrawals (municipal, industrial, agricultural, golf courses)
  - Discharges
  - Reservoir elevation
- Reservoir bathymetry and operating rules
- Subbasin characteristics (GIS)
  - Drainage area
  - Land use
- **Other data, studies, and models already developed**

Savannah River Basin

UNIMPAIRED FLOWS (UIF)

UIF Definition and Uses

- **Definition:** Estimate of natural <u>historic</u> streamflow in the absence of human intervention in the river channel:
  - Storage
  - Withdrawals
  - Discharges and Return Flow
- ***Unimpaired Flow*** *=*

  Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Discharge to Reservoirs – Return Flow + Reservoir Surface Evaporation – Reservoir Surface Precipitation + Upstream change in Reservoir Storage + Runoff from Previously Unsubmerged Area
- **Fundamental input** to the model at headwater nodes and tributary nodes
- **Comparative basis** for model results

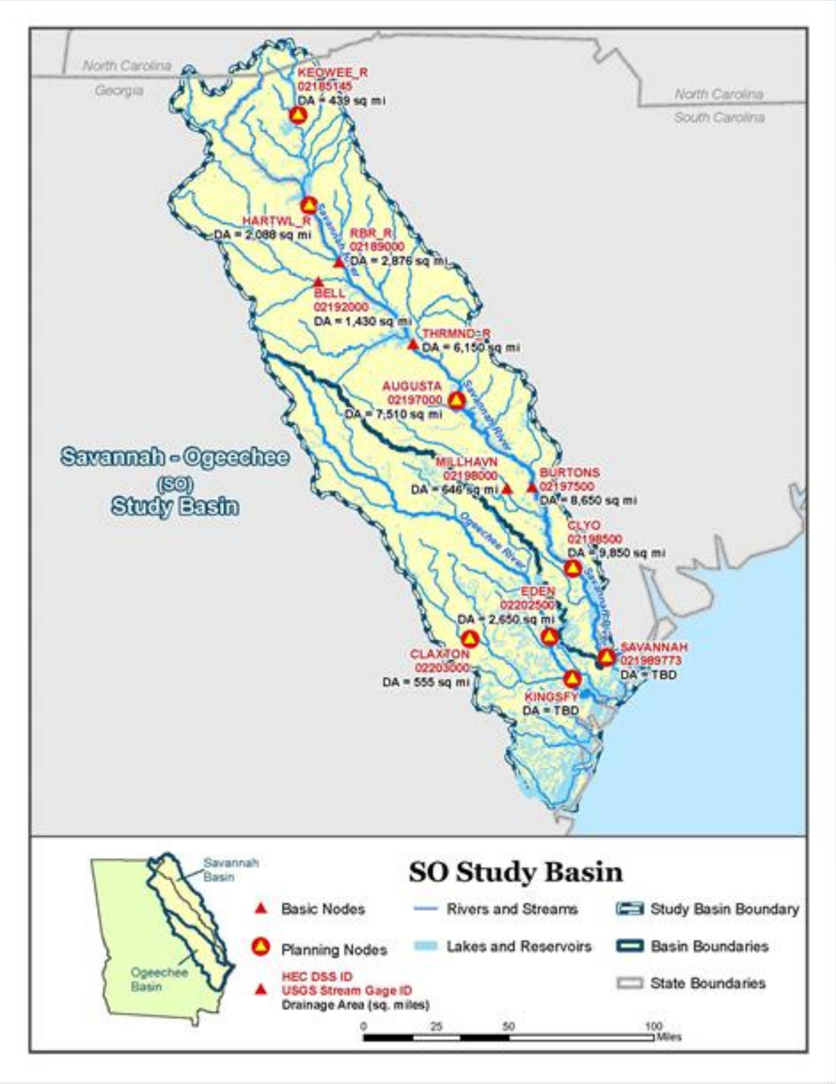
UIFs in the Savannah River Basin

Existing UIFs

- Originally developed for 1939-2007
- Extended through 2008 and added nodes
- Most recently extended through 2013 by GA EPD

UIFs to be Developed

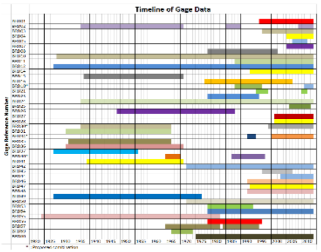
- Modeled SC tributaries to the Savannah River



Source: *GA EPD's Savannah River Basin Comprehensive Study II: 2009 – 2013 Unimpaired Flow Data Extension (Draft Report)*

Basinwide UIF Calculation Process

Step 1: UIFs for USGS Gages for their Individual Periods of Record



Work Upstream to Downstream

UIF Upstream?

Y

Perform these steps for incremental reaches and add UIFs from upstream

N

Perform these steps for the entire upstream area

Gather data: Flow, historic use, precip, evap

Fill gaps in storage for the longest downstream gage POR using prioritized techniques in guidance document.

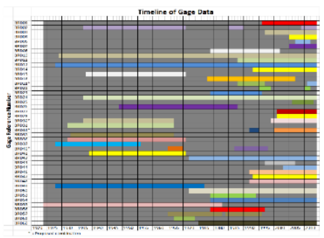
Fill gaps in withdrawals and discharges based on longest downstream gage POR using techniques in guidance doc.

Compute prior runoff from submerged areas

Compute UIFs for USGS gages (VOLUME)

UIFs for USGS gages for their POR

Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record



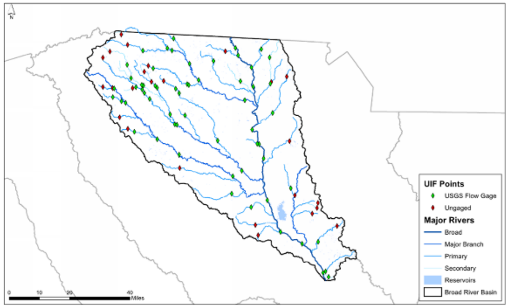
Determine longest period of record

Gather watershed characteristics: Area, Slope, Land Use

Extend / Gap Fill using area ratios, MOVE.1, climate regression, etc.

UIFs for USGS gages over a uniform basinwide POR

Step 3: Correlation between Ungaged Basins and Gaged Basins



Gather watershed characteristics for all basins upstream of **RED** nodes (ungaged headwater UIFs)

Identify appropriate reference basins from USGS gage locations

Reference gages for UIF development as model input

Gather watershed characteristics for all basins upstream of **BLACK** nodes (as needed for calibration)

Identify appropriate reference basins from USGS gage locations

Reference gages for UIF development for model calibration

Step 4: UIFs for Ungaged Basins

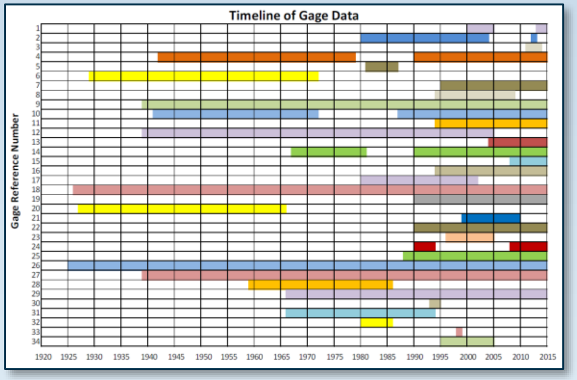
Estimate UIFs for each **RED** and **BLACK** node using area ratios, regression, etc.

UIFs for ungagged basins as model input

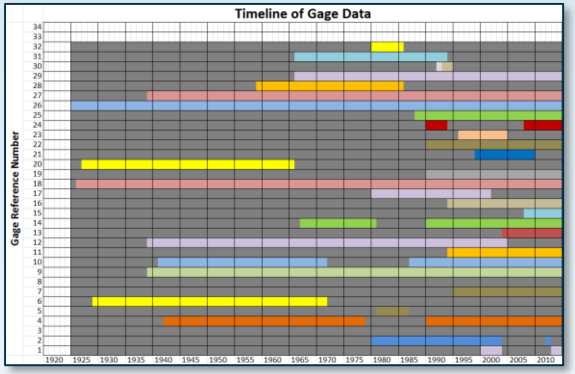
Additional UIFs at confluence nodes for calibration

Four Steps in UIF Calculation Process

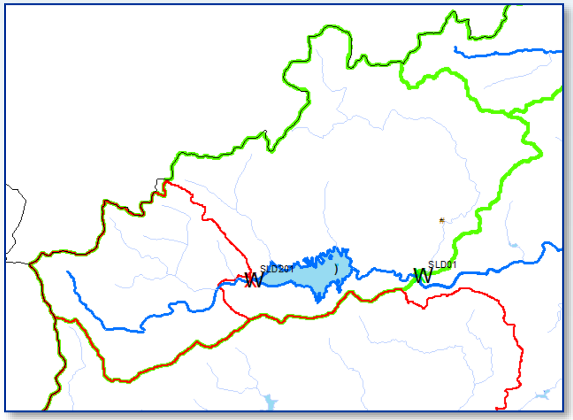
- **Step 1**: UIFs for USGS Gages for individual periods of record
  - Involves extension of operational data



- **Step 2**: Extension of UIFs for USGS Gages through the LONGEST period of record

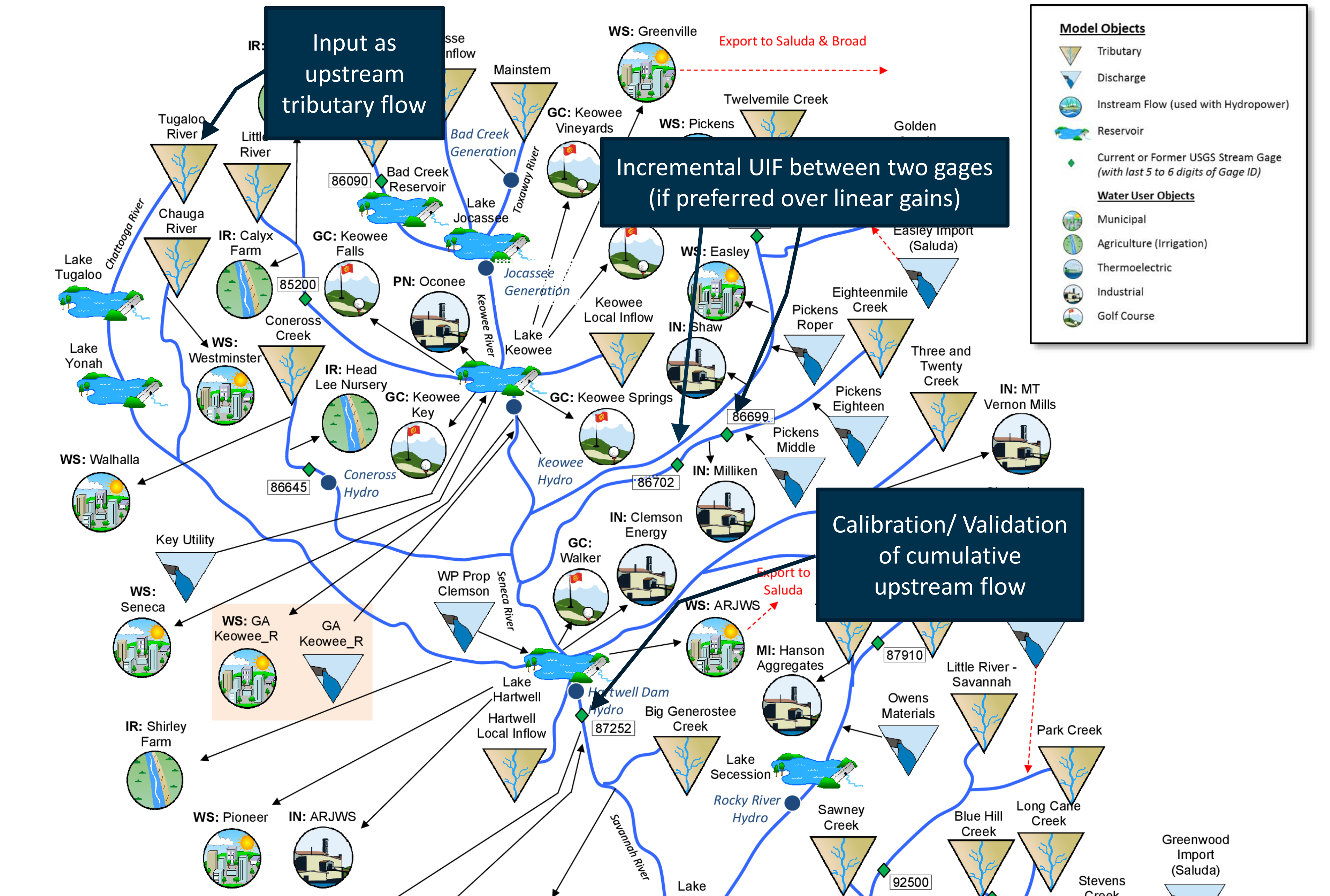


- **Step 3**: Correlation between ungaged basins and gaged basins



- **Step 4**: UIFs for ungaged basins

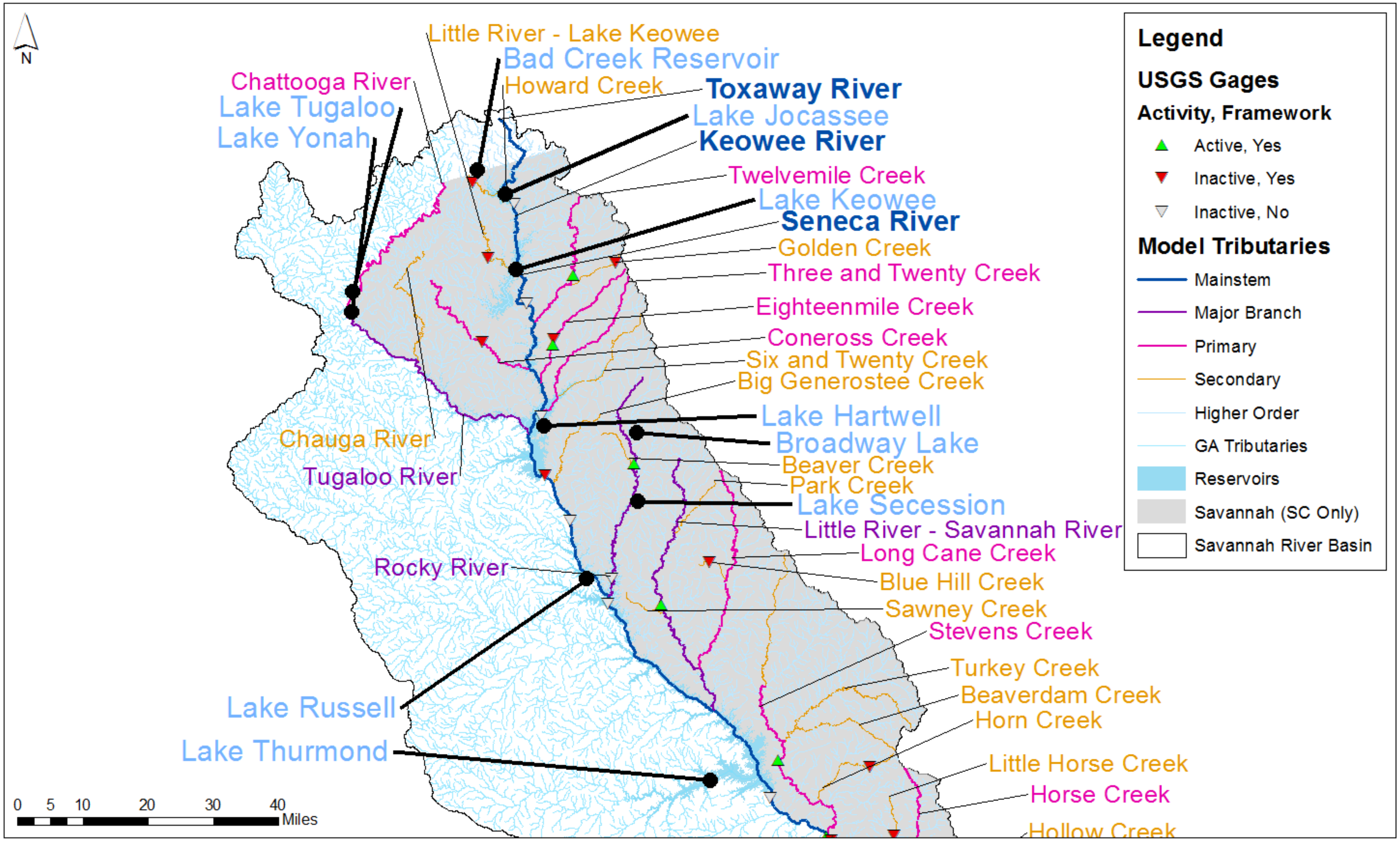
How UIFs are Used in SWAM



Savannah River Basin

OVERVIEW OF MODEL FRAMEWORK

Upper Savannah Basin
Model Tributaries



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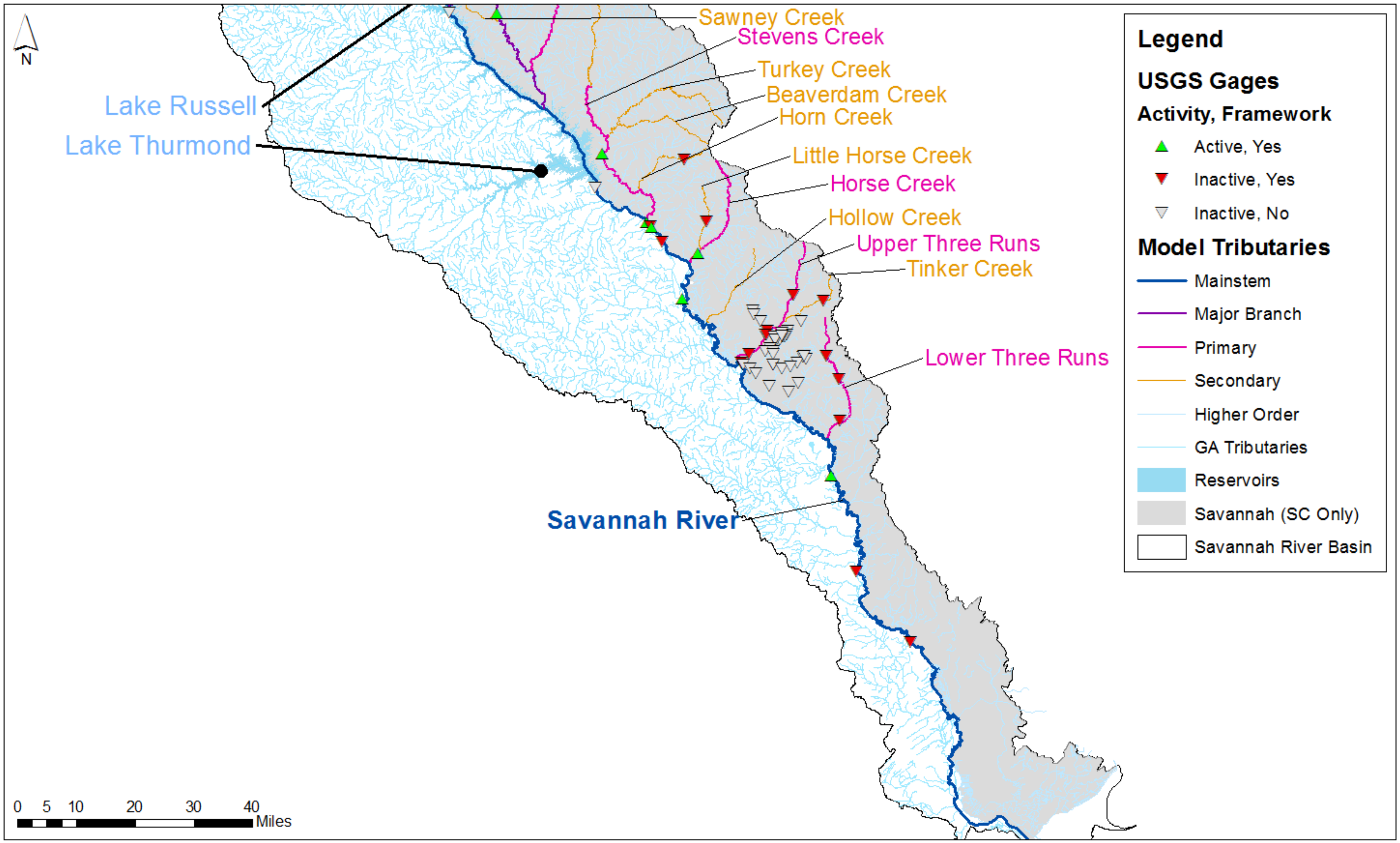
Lower Savannah Basin Model Tributaries



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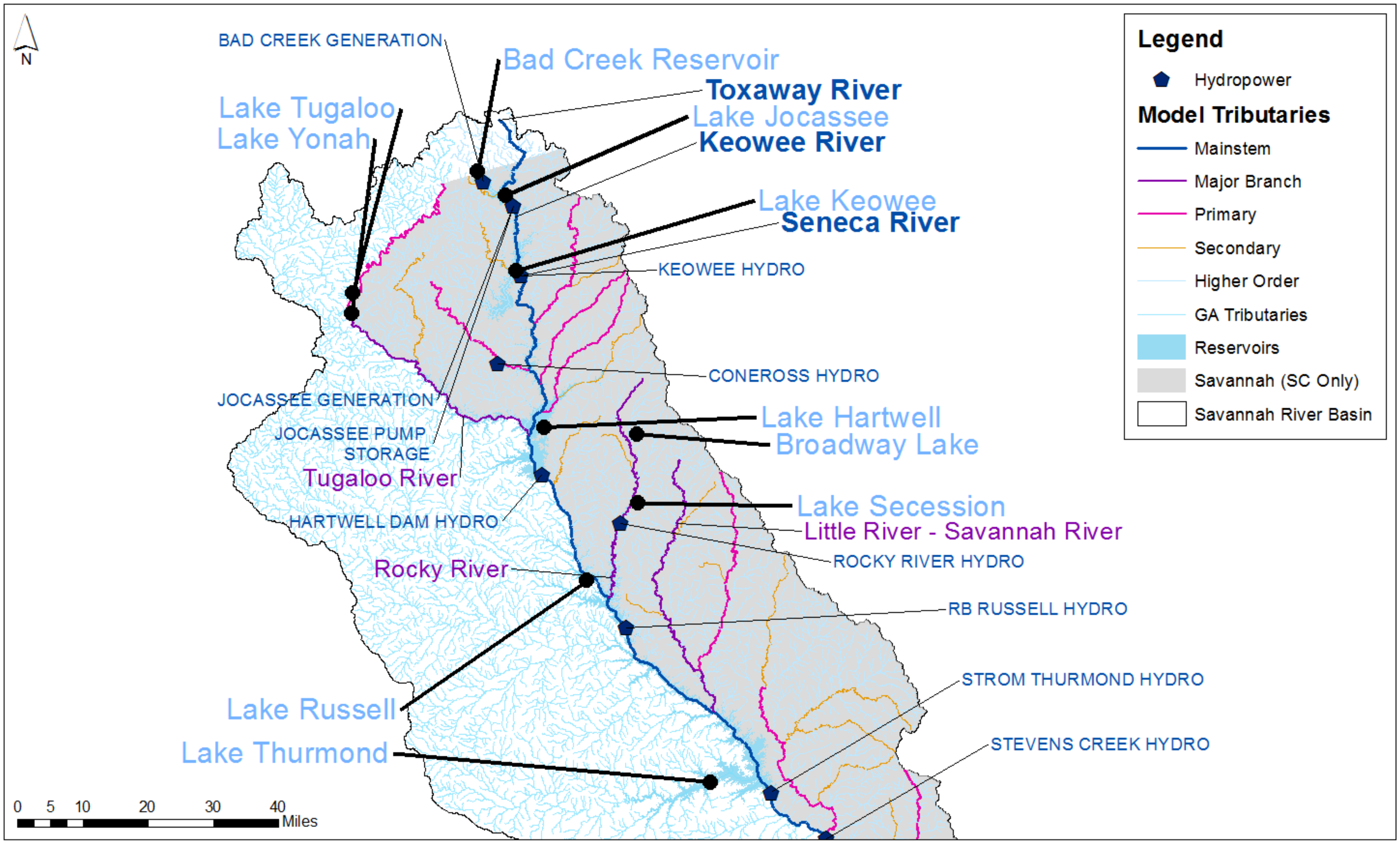
Upper Savannah Reservoirs and Hydroelectric



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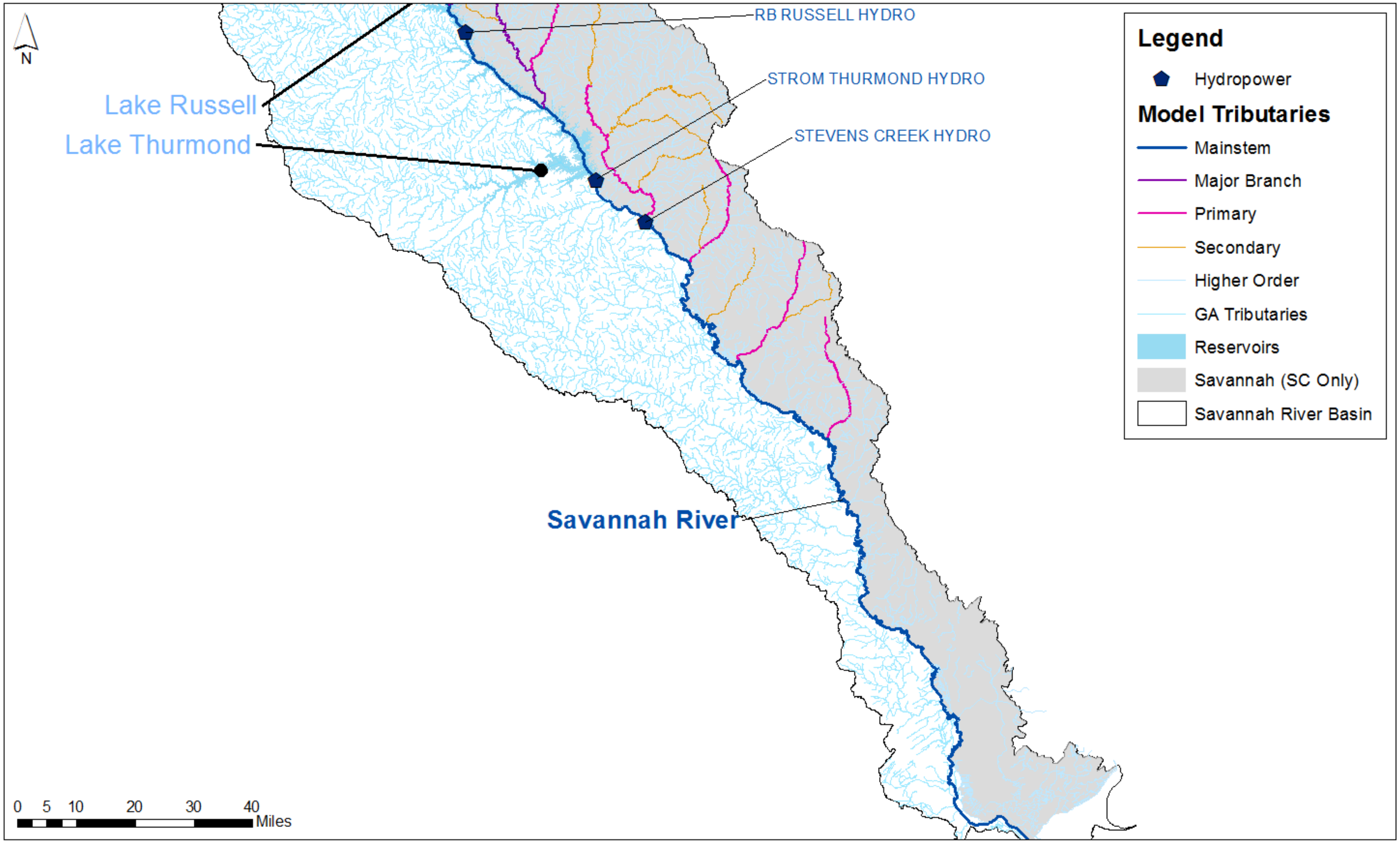
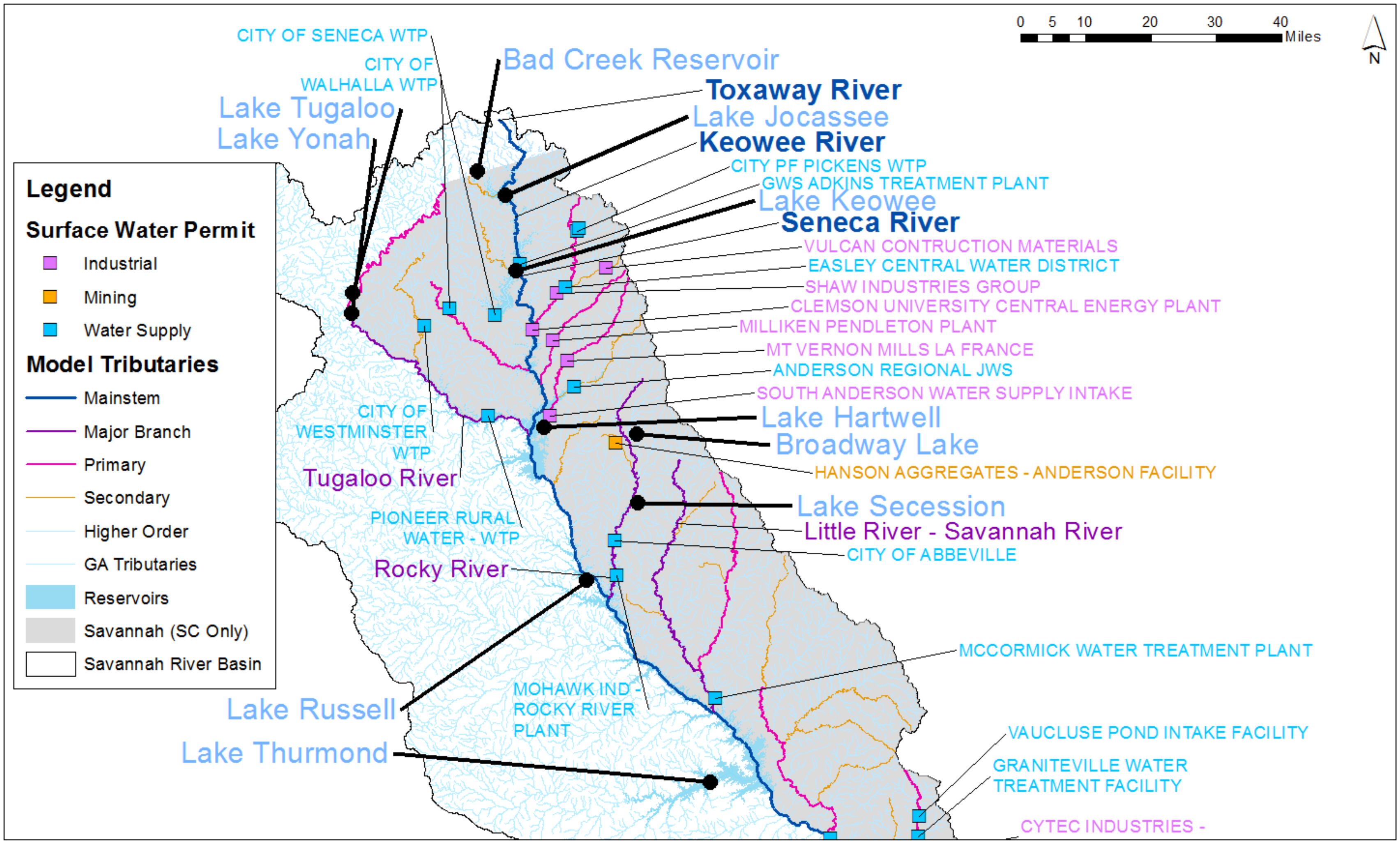
Lower Savannah Reservoirs and Hydroelectric



Upper Savannah M&I Water Withdrawals



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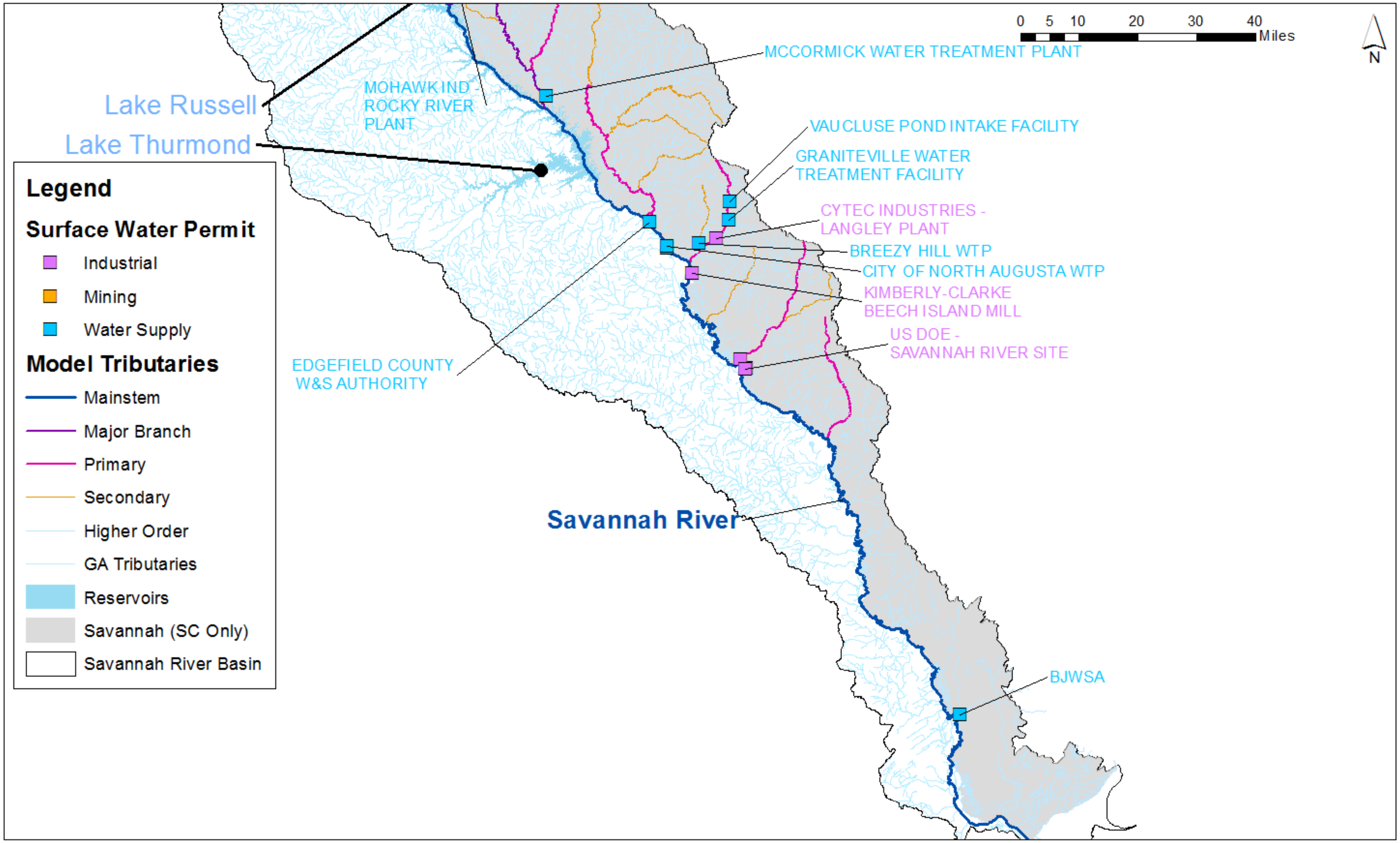
Lower Savannah
M&I Water Withdrawals



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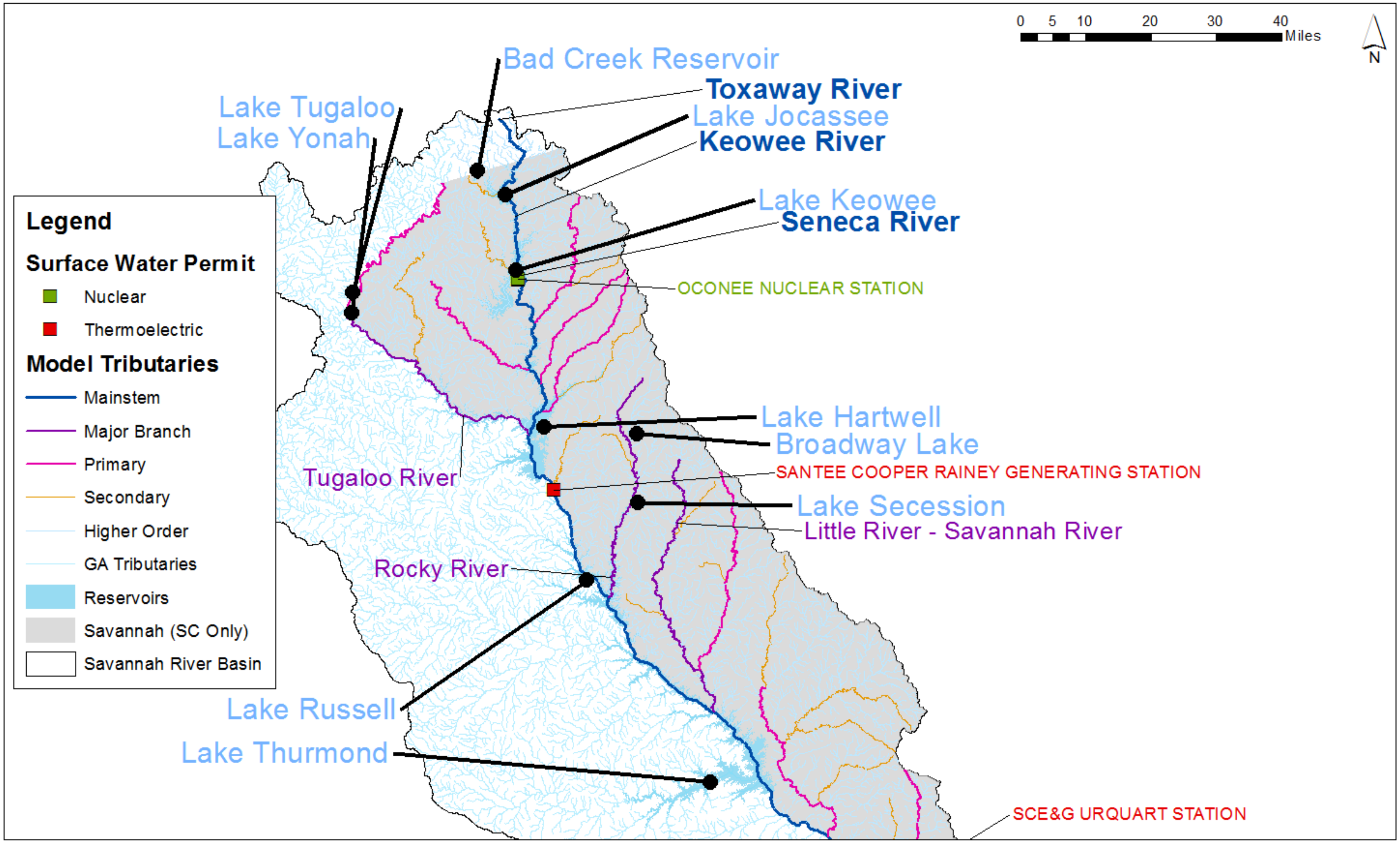
Upper Savannah Energy Surface Water Withdrawals



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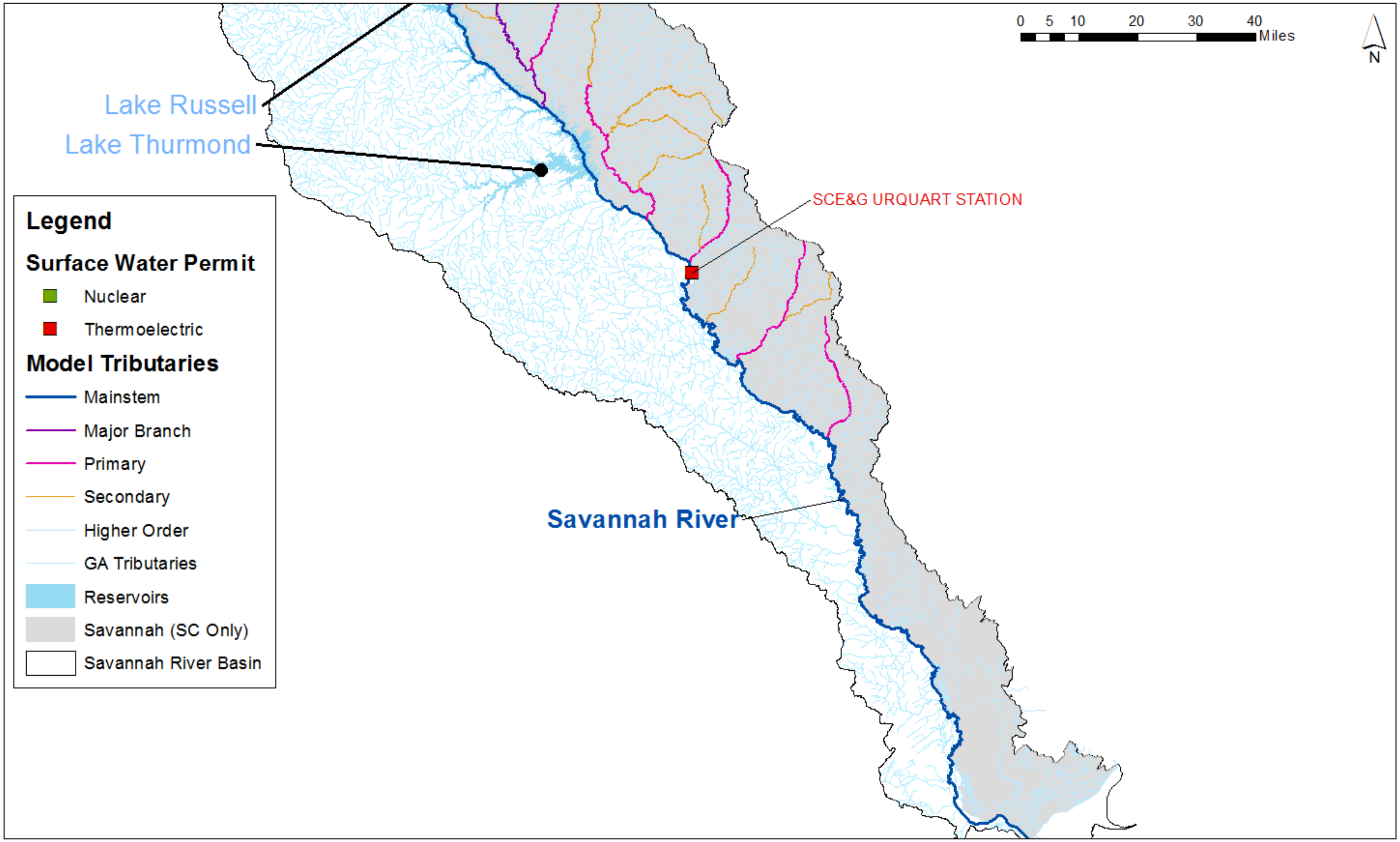
Lower Savannah Energy Surface Water Withdrawals



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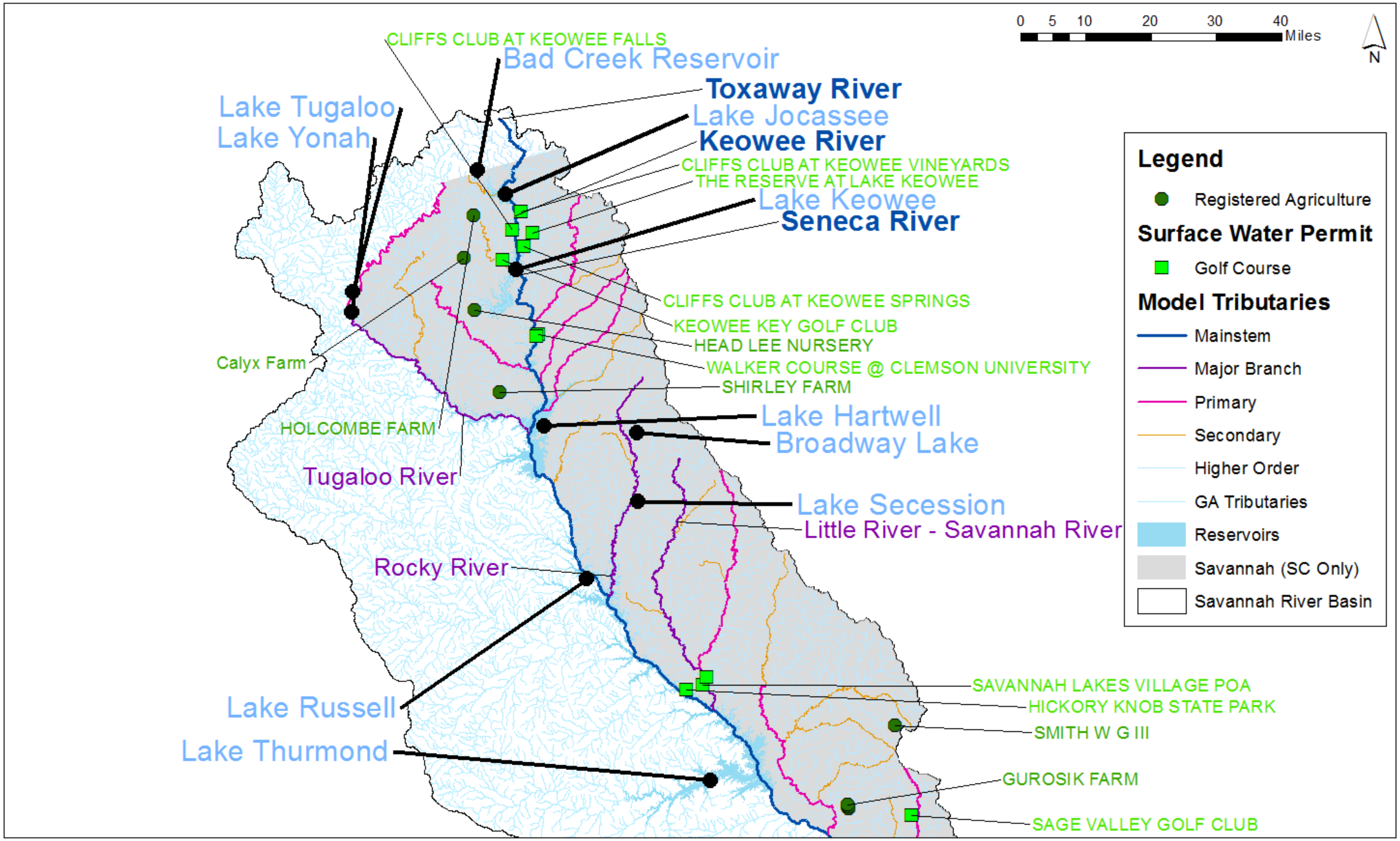
Upper Savannah Surface Water Withdrawals for Irrigation



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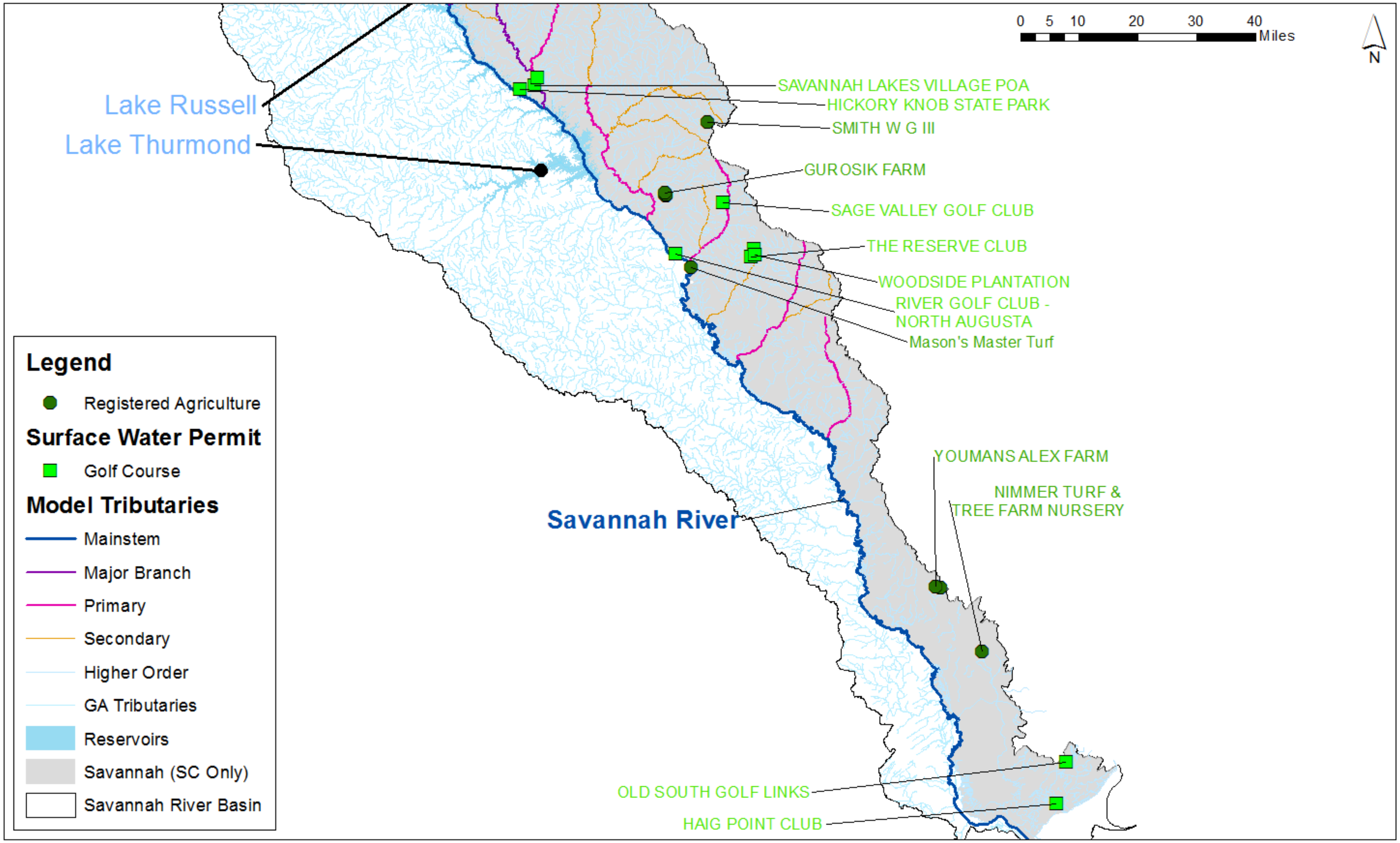
Lower Savannah Surface Water Withdrawals for Irrigation



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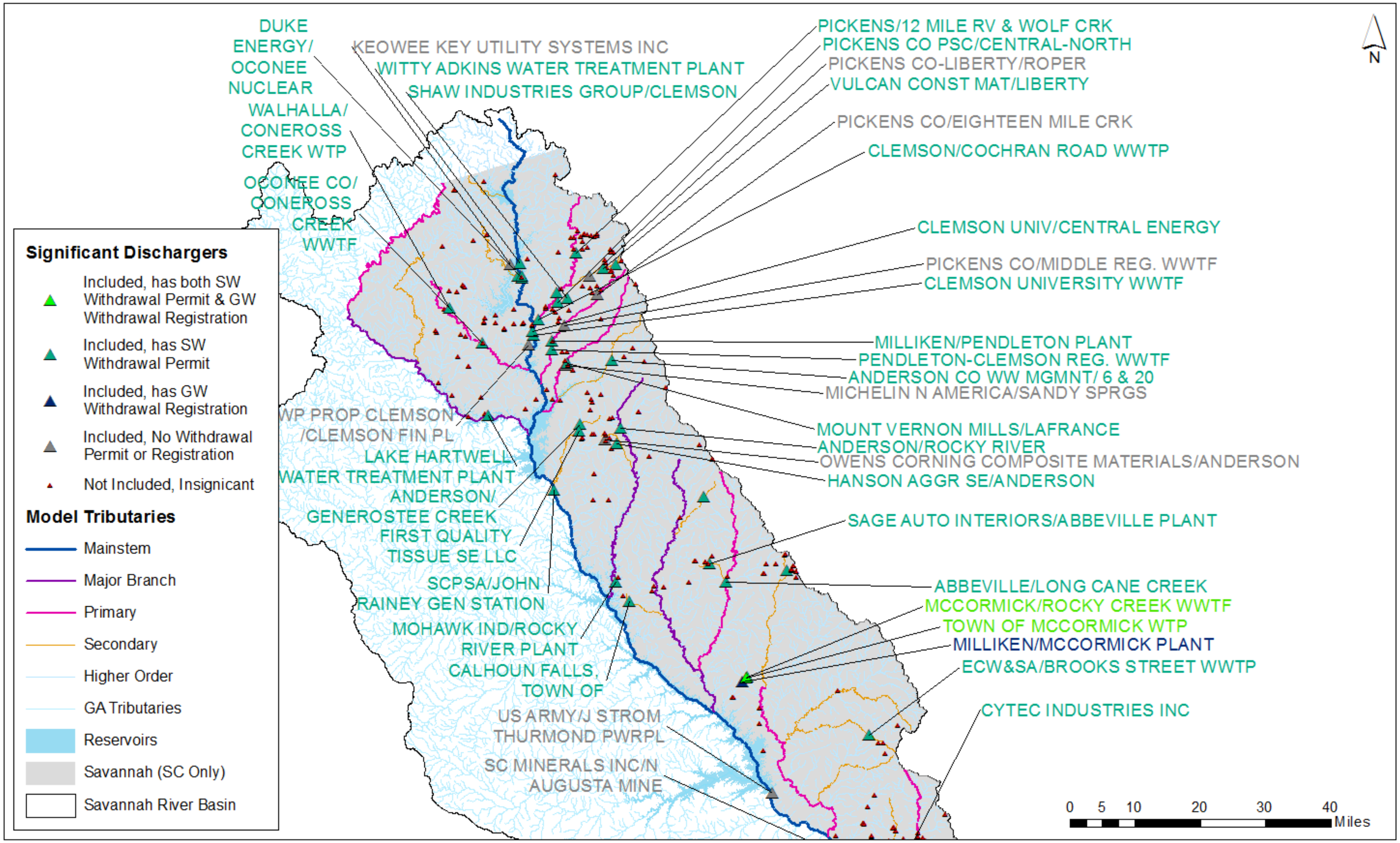
Upper Savannah
Discharges to Surface Water



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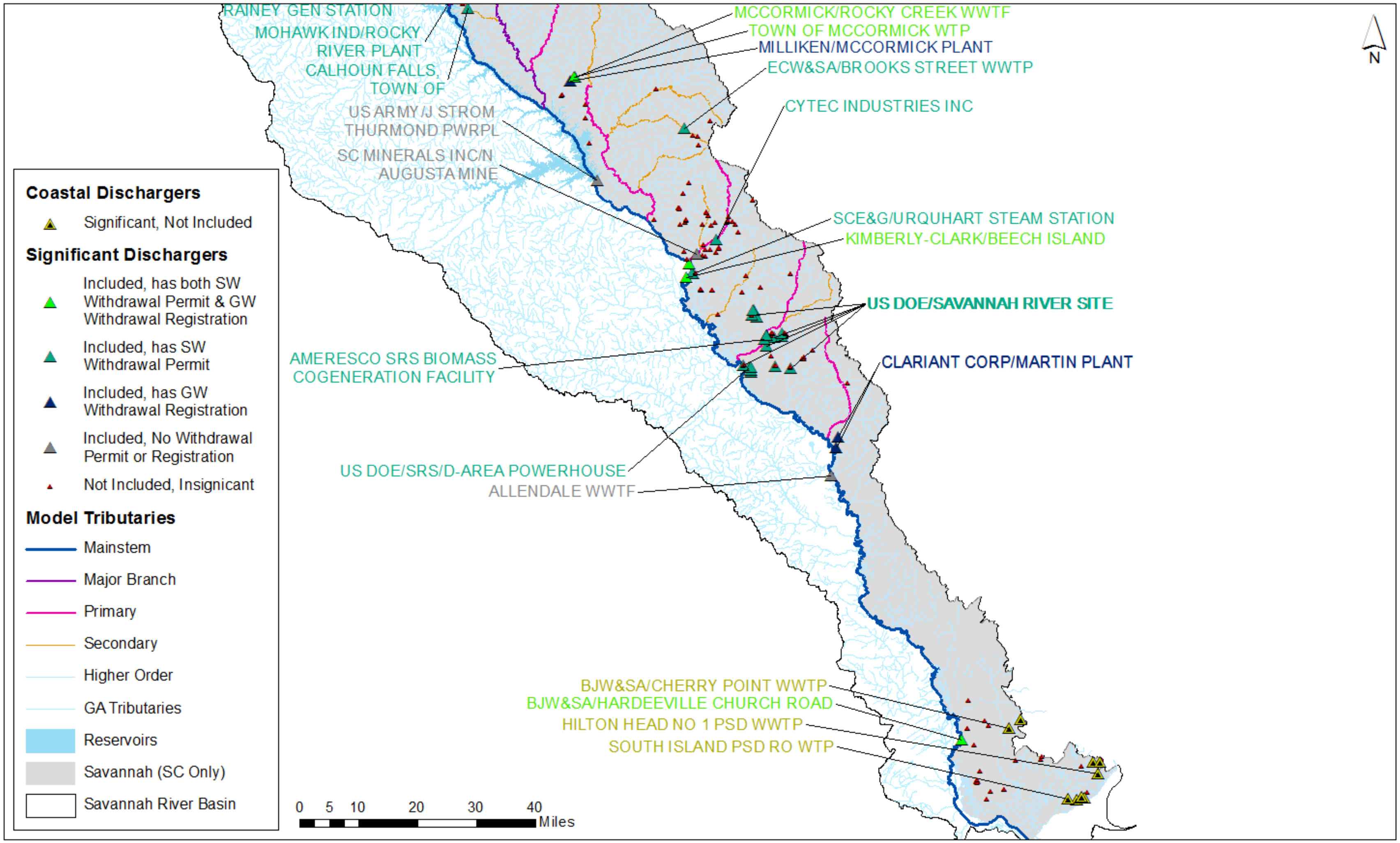
Lower Savannah
Discharges to Surface Water



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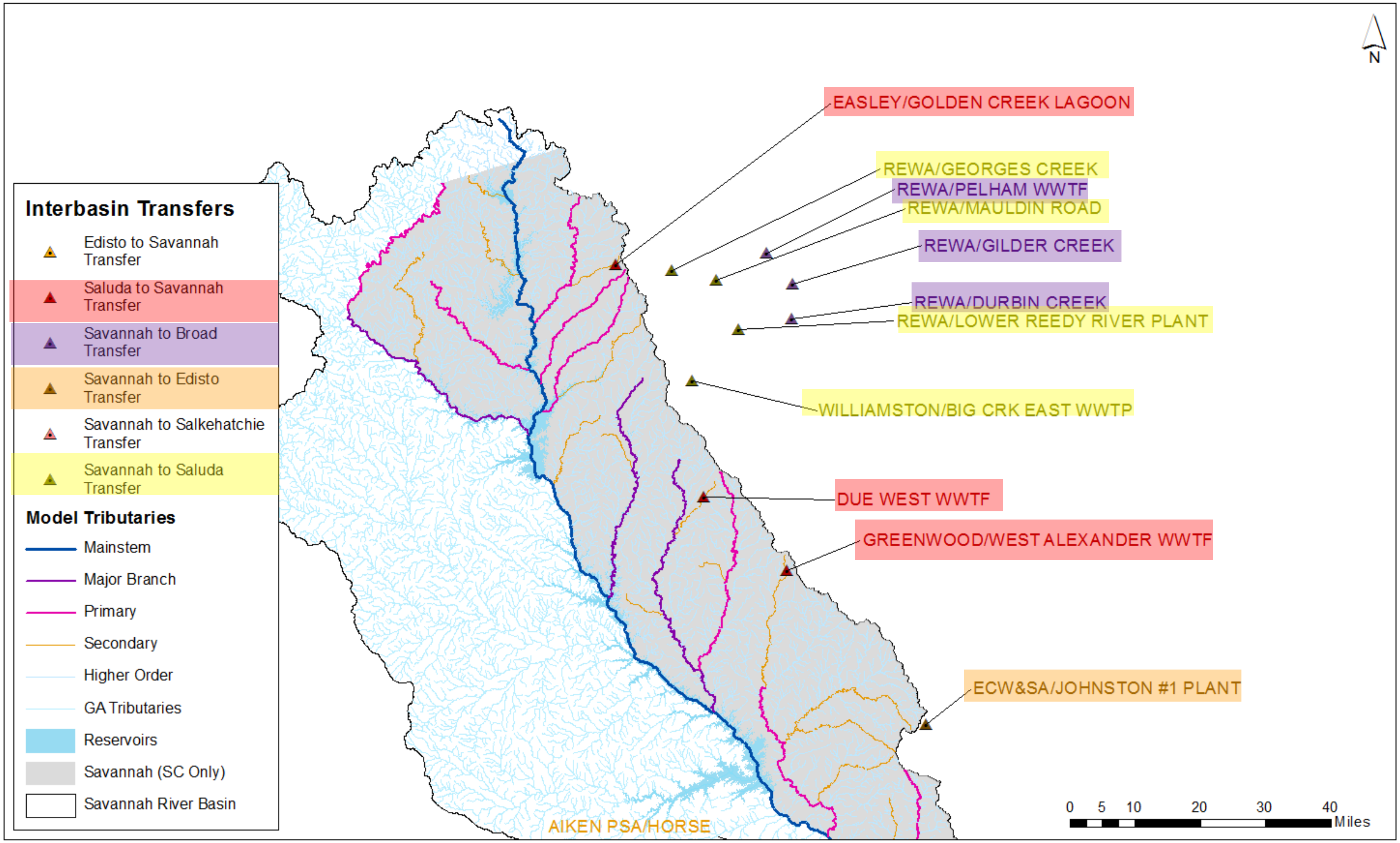
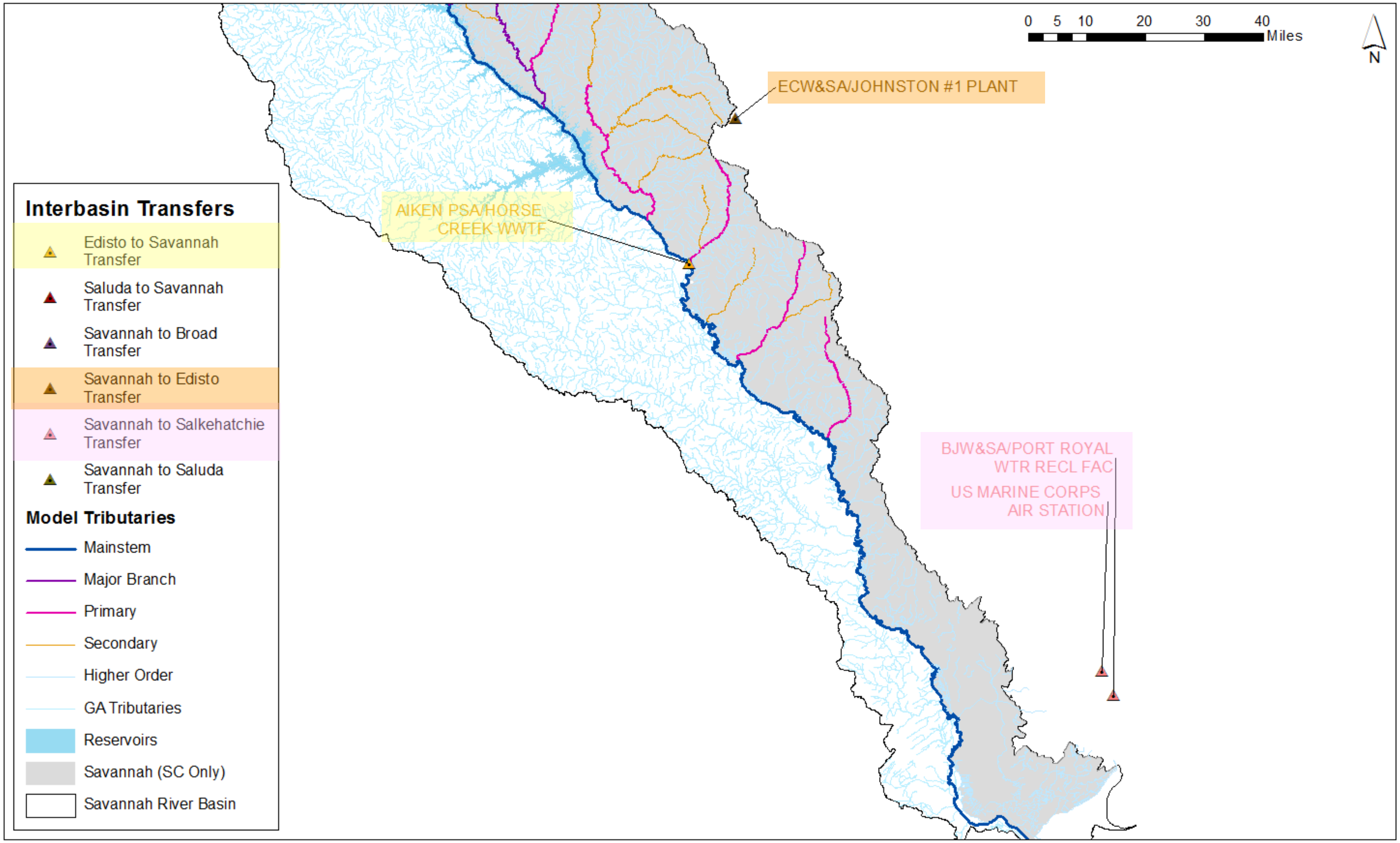
Upper Savannah Interbasin Transfers



Lower Savannah Interbasin Transfers



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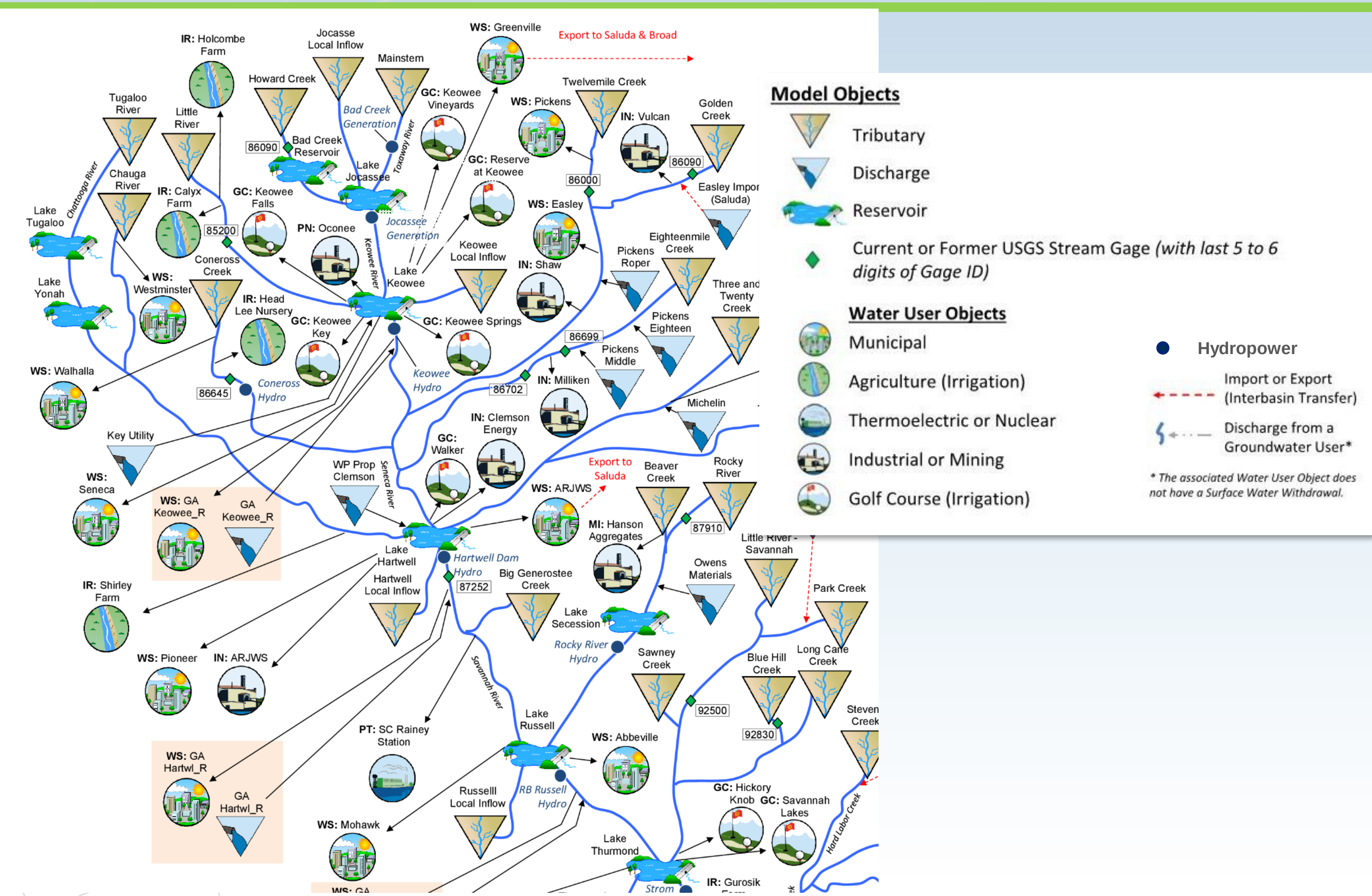
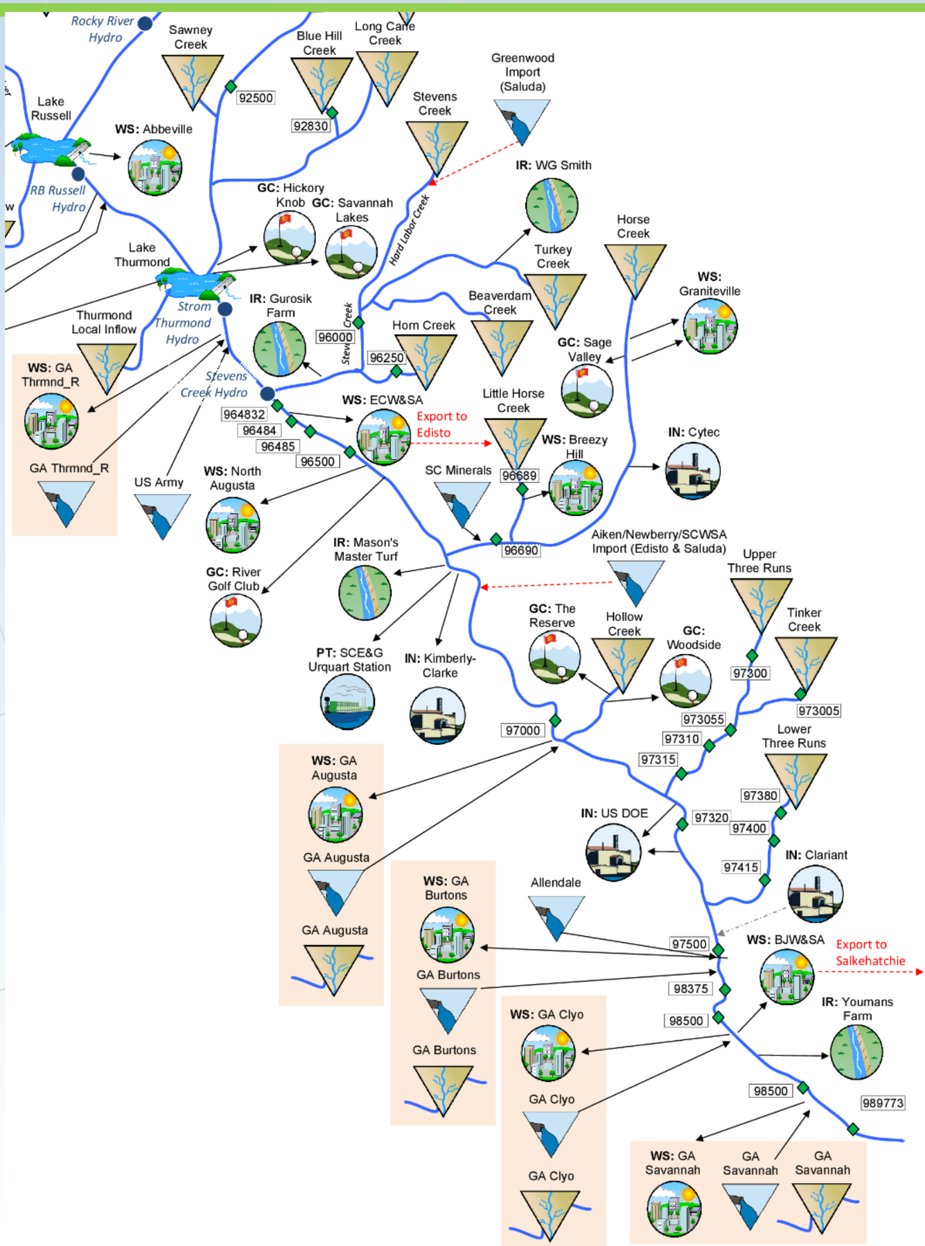
Upper Savannah Basin – SWAM Framework



Lower Savannah Basin – SWAM Framework



Model Objects

- Tributary
- Discharge
- Reservoir
- Current or Former USGS Stream Gage *(with last 5 to 6 digits of Gage ID)*

Water User Objects

- Municipal
- Agriculture (Irrigation)
- Thermoelectric or Nuclear
- Industrial or Mining
- Golf Course (Irrigation)

- Hydropower
- Import or Export (Interbasin Transfer)
- Discharge from a Groundwater User*

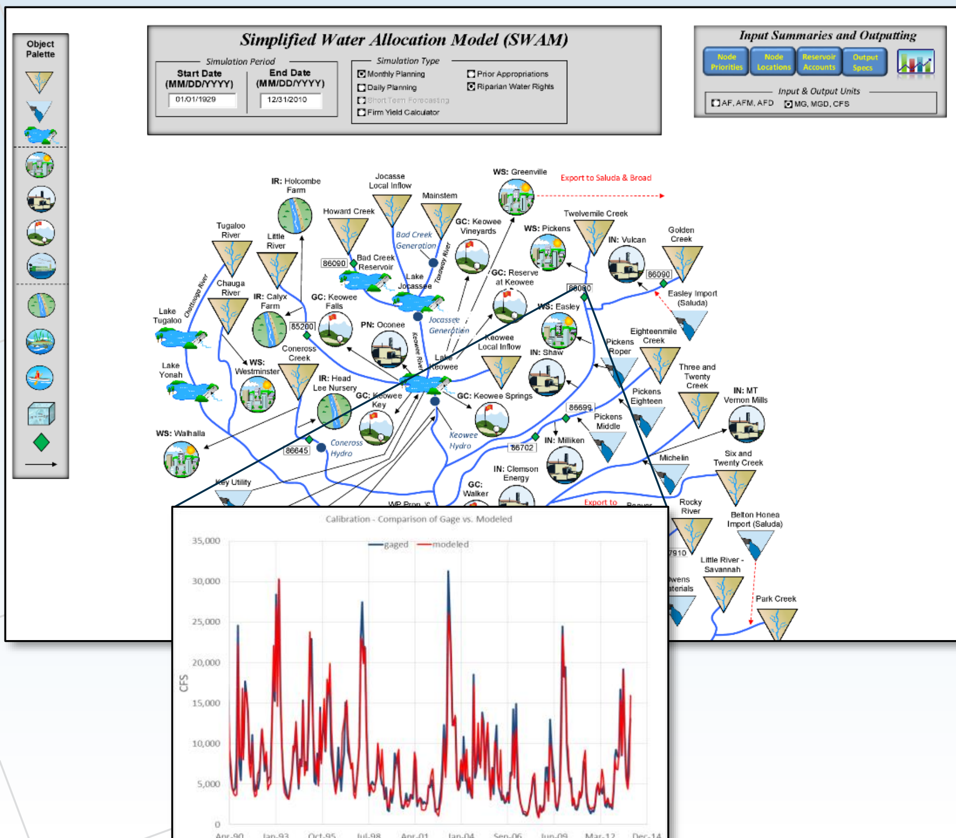
** The associated Water User Object does not have a Surface Water Withdrawal.*

Savannah River Basin

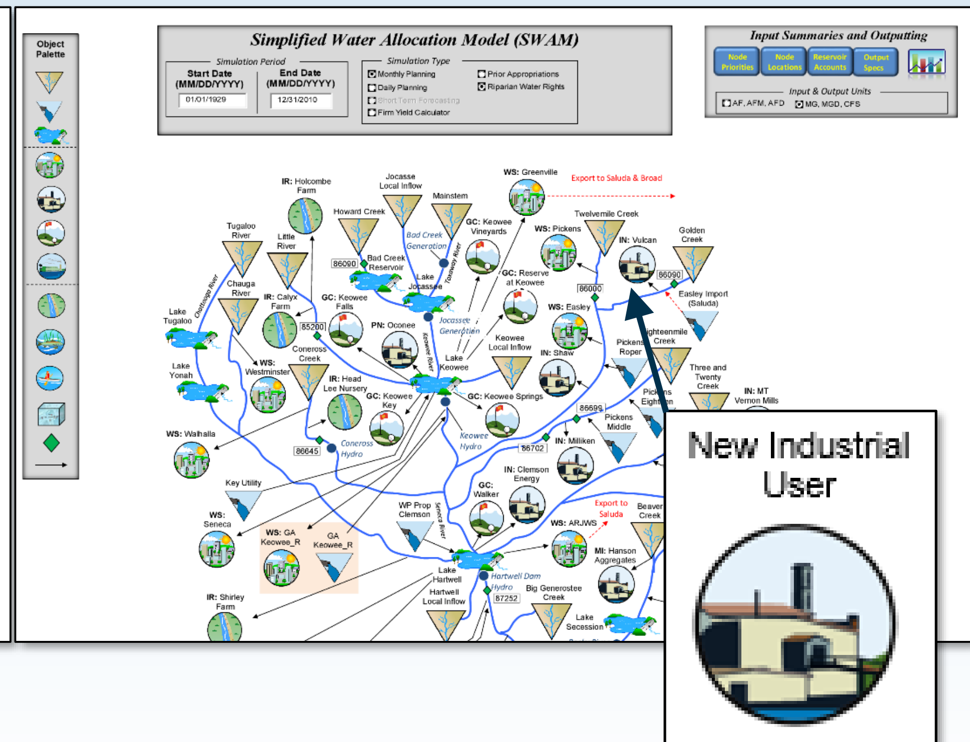
MODEL SETUP

Two Versions of Every Model

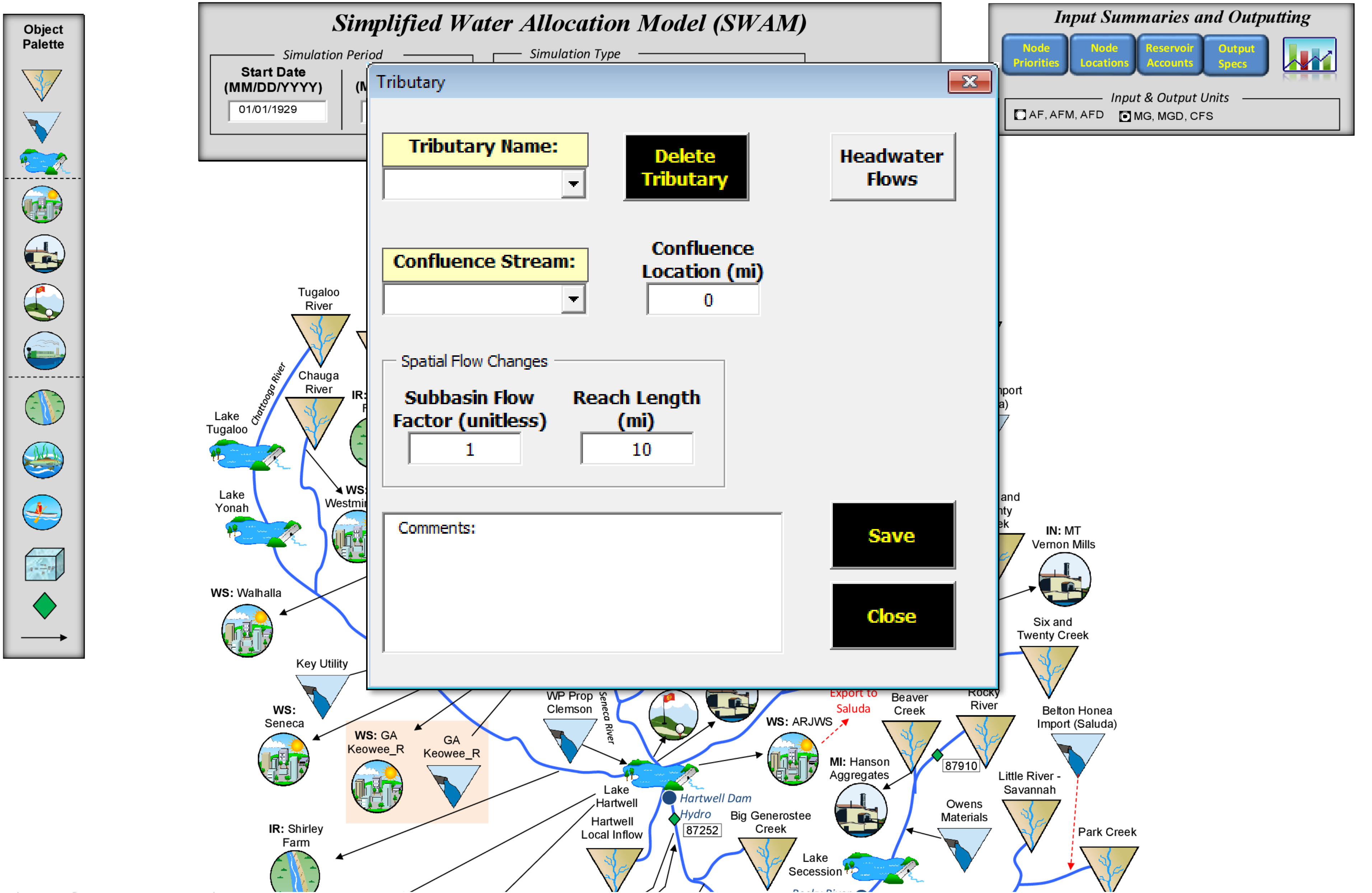
Calibration with UIFs and Historic Use Records



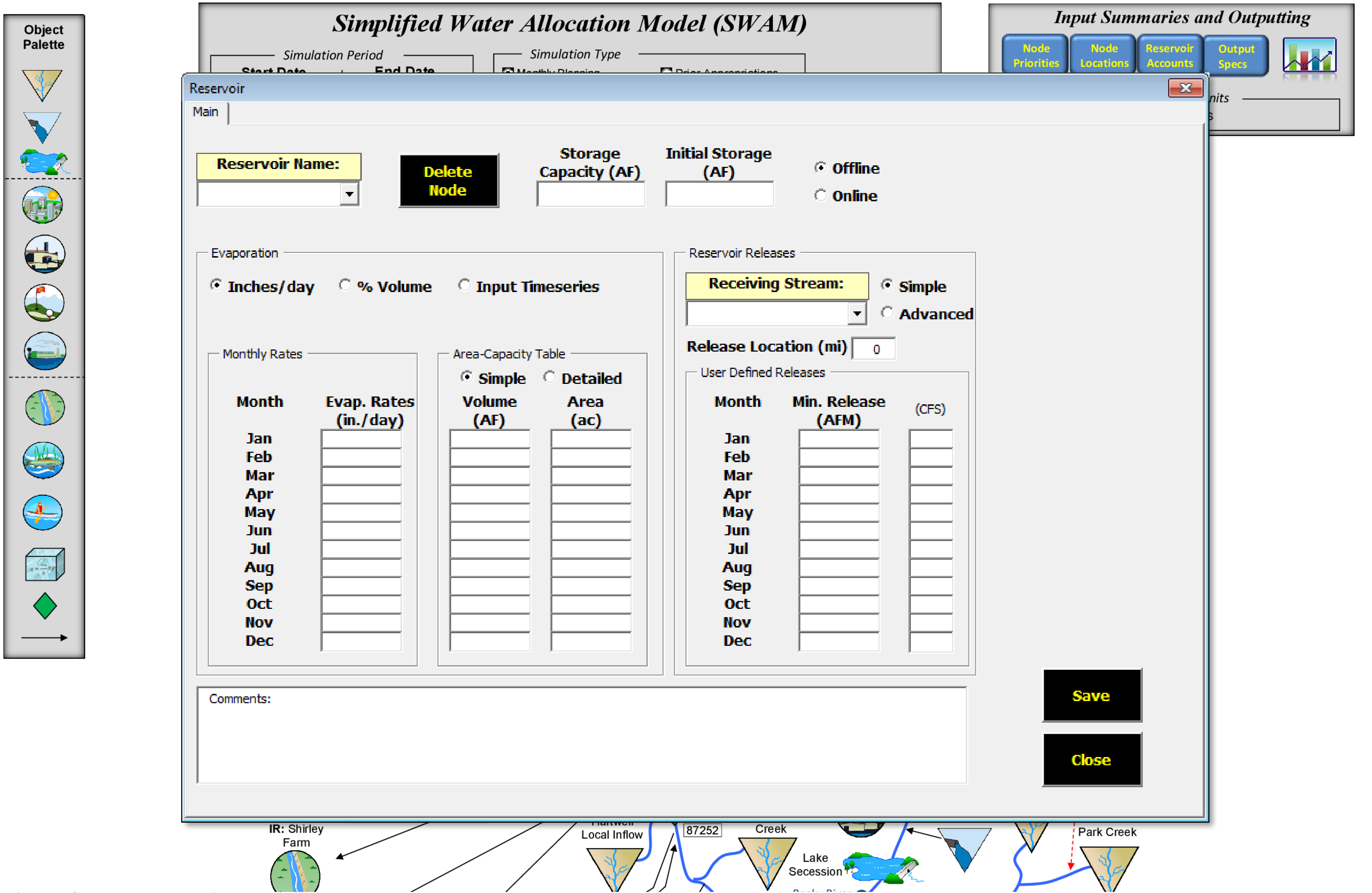
Planning with UIFs, Current Uses, and User-Defined Future Uses



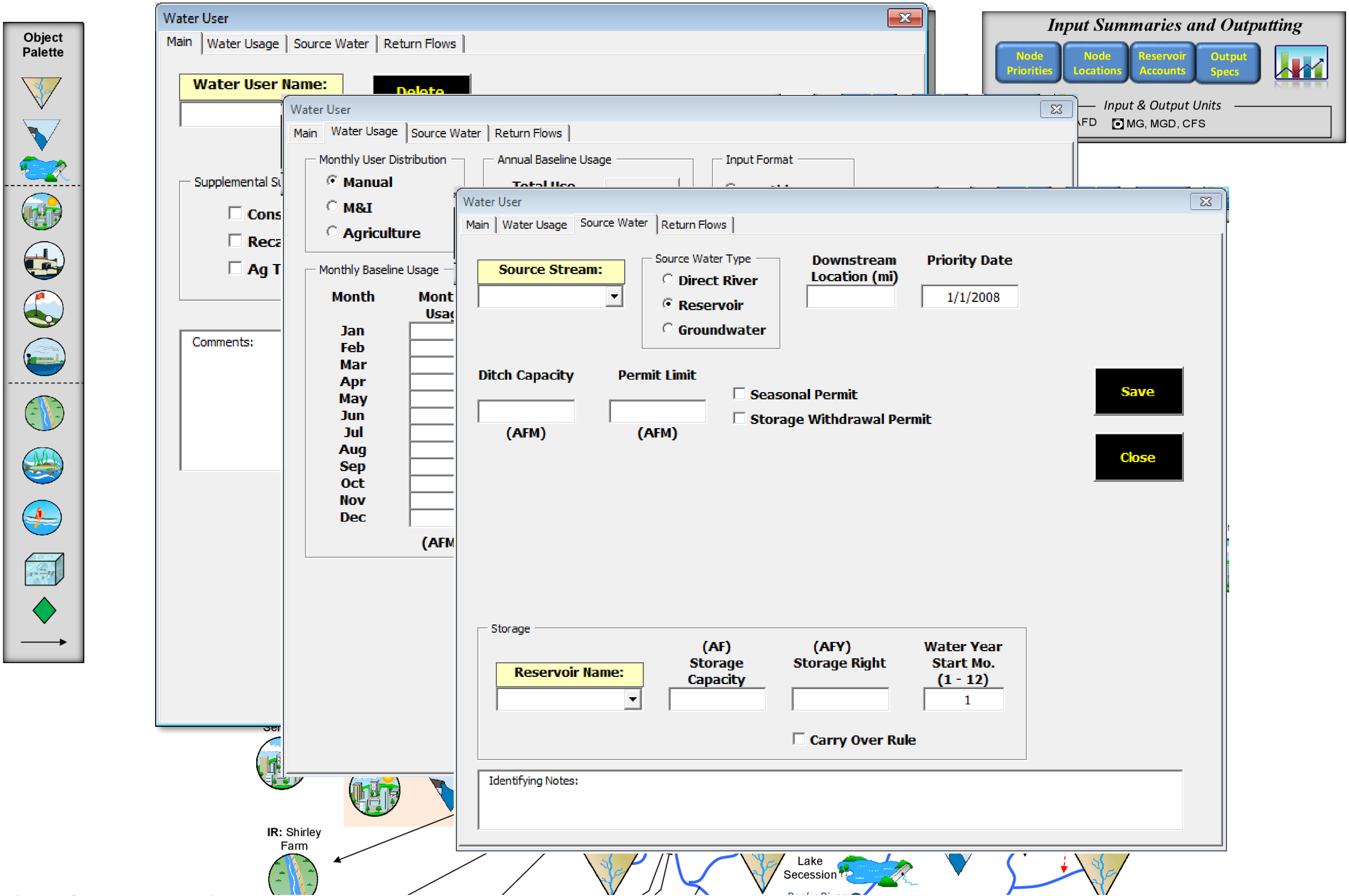
Tributary Input Form



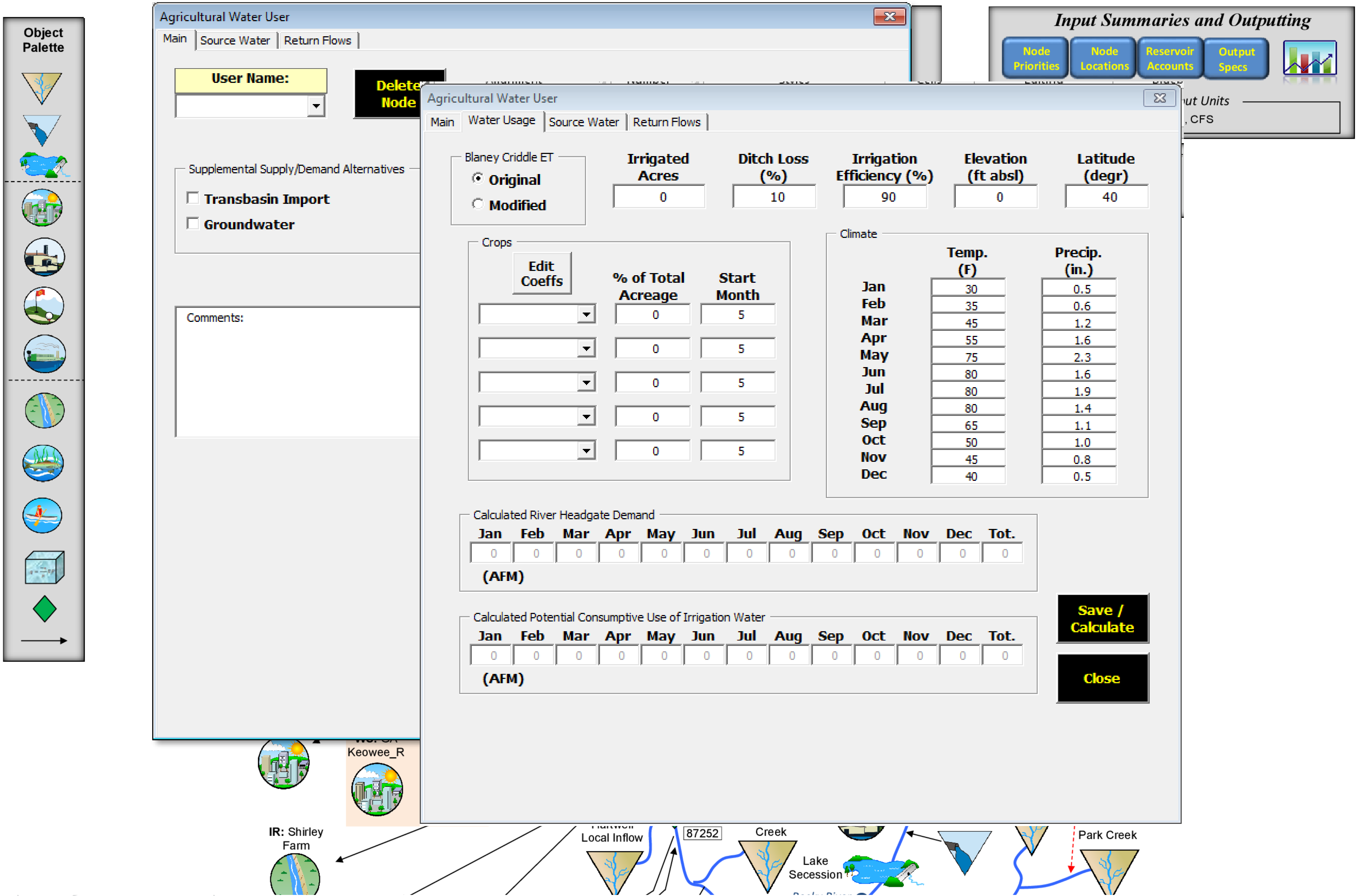
Reservoir Input Form



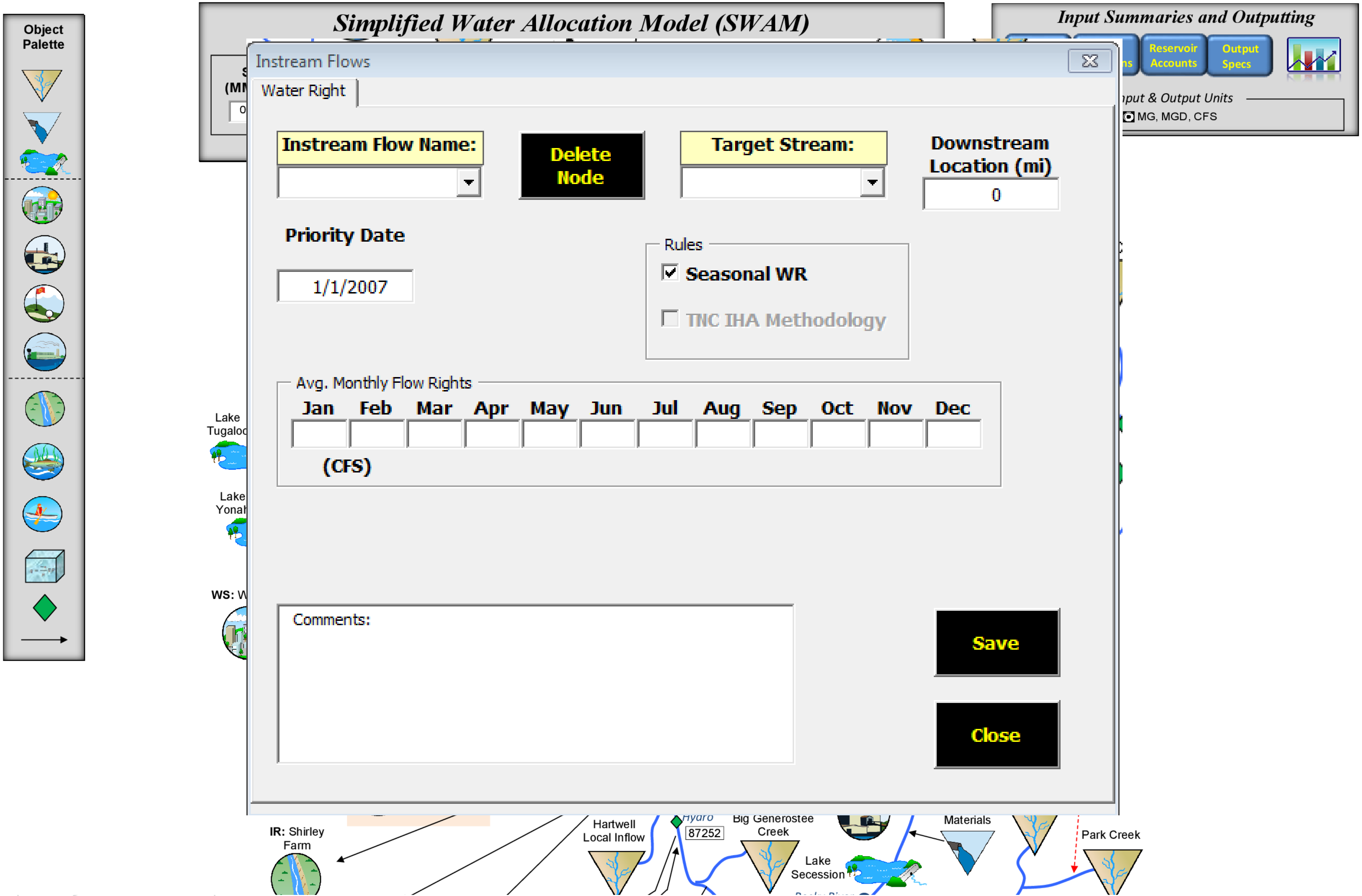
Water User Input Form – Main



Agricultural Water User Input Forms



Instream Flow Input Form



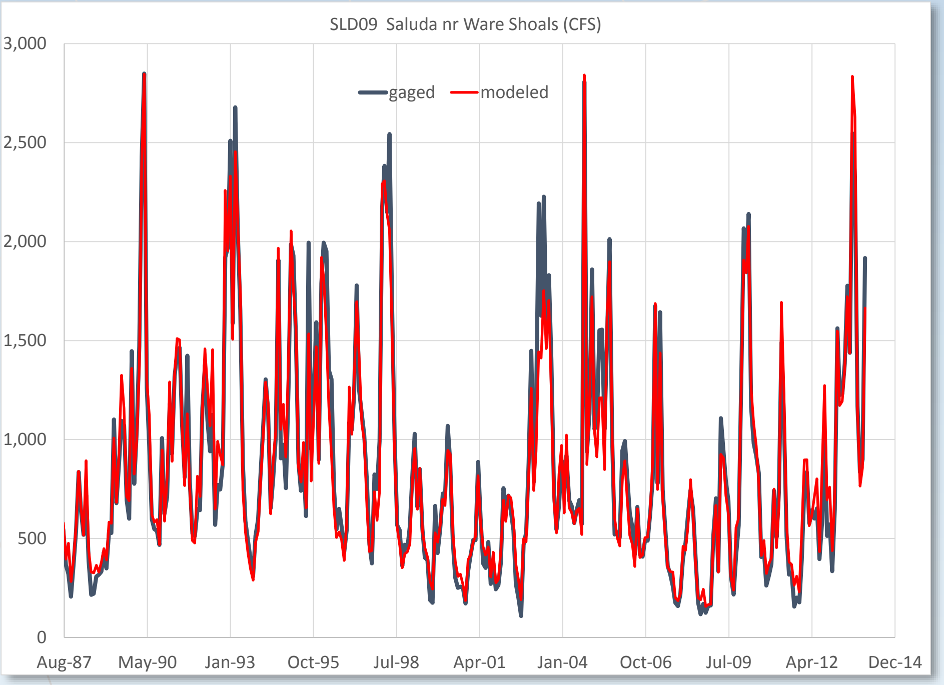
Savannah River Basin

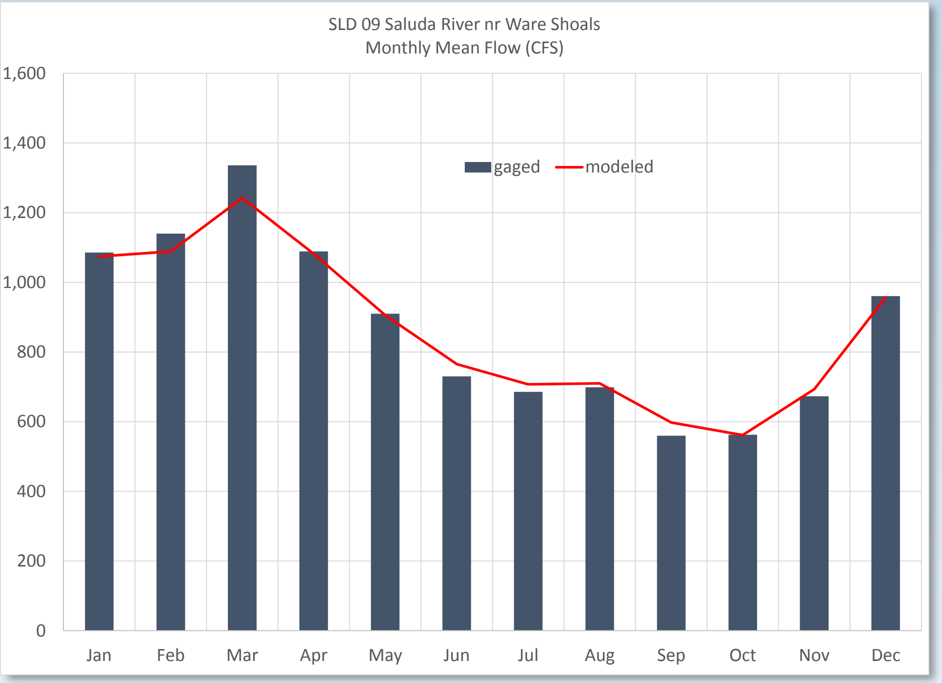
MODEL VALIDATION

SWAM Calibration/Validation

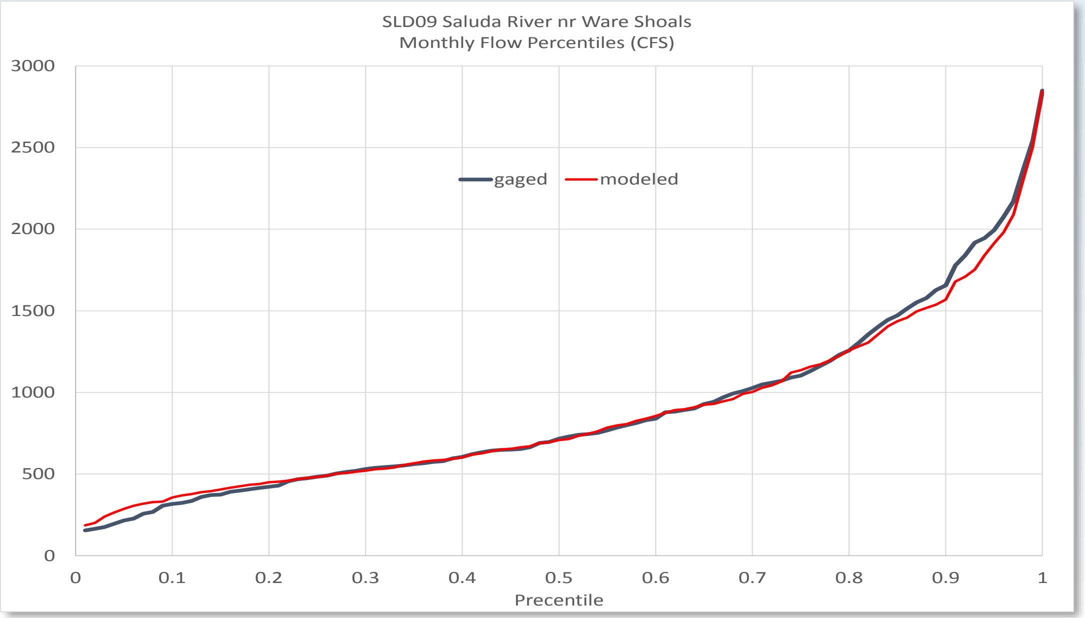
- Calibration targets = downstream flow gage records
- Calibration parameters =
  - reach gains/losses,
  - ungaged flow records,
  - reservoir operations
  - ag return flow percentages, locations, lags
- Performance metrics =
  - Annual avg flows (overall water balance)
  - Monthly avg flows (seasonality)
  - Flow percentile distributions (variability, extreme events)
  - Flow timeseries (specific timings, operations)
  - Cumulative flows over entire calibration period
  - Reservoir storage timeseries

Calibration Result Graphs





Examples from the Saluda Basin



Savannah River Basin

THANK YOU