South Carolina Surface Water Quantity Modeling Project

Salkehatchie River Basin Meeting – Introduction to the Draft Model

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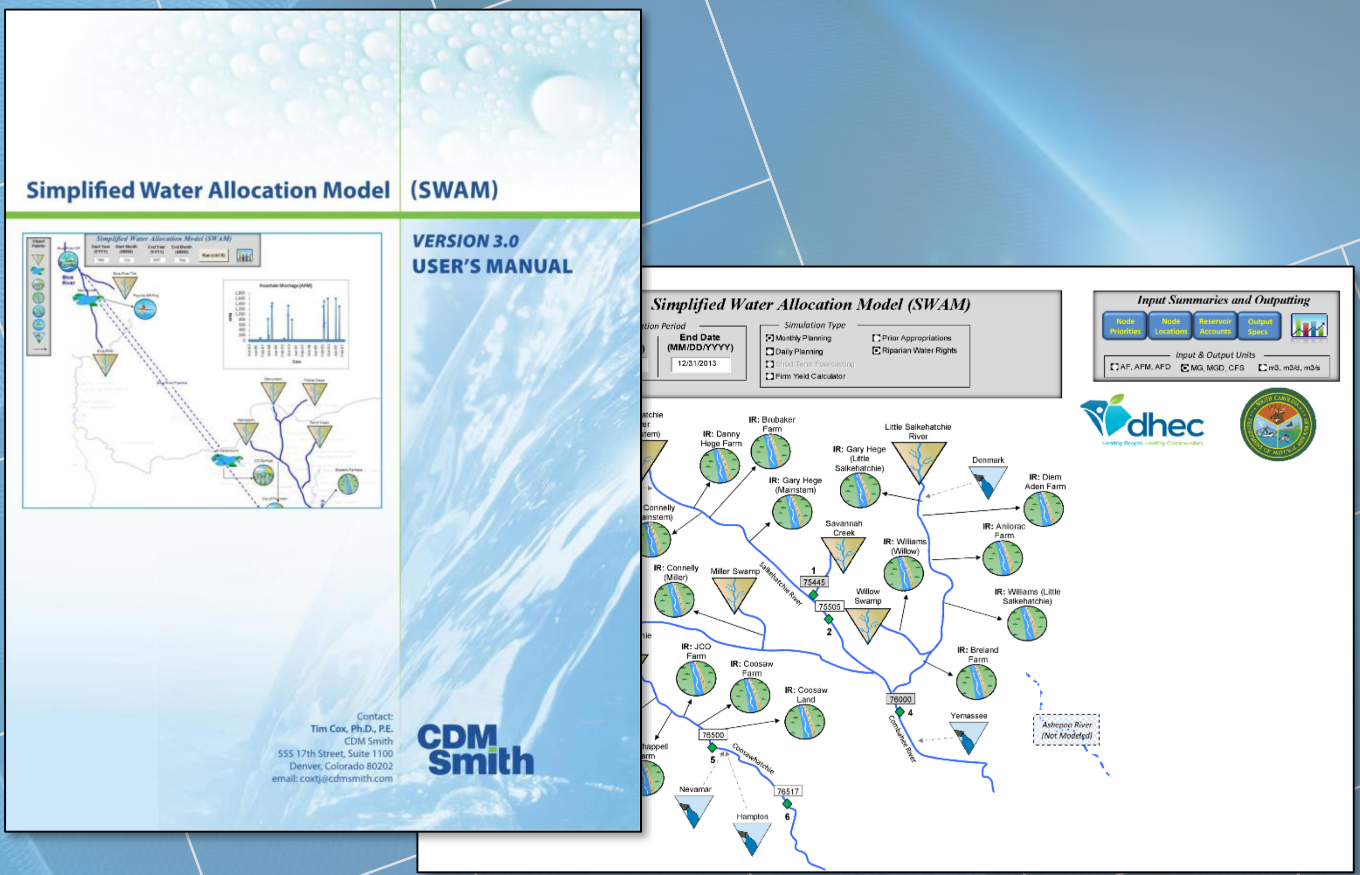
Nina Caraway

August 9, 2016



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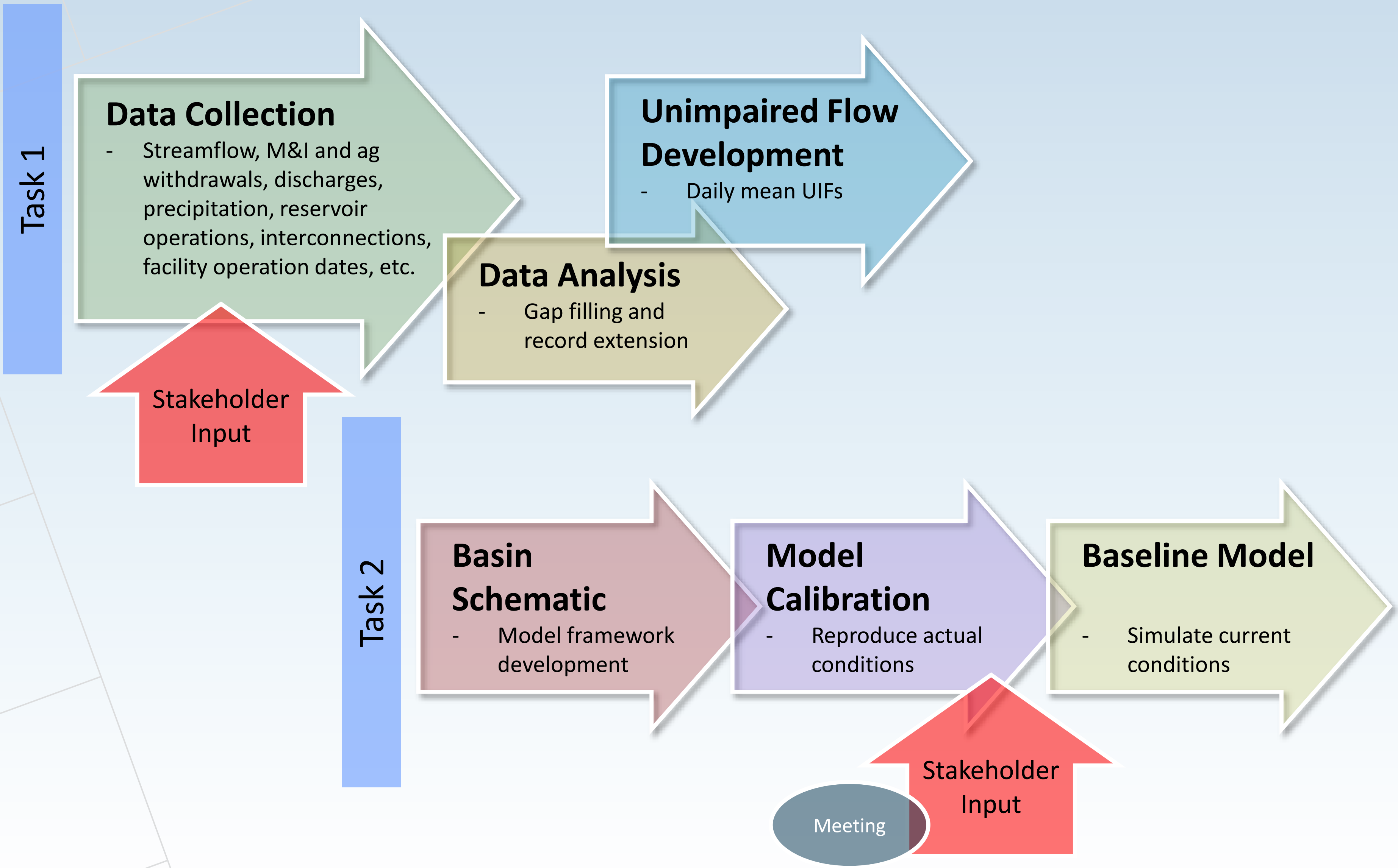
Presentation Outline

- Project background and status
- Introduction to SWAM
- Data collection and unimpaired flows
- Model framework and development
- Model calibration/verification
  - Calibration/verification philosophy and approach
  - Calibration results and discussion
- Baseline model and uses

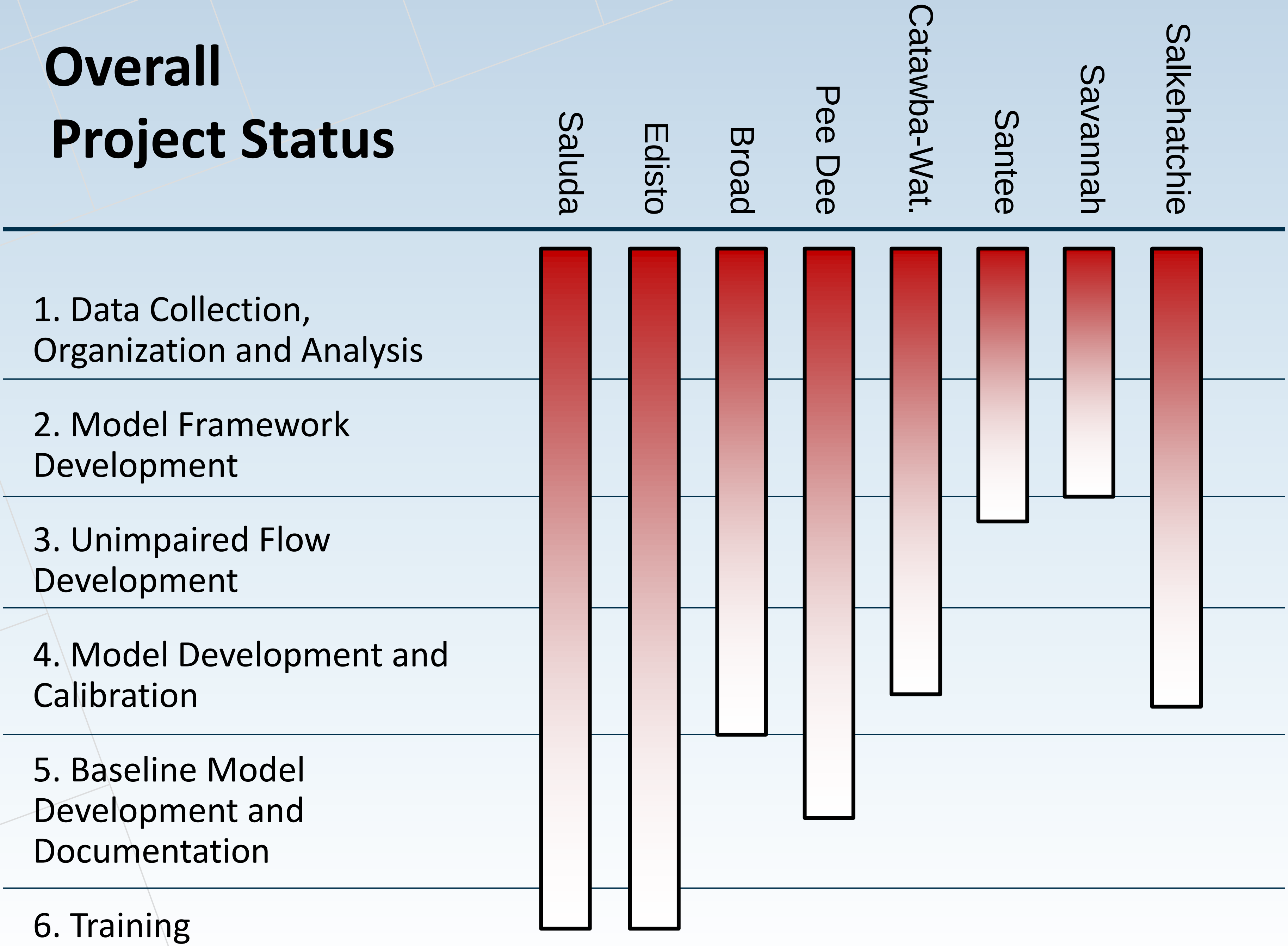
Project Purpose

- Build surface water quantity models capable of:
  - Accounting for inflows and outflows from a basin
  - 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.

Project Status – Salkehatchie Basin

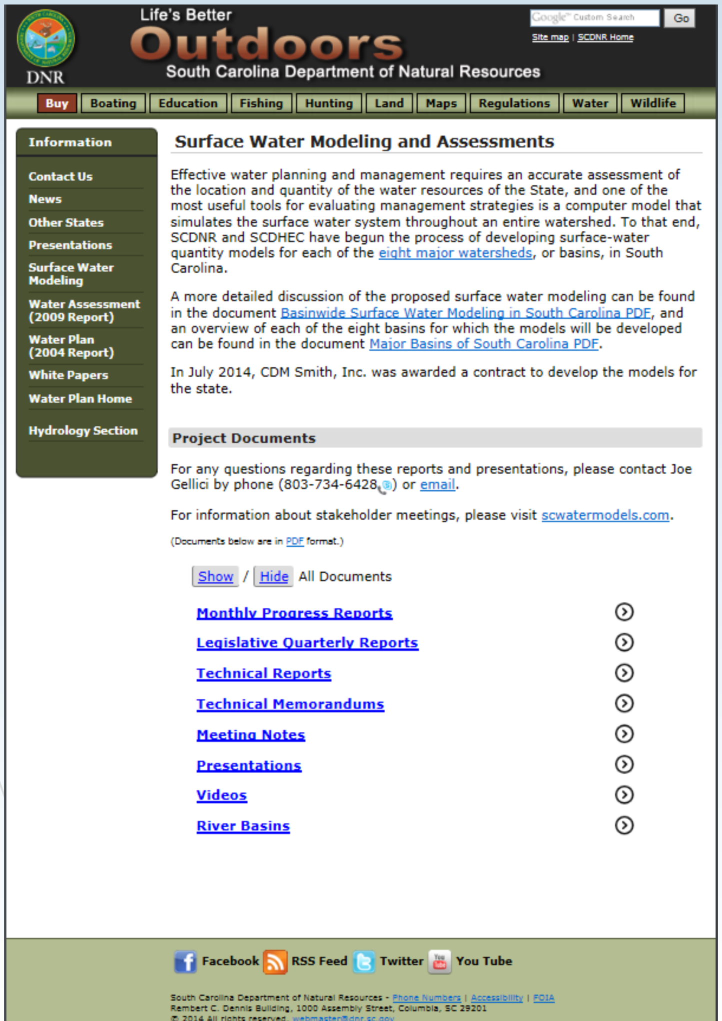


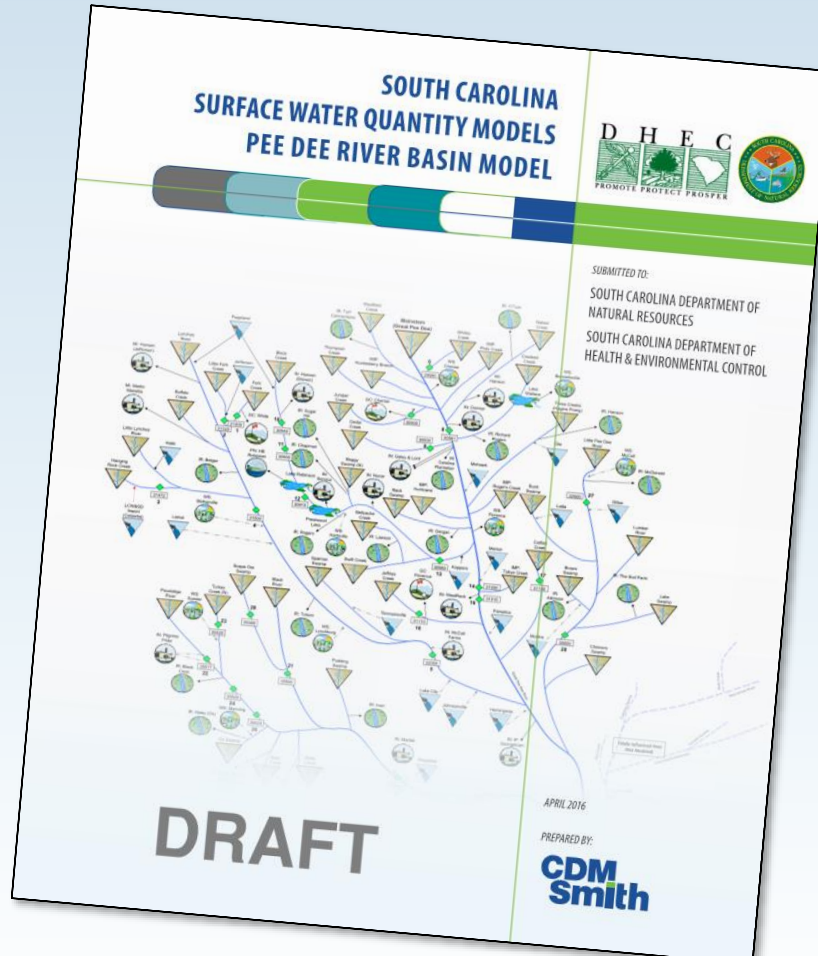
Overall Project Status



Modeling Report and Other Documents

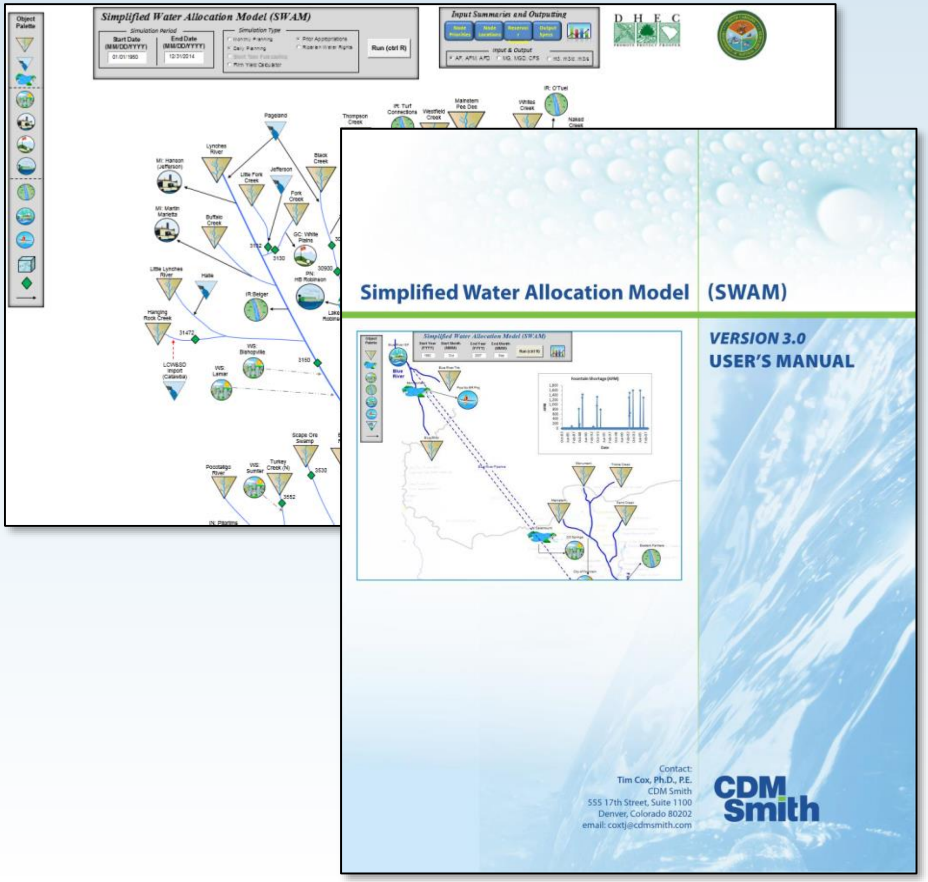
- http://www.dnr.sc.gov/water/waterplan/surfacewater.html





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)

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

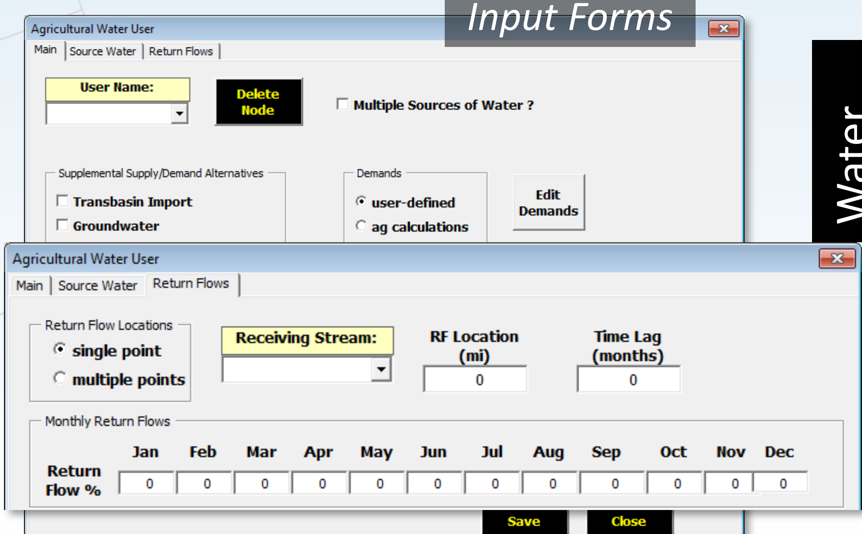
RiverWare

- 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

Input Forms

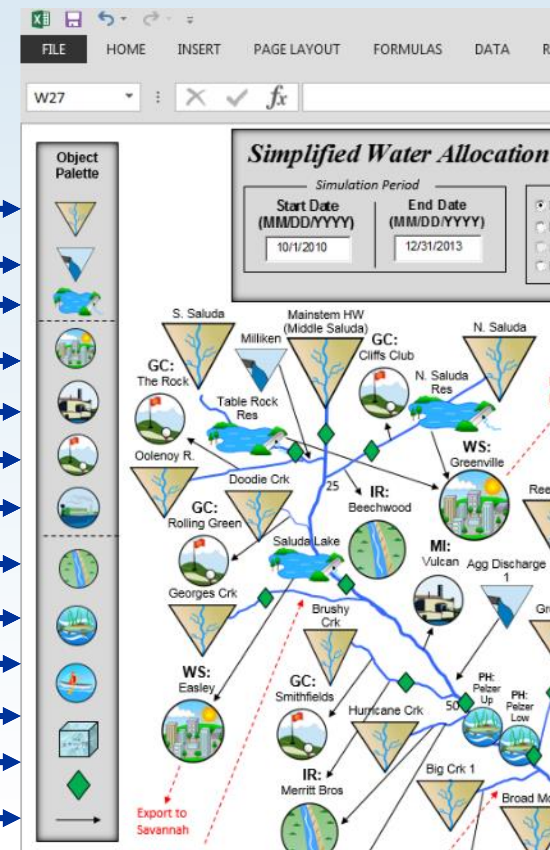


Objects

Tributaries
Discharges
Reservoirs

Water User Objects:
Municipal
Industrial
Golf Courses
Power Plants
Agriculture

Instream Flow
Recreational Pool
Aquifer
USGS Gage
Interbasin Transfer



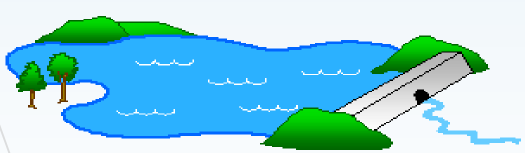
Simplified Water Allocation Model (SWAM)

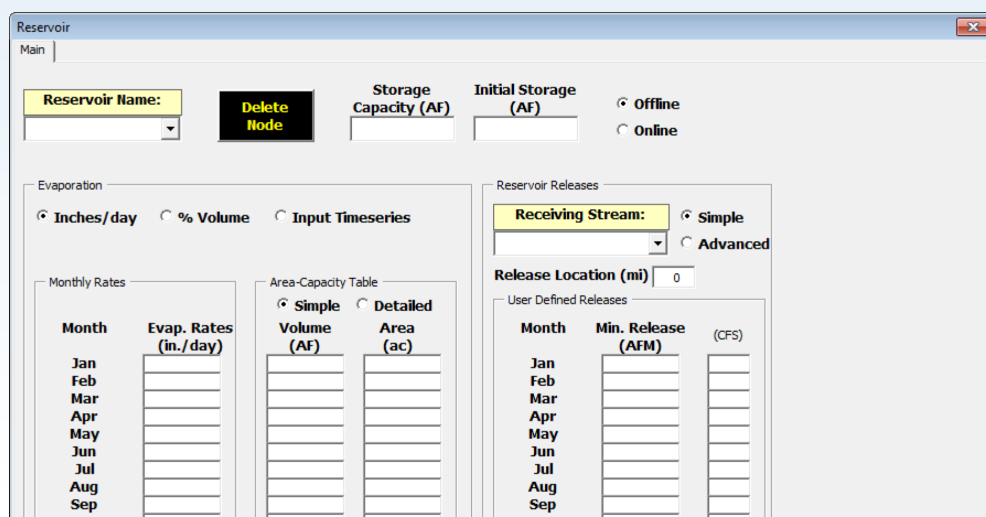
- Supports multiple layers of complexity for development of a range of systems, for example…

  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





Salkehatchie River Basin

MODELING DATA REQUIREMENTS

Data Collected for Model Development

- USGS daily flow records
- Historical Operational Data
  - Withdrawals (municipal, industrial, agricultural, golf courses)
  - Discharges
- Subbasin characteristics (GIS)
  - Drainage area
  - Land use

Salkehatchie River Basin

UNIMPAIRED FLOWS (UIF)

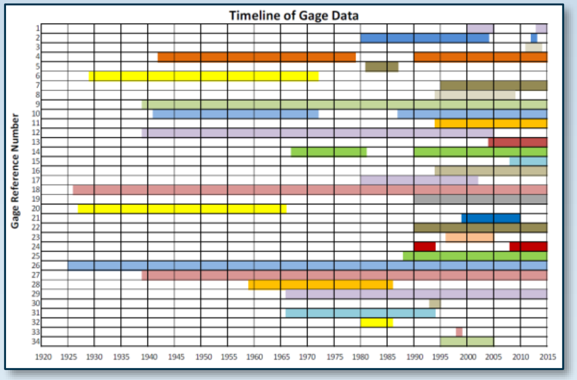
UIF Definition and Uses

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

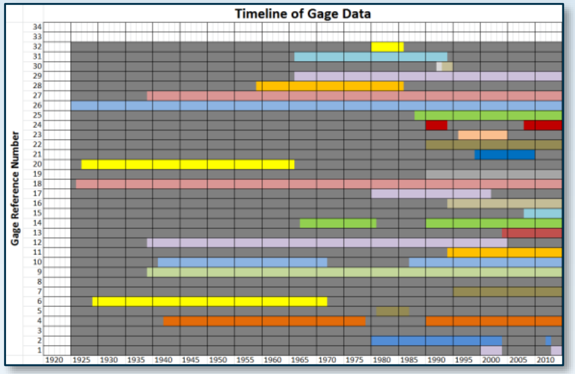
  Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Discharge to Reservoirs – Return Flow + Reservoir Surface Evaporation – Reservoir Surface Precipitation + Upstream change in Reservoir Storage + Runoff from Previously Unsubmerged Area
- **Fundamental input** to the model at headwater nodes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

Four Steps in UIF Calculation Process

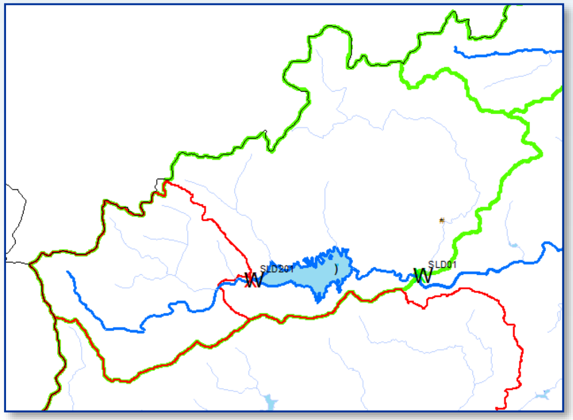
- **Step 1**: UIFs for USGS Gages for individual periods of record
  - Involves extension of operational data



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

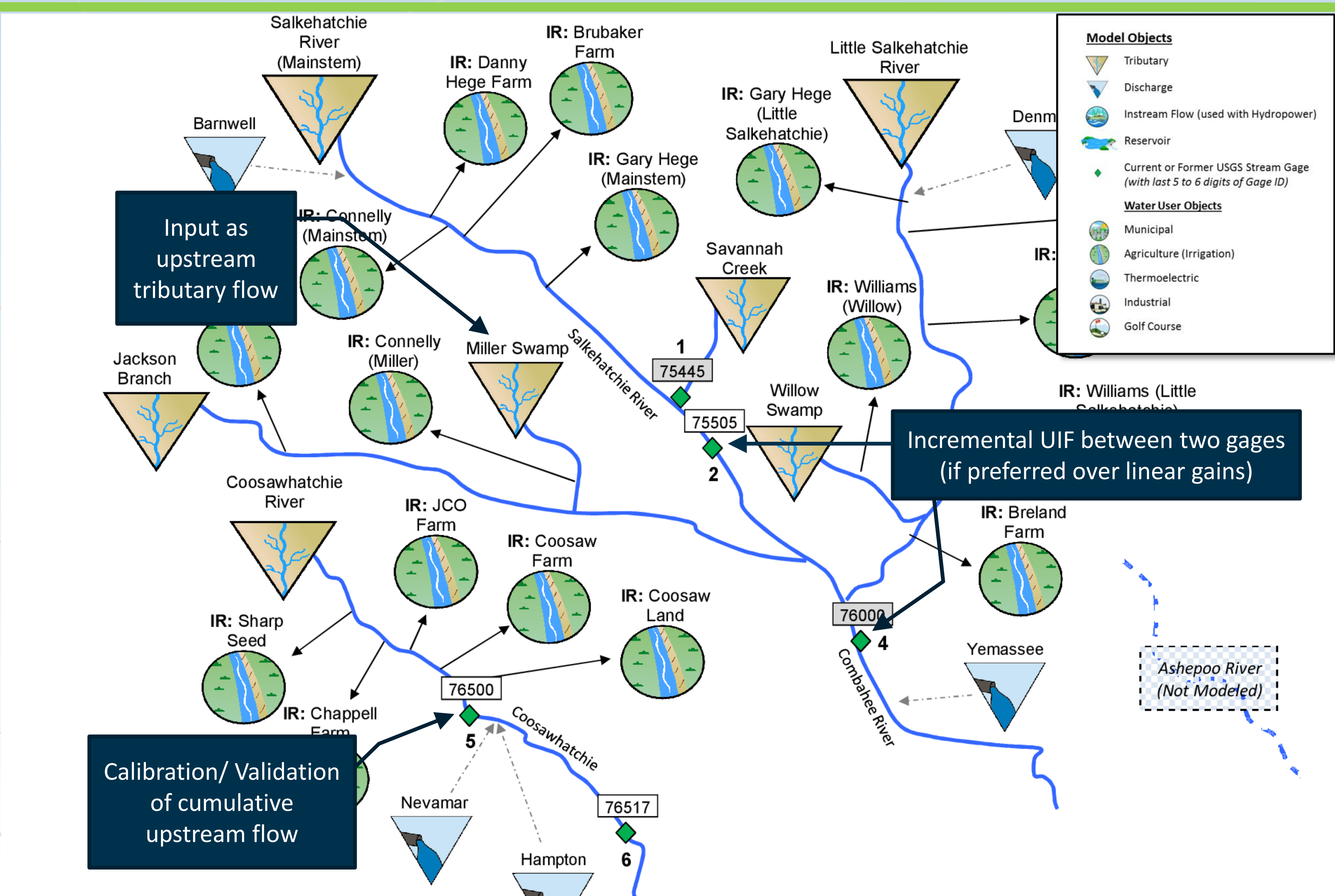


- **Step 3**: Correlation between ungaged basins and gaged basins



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

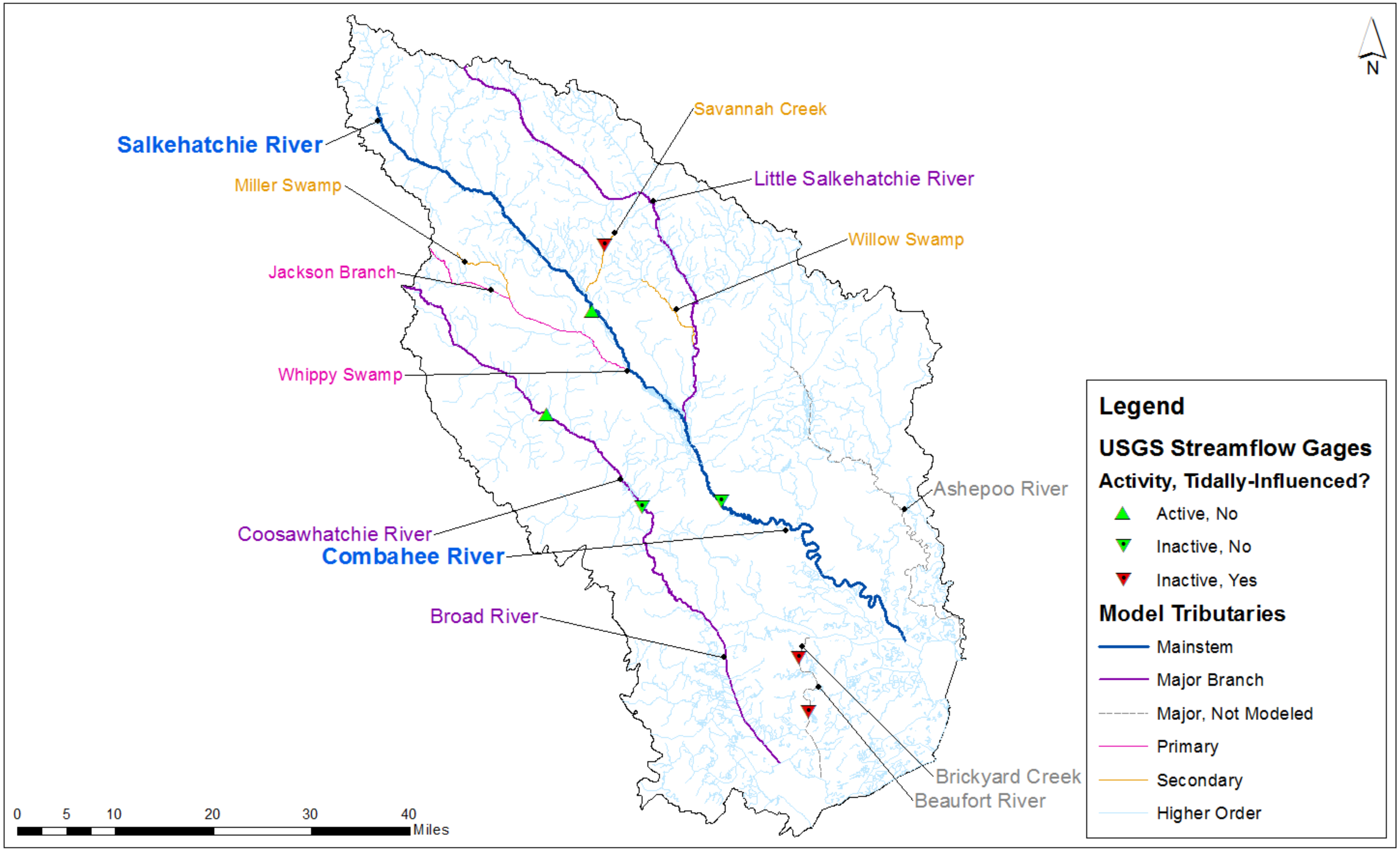
How UIFs are Used in SWAM



Salkehatchie River Basin

OVERVIEW OF MODEL FRAMEWORK

Salkehatchie Basin – Model Tributaries



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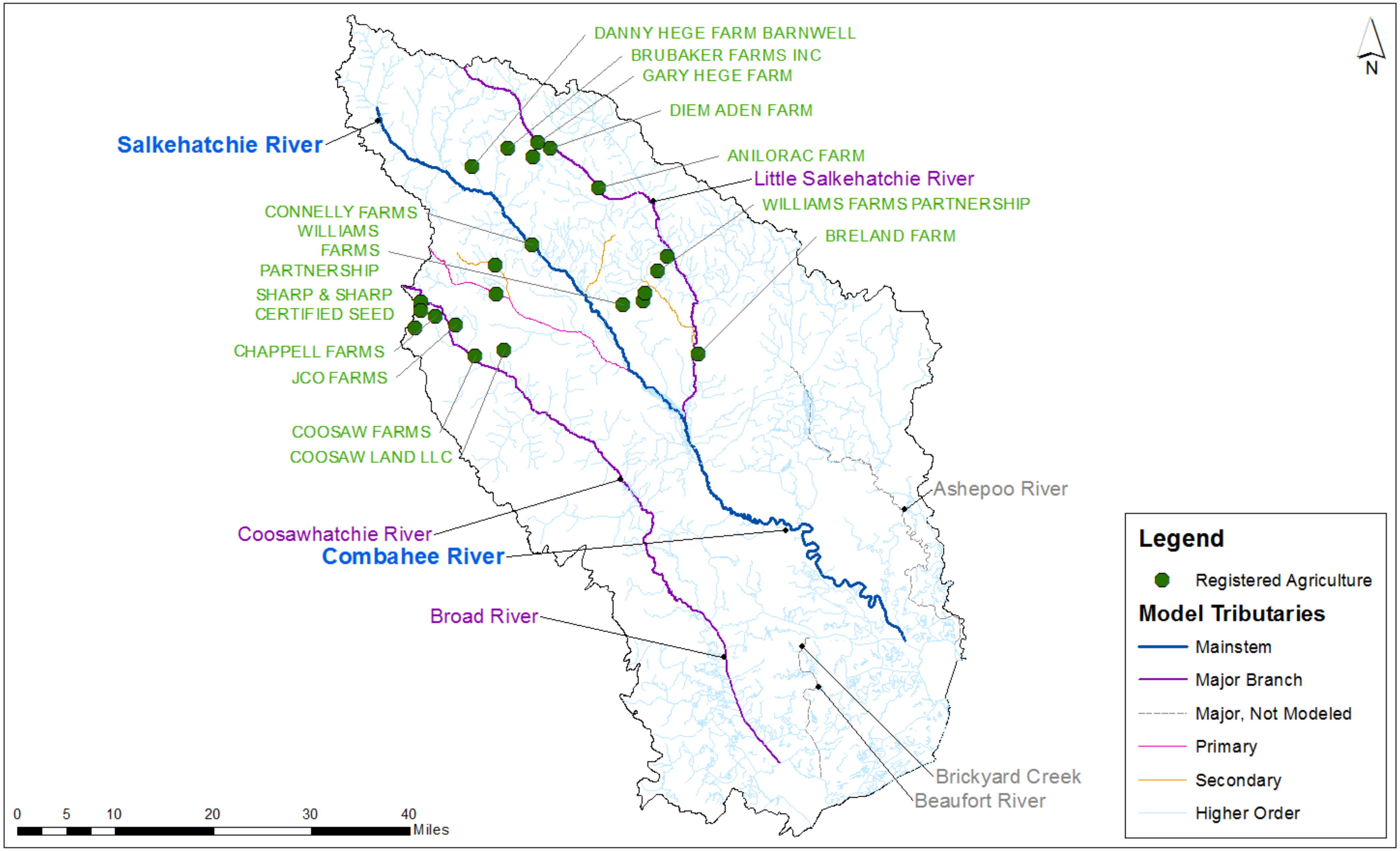
Agriculture Surface Water Withdrawals



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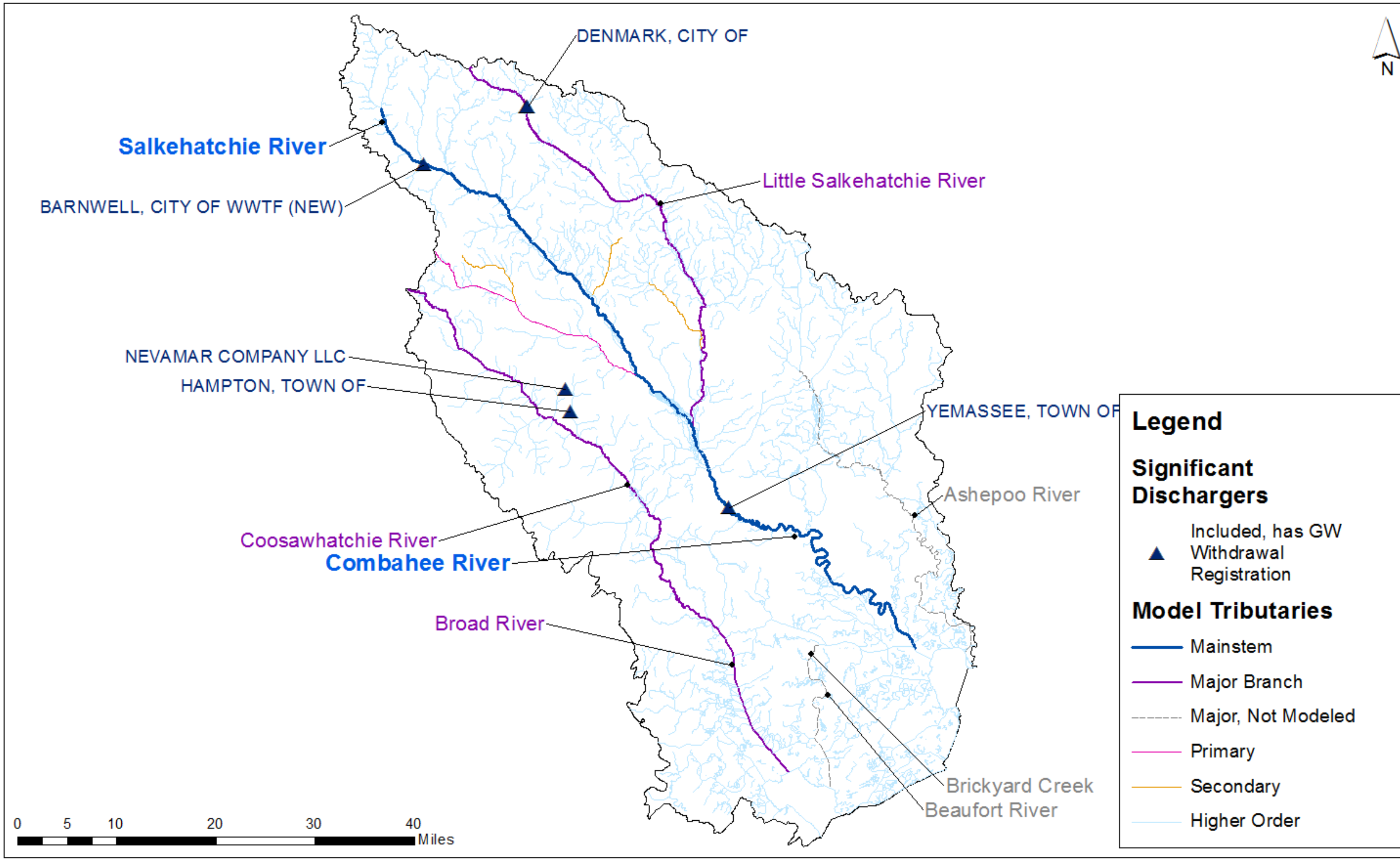
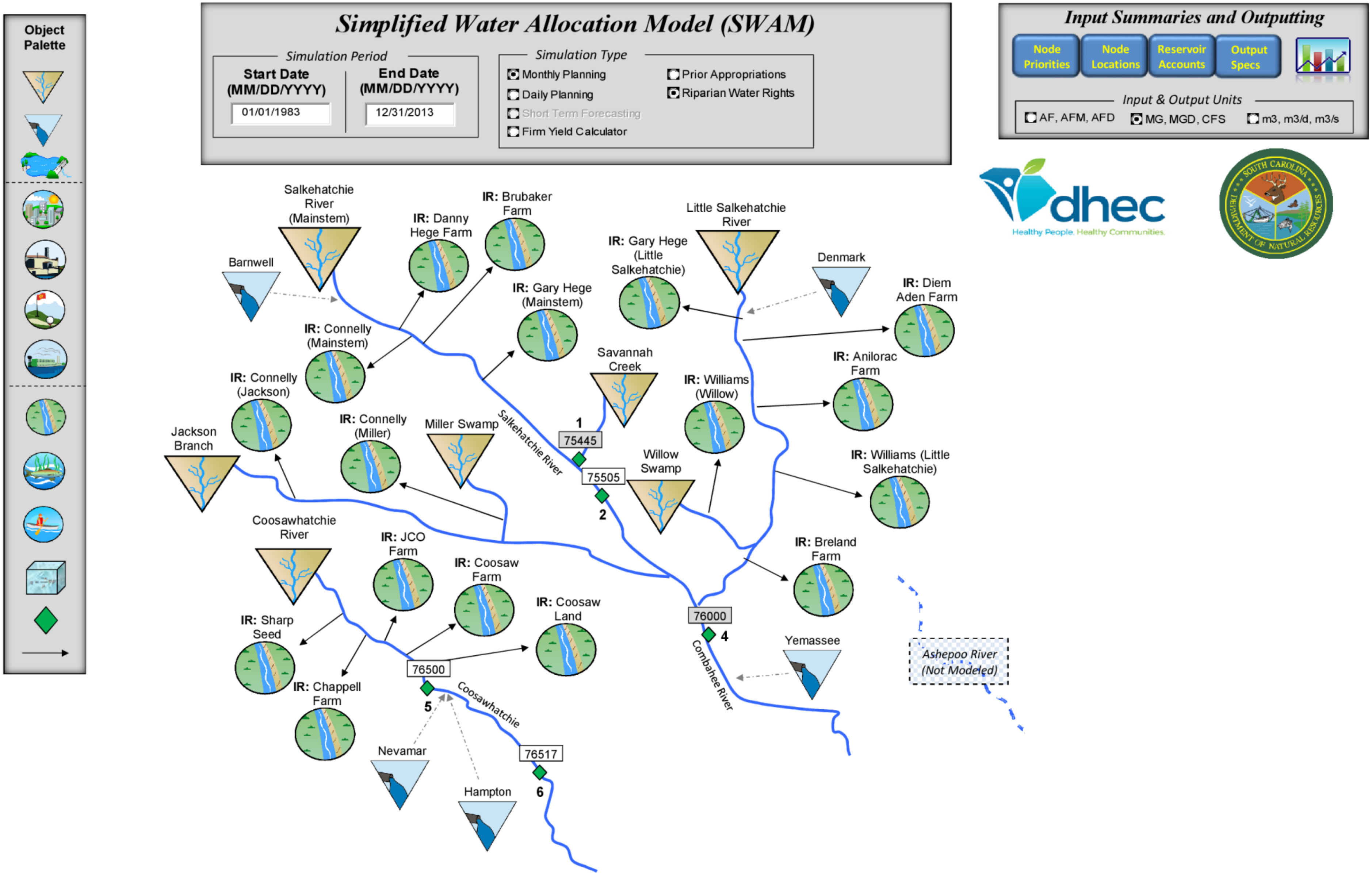
Discharges to Surface Water



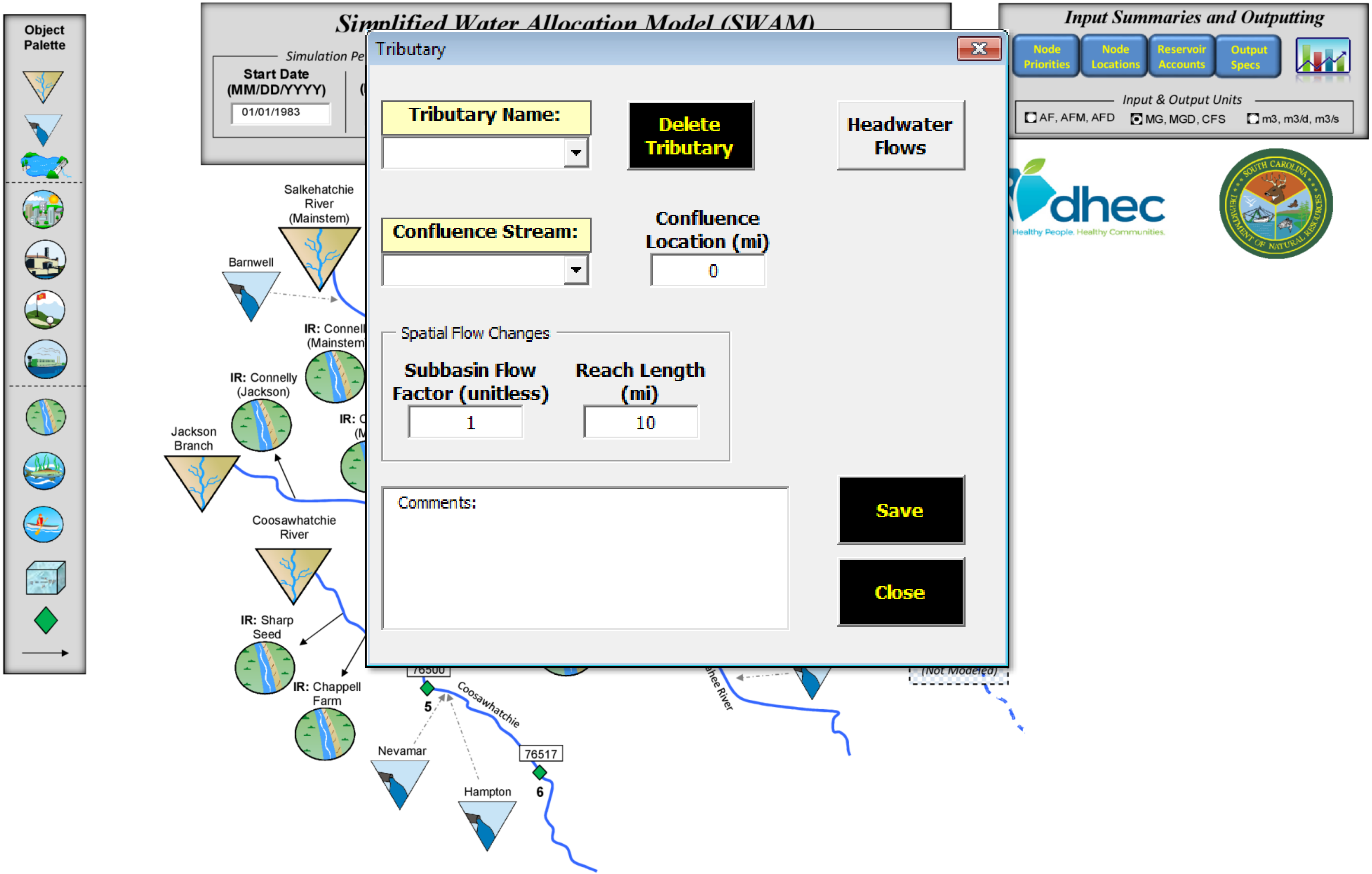
Salkehatchie Basin – SWAM Framework



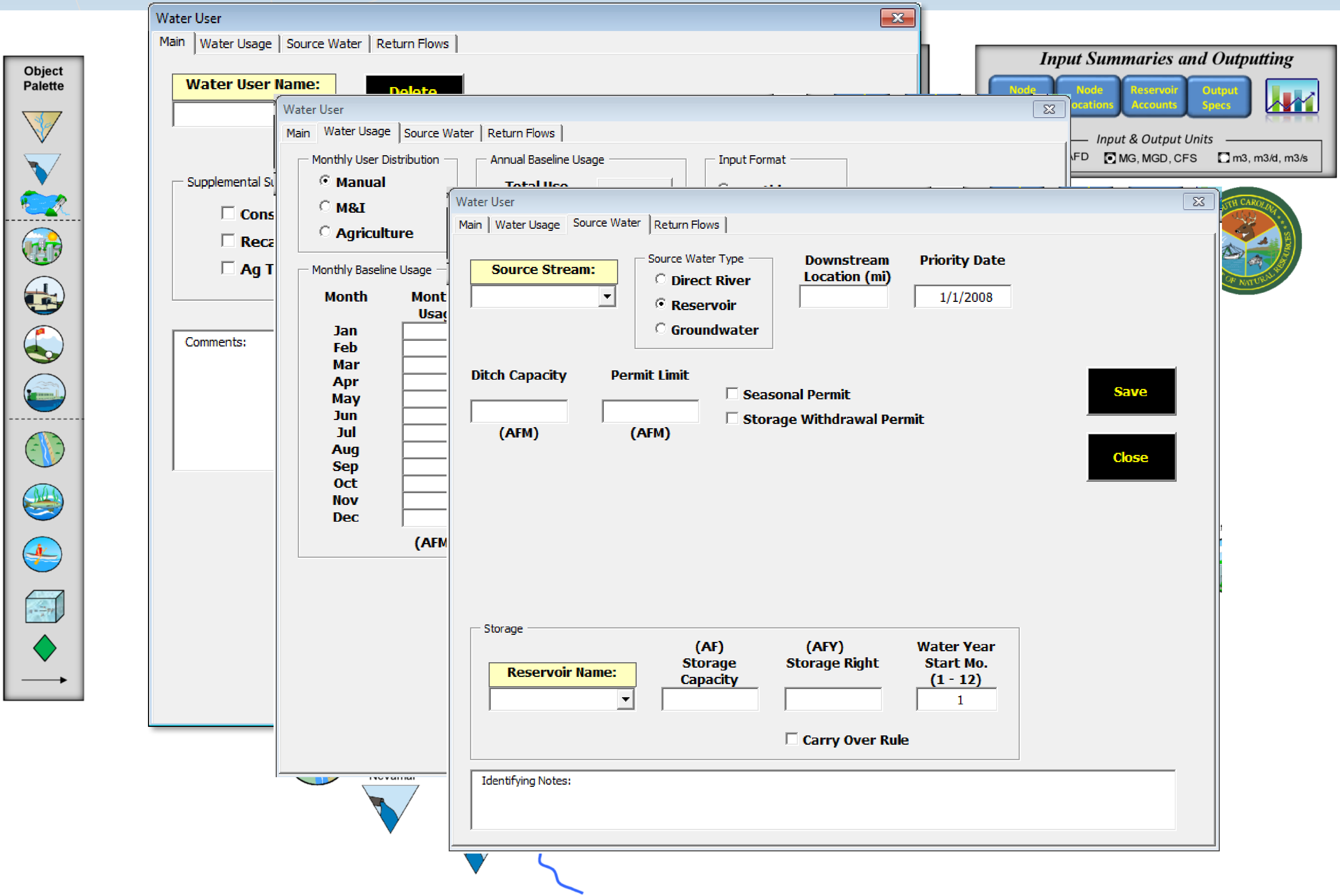
Salkehatchie River Basin

MODEL SETUP

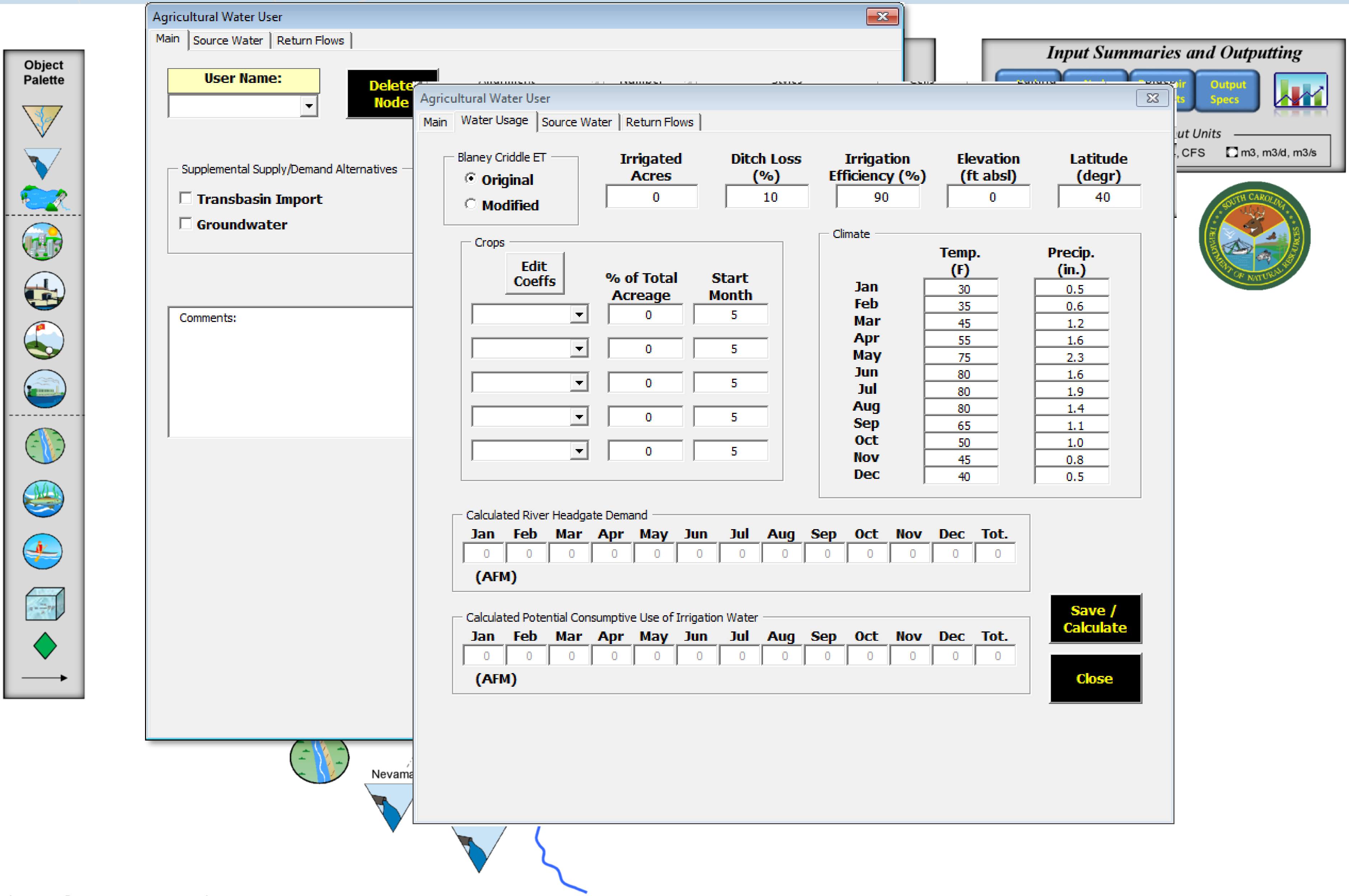
Tributary Input Form



Water User Input Form – Main



Agricultural Water User Input Forms



Salkehatchie River Basin

MODEL CALIBRATION/VALIDATION

Calibration Objectives

1. Extend hydrologic inputs (headwater UIFs) spatially to adequately represent entire basin hydrology by parameterizing reach hydrologic inputs

2. Refine initial parameter estimates, as appropriate
   - E.g. reservoir operating rules, %Consumptive Use assumptions, return flow locations

3. Gain confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use
   - **without being overly prescriptive**

Calibration/Validation General Approach

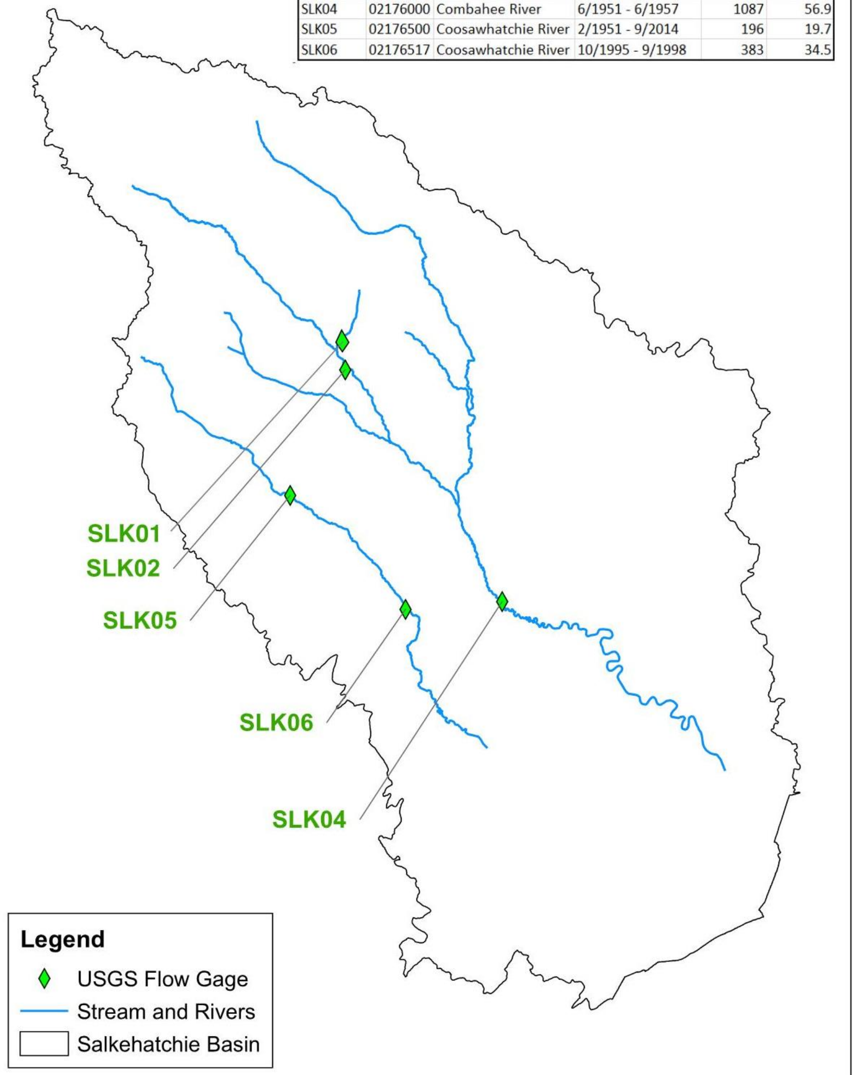
- 1983 – 2013 hindcast period; monthly timestep
  - Includes droughts in both early and late 2000’s
- Comparison to gaged (measured) flow data only
  - operations and impairments are implicit in that data
- Assess performance at (subject to gage data availability):
  - multiple mainstem locations
  - all tributary confluence locations
  - major reservoirs (where levels/storage are available)
- Multiple model performance metrics, including:
  - timeseries plots (monthly and daily variability)
  - annual and monthly means (water balance and seasonality)
  - percentile plots (extremes and frequency)

Potential Sources of Model Error and Uncertainty

- Gaged flow data (± 20%)
- Gaged reservoir levels (± ?%)
- Basin climate and hydrologic variability
- Reported withdrawal data
- Consumptive use percentages
- Return flow locations (outdoor use)
- Return flow lag times (if applicable, e.g. outdoor use)
- *Reservoir operations (operator decision making)*
- *Reach hydrology: gains, losses, local runoff and inflow*

Calibration/Validation Locations

Project Gage ID	USGS Number	Tributary Object	Periods of Record	Basin Area (sq. mi.)	River Mile
SLK02	02175500	Salkehatchie River	2/1951 - 9/2014	342	29.3
SLK04	02176000	Combahee River	6/1951 - 6/1957	1087	56.9
SLK05	02176500	Coosawhatchie River	2/1951 - 9/2014	196	19.7
SLK06	02176517	Coosawhatchie River	10/1995 - 9/1998	383	34.5



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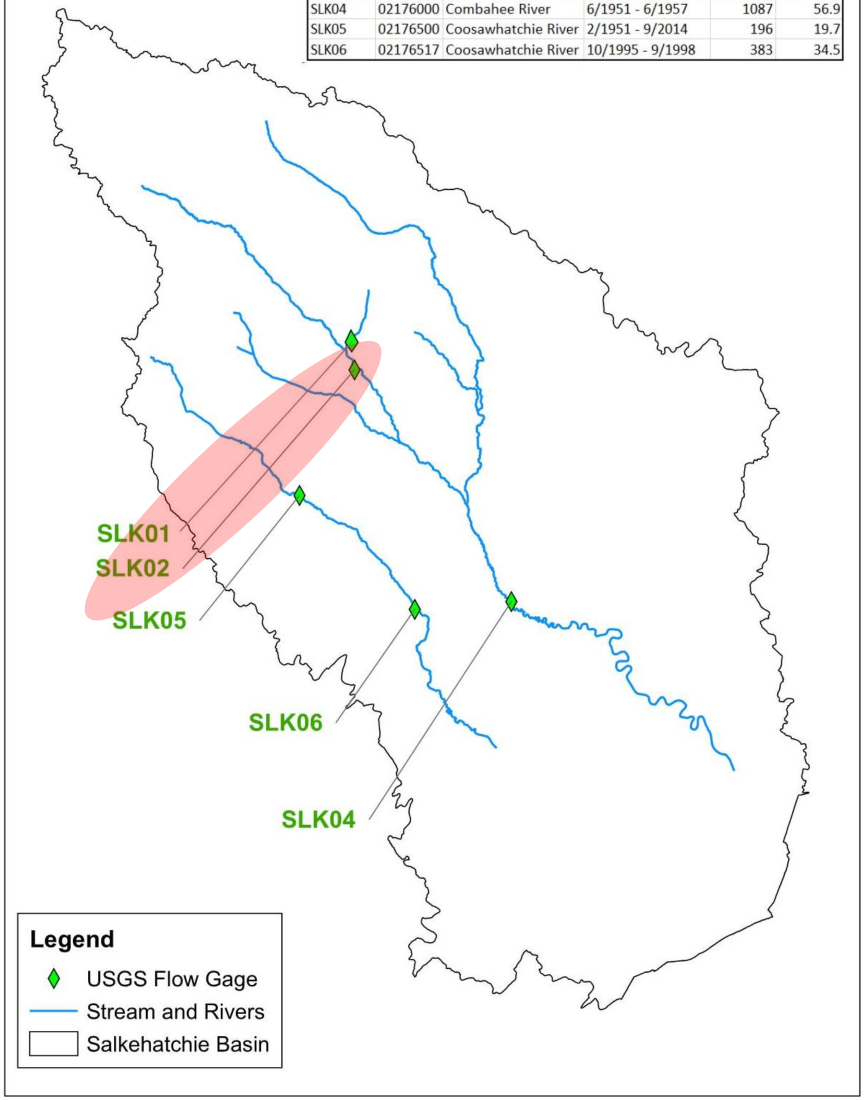
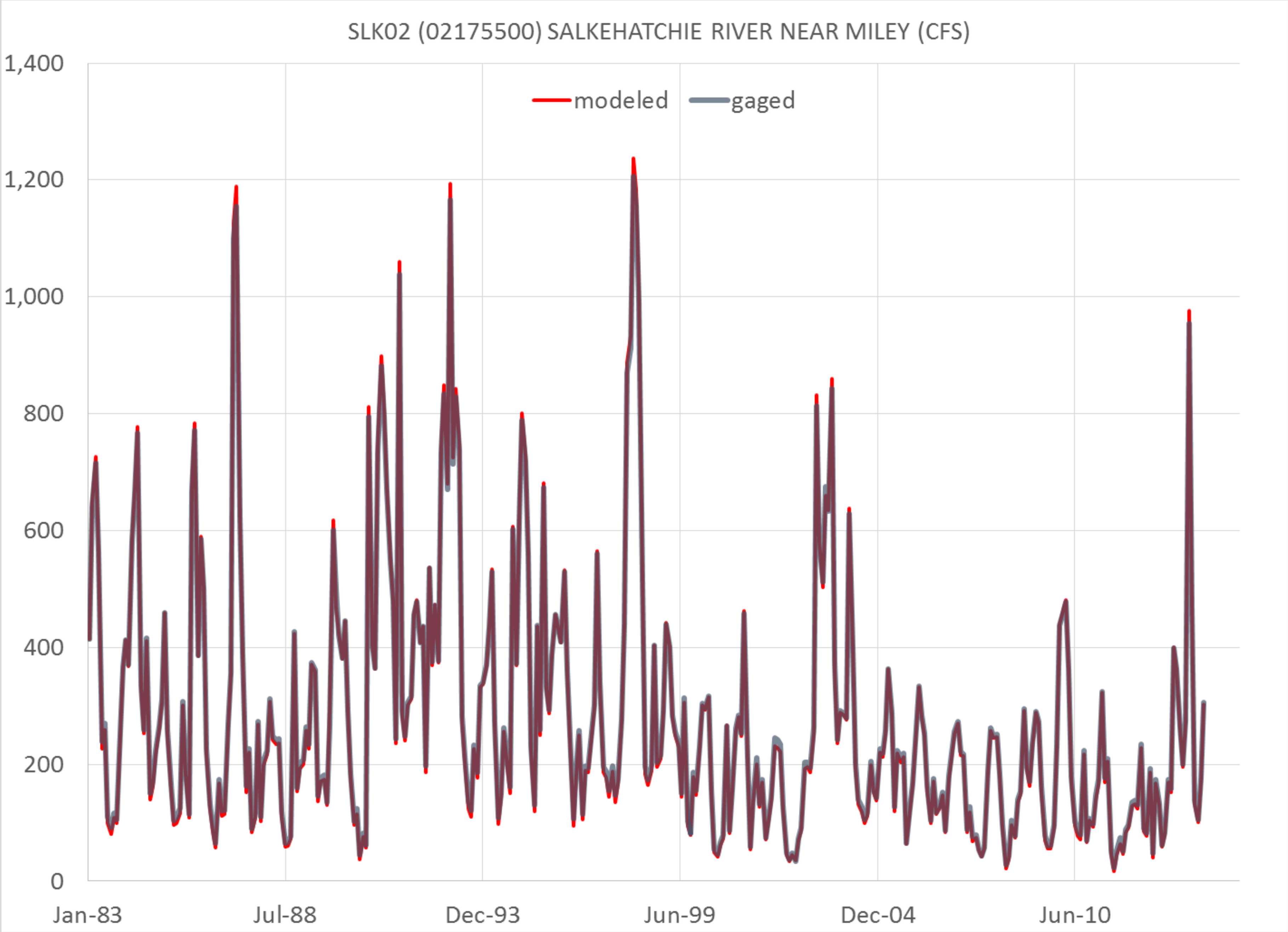
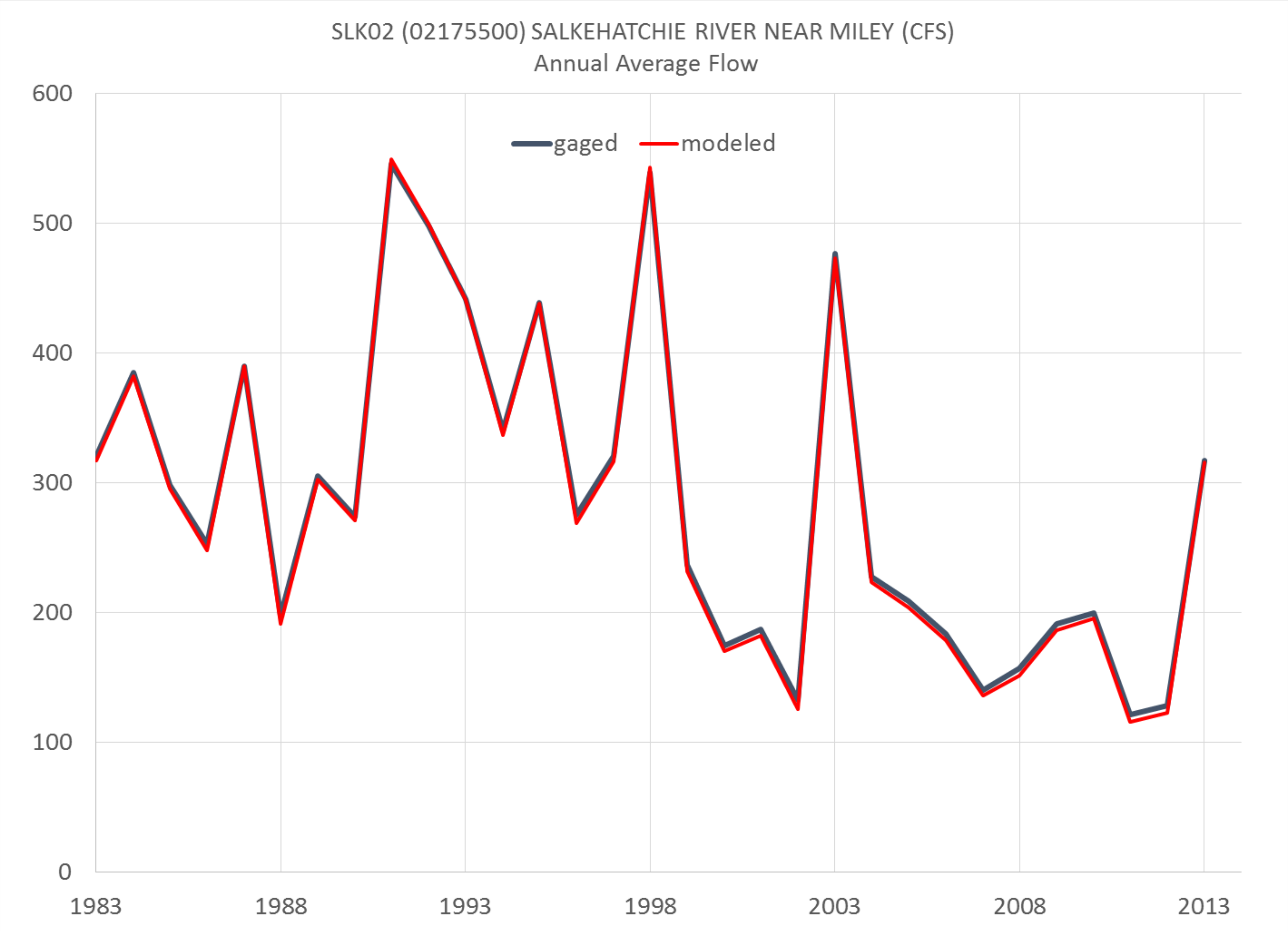


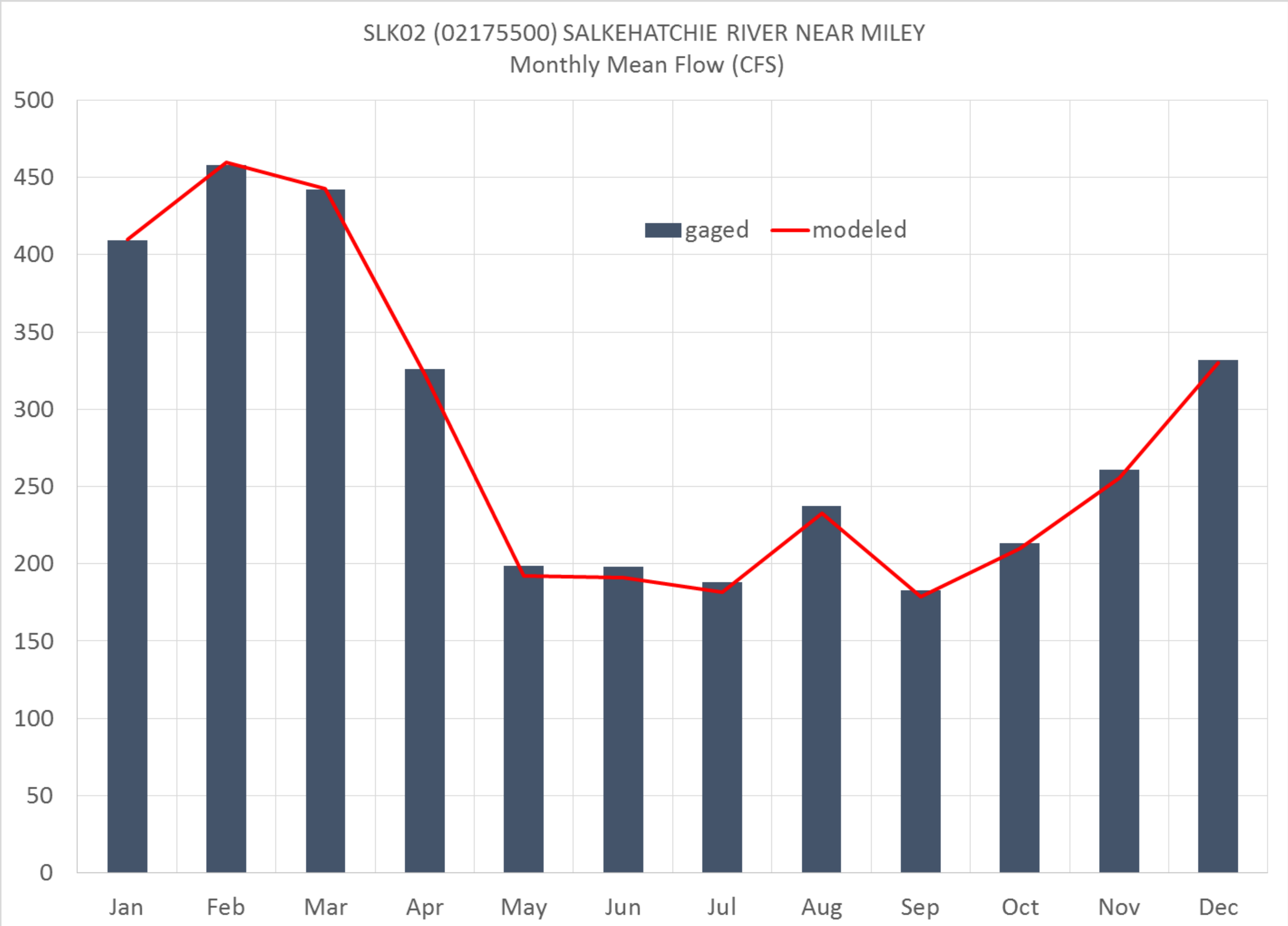
Monthly Flow Comparison



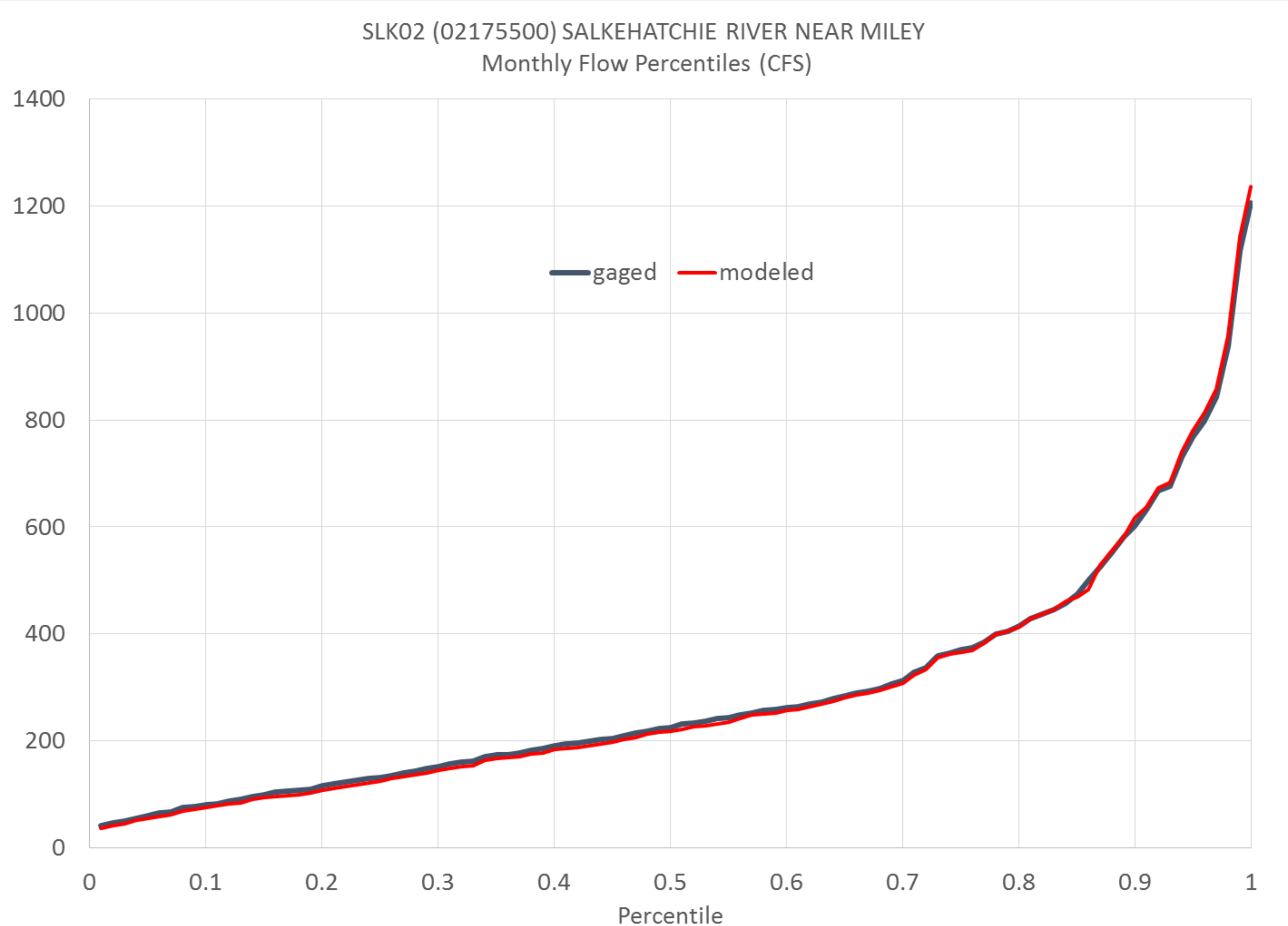
Annual Average Flow Comparison



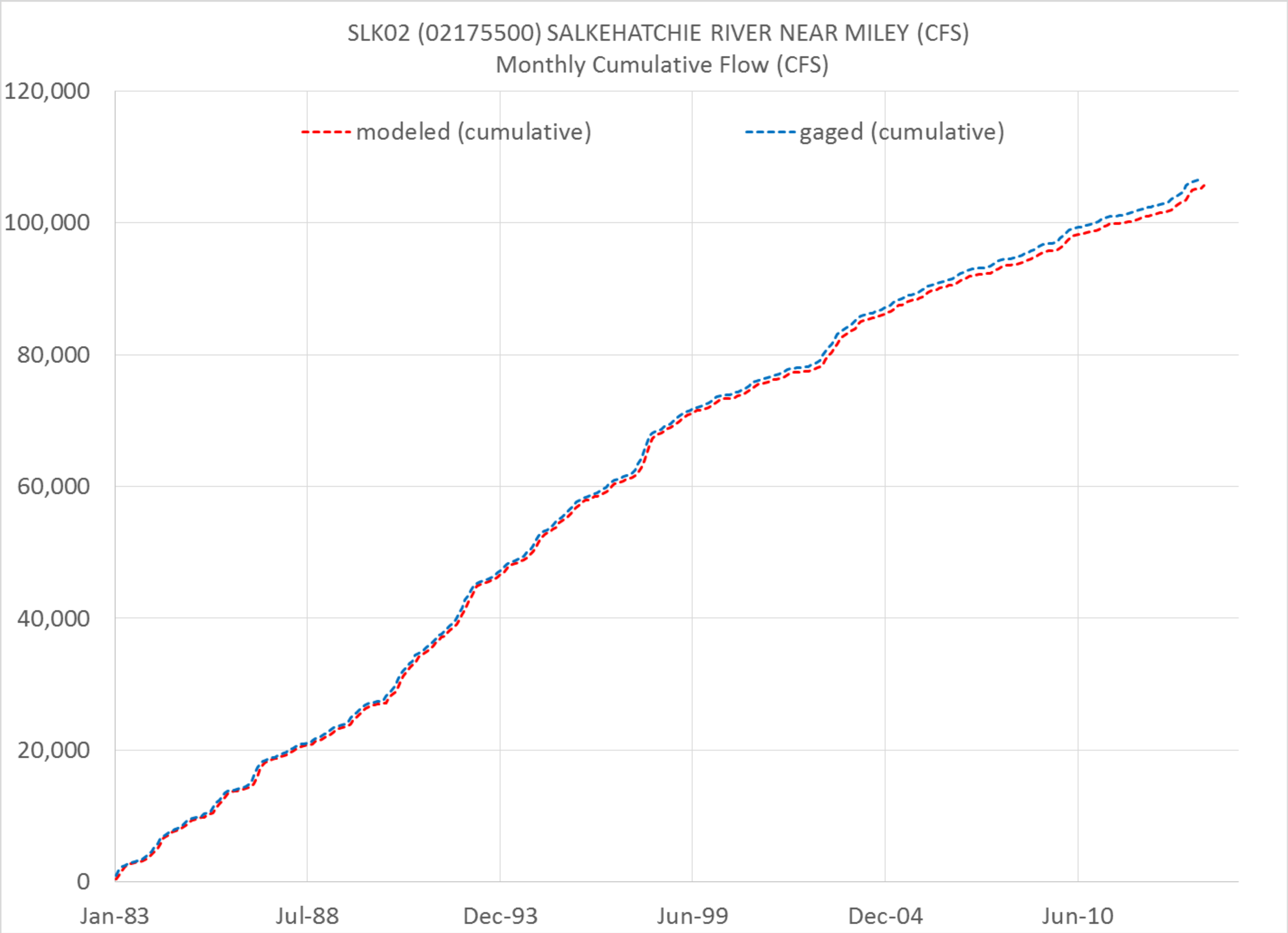
Monthly Mean Flow Comparison



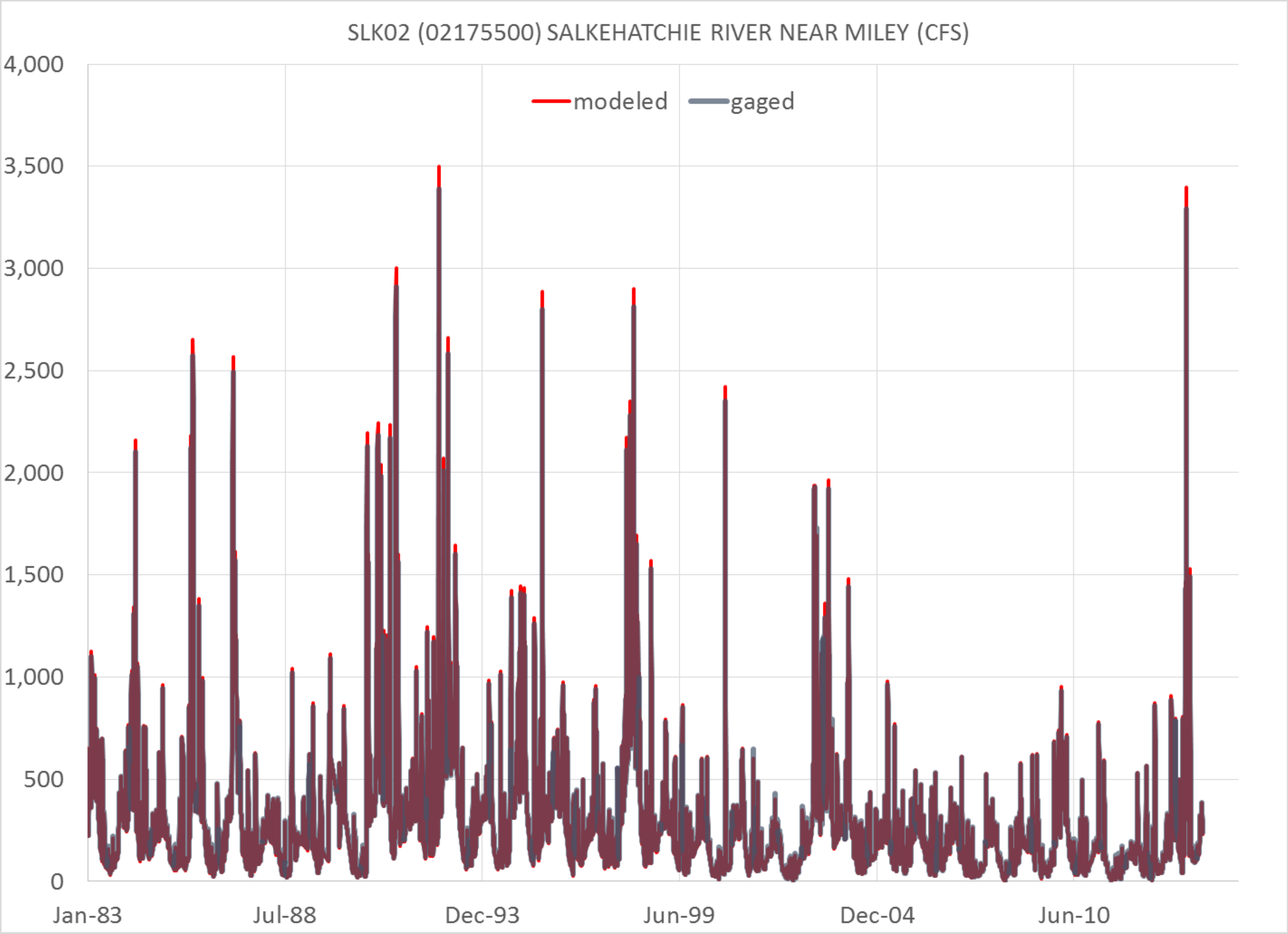
Monthly Flow Percentiles Comparison



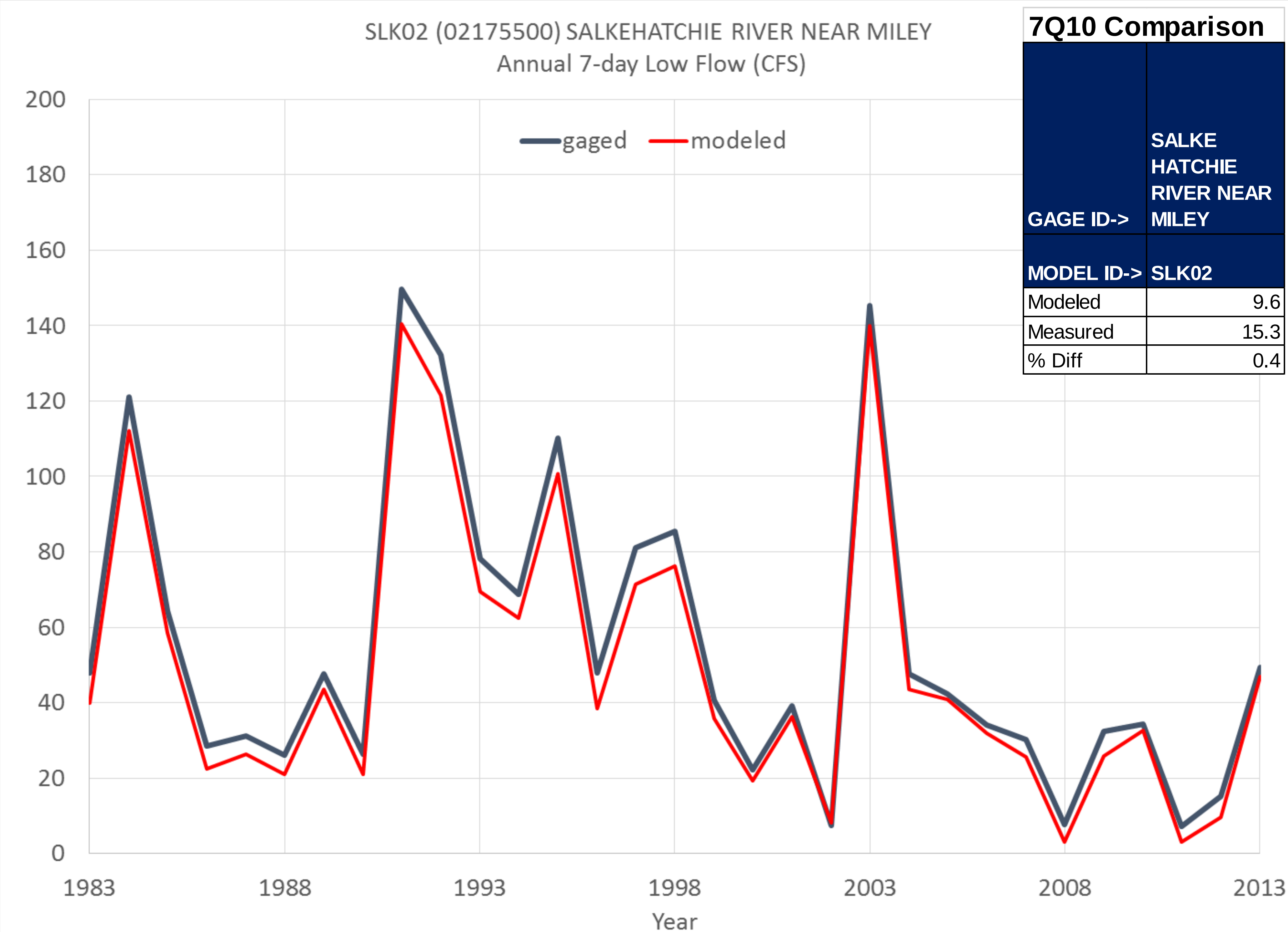
Cumulative Flow Comparison



Daily Flow Comparison



Annual 7 Day Low Flows



7Q10 Comparison

GAGE ID->	SALKE HATCHIE RIVER NEAR MILEY
MODEL ID->	SLK02
Modeled	9.6
Measured	15.3
% Diff	0.4

Calibration/Validation Locations

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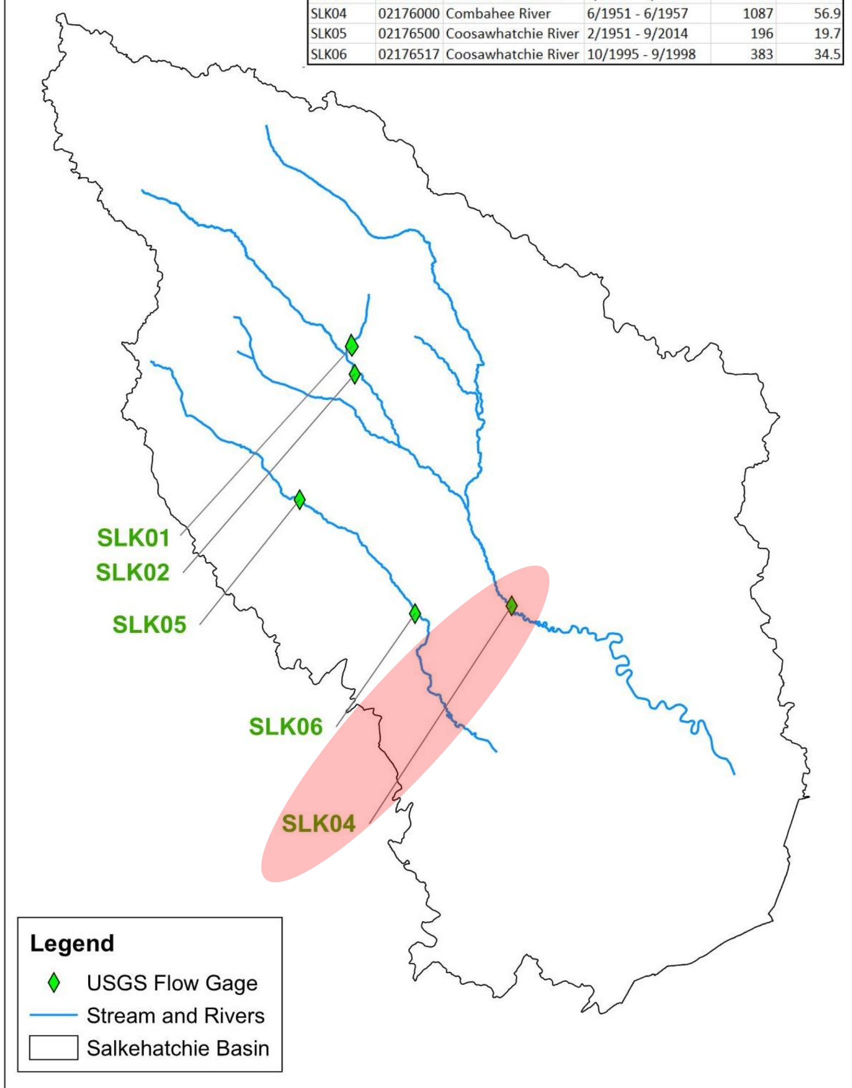
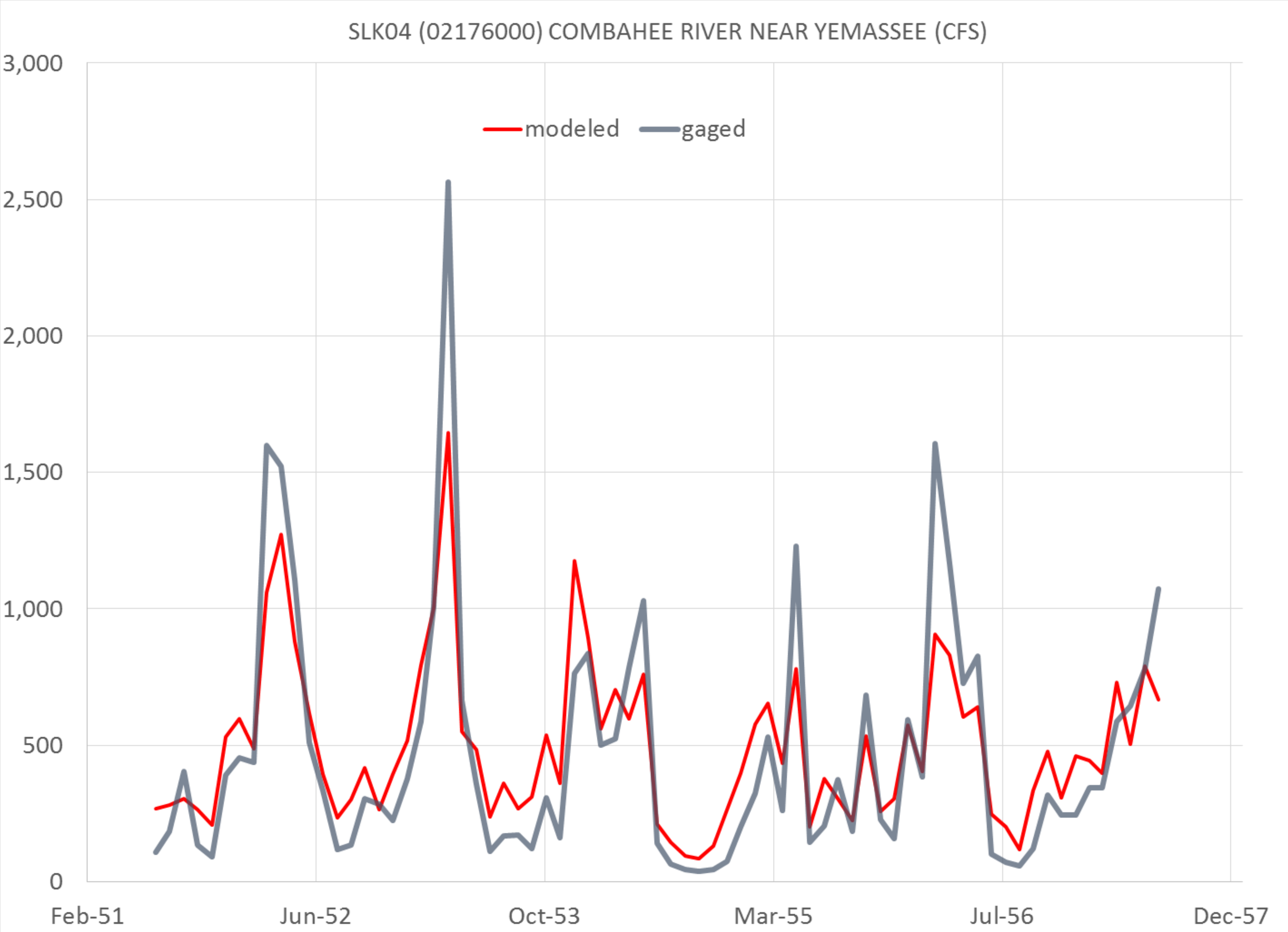


Monthly Flow Comparison



SWAM Calibration/Validation Summary

- For most sites, modeled mean flow values, averaged over the full period of record, are within 1% of measured mean flows

ID	Station	Modeled (cfs)	Measured (cfs)	% Difference	Years to Compare
SLK02	SALKEHATCHIE RIVER NEAR MILEY	278	287	-3.2%	31
SLK05	COOSAWHATCHIE RIVER NEAR HAMPTON	138	139	-0.5%	12
SLK01	SAVANNAH CREEK AT EHRHARDT	4	4	-0.1%	21
SLK06	COOSAWHATCHIE RIVER NR EARLY BRANCH	409	399	2.4%	31
SLK04	COMBAHEE RIVER NEAR YEMASSEE	493	471	4.5%	7

5% or less diff.

1% or less difference

5% or less diff.

Salkehatchie River Basin

BASELINE MODEL AND USES

Calibration vs. Baseline Model

- **Calibration Model**
  - Purpose: Confirm models ability to accurately simulate river basin flows and storage amounts
  - Uses recent withdrawal, discharge and flow records

- **Baseline Model**
  - Purpose: Evaluate water availability under future conditions
  - Uses entire record of flow and most current withdrawals and discharges

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

Demonstrations and Q&A

- Station 1 (John)

  Evaluate an increase in Ag User demands

- Station 2 (Nina)

  Evaluate a proposed new municipal water supply withdrawal

Salkehatchie River Basin

THANK YOU