

Presentation Outline

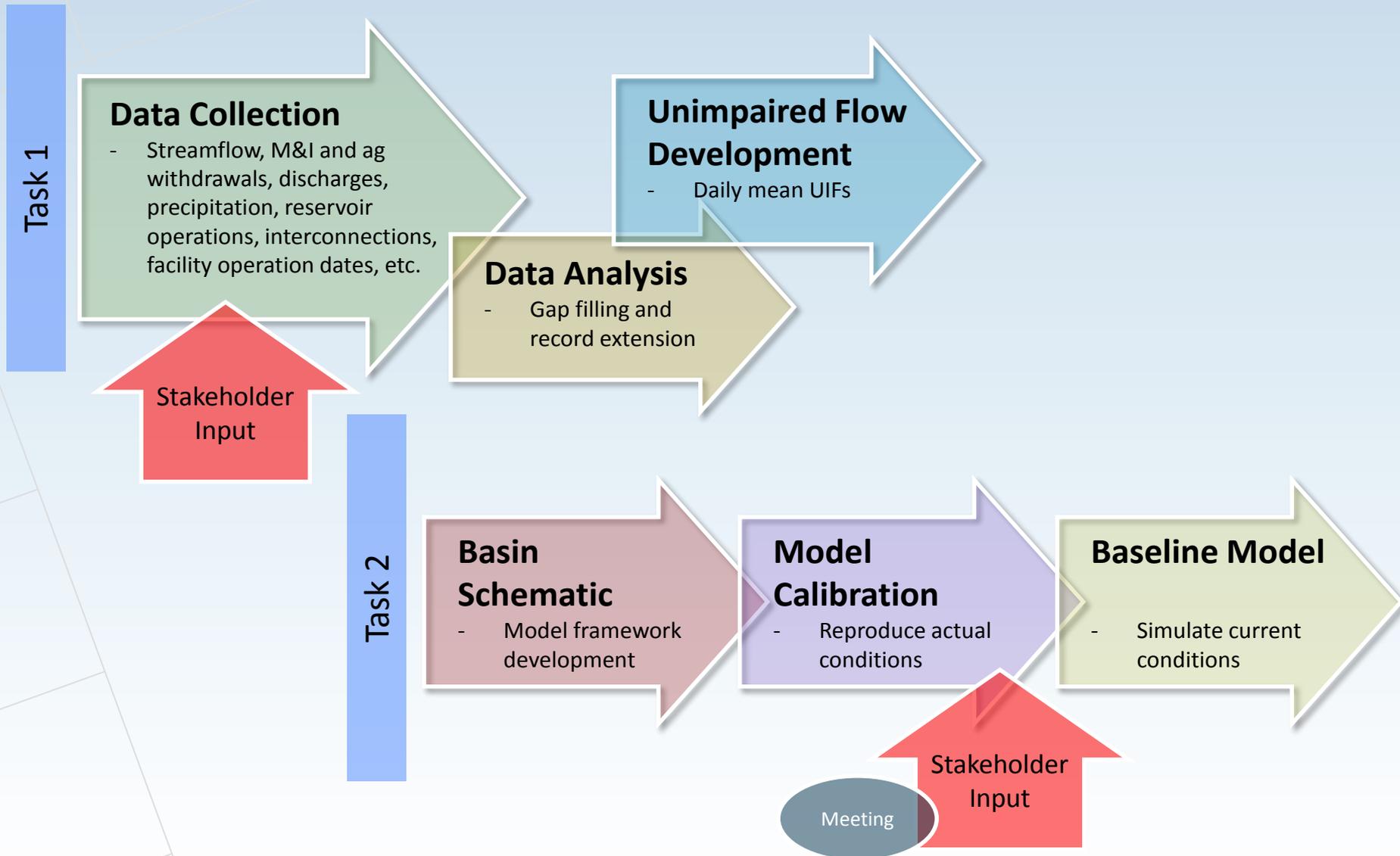
- Project background and status
- Introduction to SWAM
- Data collection and unimpaired flows
- Model framework and development
- Model calibration/verification
 - Calibration/verification philosophy and approach
 - Calibration results and discussion
- Baseline model and uses

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



Modeling Report and Other Documents

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

The screenshot shows the website for the South Carolina Department of Natural Resources (DNR). The header includes the DNR logo and the slogan "Life's Better Outdoors". A navigation menu lists various topics: Boating, Education, Fishing, Hunting, Land, Maps, Regulations, Water, and Wildlife. The main content area is titled "Surface Water Modeling and Assessments" and contains the following text:

Effective water planning and management requires an accurate assessment of the location and quantity of the water resources of the State, and one of the most useful tools for evaluating management strategies is a computer model that simulates the surface water system throughout an entire watershed. To that end, SCDNR and SCDHEC have begun the process of developing surface-water quantity models for each of the [eight major watersheds](#), or basins, in South Carolina.

A more detailed discussion of the proposed surface water modeling can be found in the document [Basinwide Surface Water Modeling in South Carolina PDF](#), and an overview of each of the eight basins for which the models will be developed can be found in the document [Major Basins of South Carolina PDF](#).

In July 2014, CDM Smith, Inc. was awarded a contract to develop the models for the state.

Project Documents

For any questions regarding these reports and presentations, please contact Joe Gellici by phone (803-734-6428, [@](#)) or [email](#).

For information about stakeholder meetings, please visit [scwatermodels.com](#).

(Documents below are in PDF format.)

[Show](#) / [Hide](#) All Documents

- [Monthly Progress Reports](#)
- [Legislative Quarterly Reports](#)
- [Technical Reports](#)
- [Technical Memorandums](#)
- [Meeting Notes](#)
- [Presentations](#)
- [Videos](#)
- [River Basins](#)

The footer includes social media icons for Facebook, RSS Feed, Twitter, and YouTube, along with contact information for the South Carolina Department of Natural Resources.

The image shows the cover of a report titled "SOUTH CAROLINA SURFACE WATER QUANTITY MODELS PEE DEE RIVER BASIN MODEL". The cover features a large, colorful map of the Pee Dee River Basin, showing the river network and various sub-basins. The map is overlaid with a grid and various symbols representing different data points or model outputs. The title is prominently displayed at the top in blue and green text. Below the title, the logos for the South Carolina Department of Natural Resources (DNR) and the South Carolina Department of Health & Environmental Control (DHEC) are visible. The text "SUBMITTED TO:" is followed by the names of the two departments. At the bottom, the word "DRAFT" is written in large, bold, grey letters. The date "APRIL 2016" and the name of the consulting firm, "CDM Smith", are also present.

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 image displays two components related to the Simplified Water Allocation Model (SWAM). The top component is a screenshot of the software's main interface, which includes a 'Project Palette' on the left, a central simulation diagram with various nodes and flow paths, and a top control panel with fields for 'Start Date' and 'End Date', a 'Simulation Type' dropdown, and an 'Input Summary and Outputting' section. The bottom component is the cover of the 'Simplified Water Allocation Model (SWAM) VERSION 3.0 USER'S MANUAL'. The cover features a blue background with a water droplet pattern and a smaller version of the software interface screenshot. The CDM Smith logo is visible in the bottom right corner of the manual cover.

Contact:
Tim Cox, Ph.D., P.E.
CDM Smith
555 17th Street, Suite 1100
Denver, Colorado 80202
email: cox@cdmsmith.com

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)

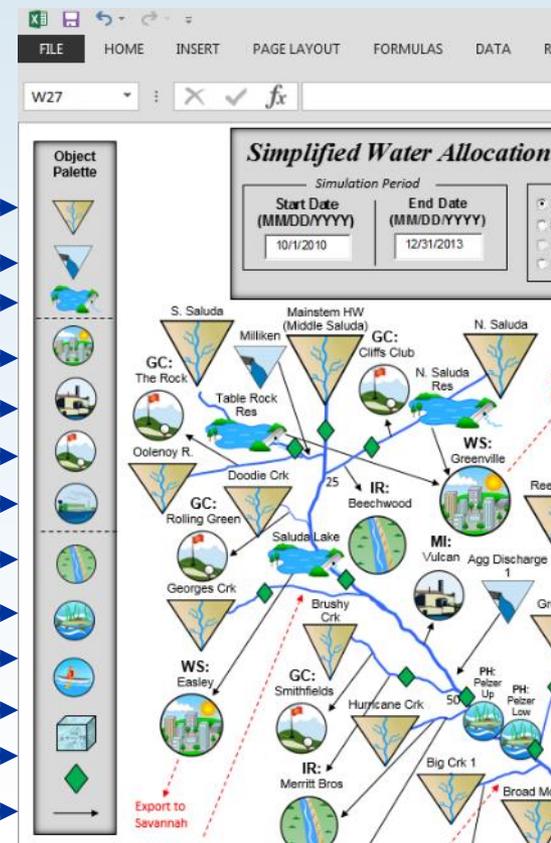
- Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities
- Resides within Microsoft Excel
- Point and click setup and output access

Input Forms

**Water
User
Objects**

Objects

- Tributaries →
- Discharges →
- Reservoirs →
- 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

A screenshot of the 'Reservoir' configuration window in the SWAM software. The window has a title bar 'Reservoir' and a 'Main' tab. It contains several sections for configuring the reservoir's properties and behavior.

Reservoir Name: [Dropdown menu] **Delete Node** **Storage Capacity (AF)** [Input field] **Initial Storage (AF)** [Input field] Offline Online

Evaporation
 Inches/day % Volume Input Timeseries

Monthly Rates

| Month | Evap. Rates (in./day) |
|-------|-----------------------|
| Jan | |
| Feb | |
| Mar | |
| Apr | |
| May | |
| Jun | |
| Jul | |
| Aug | |
| Sep | |

Area-Capacity Table
 Simple Detailed

| Volume (AF) | Area (ac) |
|-------------|-----------|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Reservoir Releases
Receiving Stream: [Dropdown menu] Simple Advanced
Release Location (mi) [Input field: 0]

User Defined Releases

| Month | Min. Release (AFM) | (CFS) |
|-------|--------------------|-------|
| Jan | | |
| Feb | | |
| Mar | | |
| Apr | | |
| May | | |
| Jun | | |
| Jul | | |
| Aug | | |
| Sep | | |

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

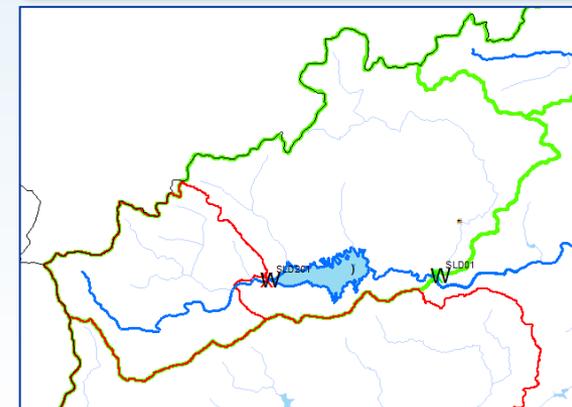
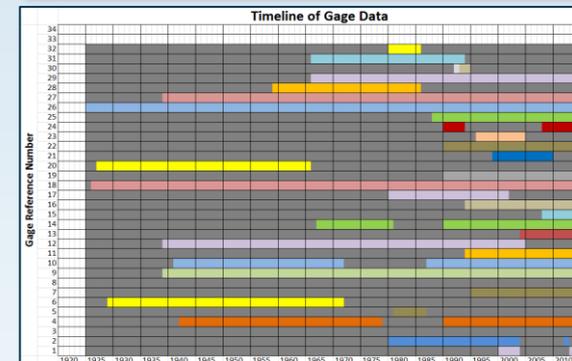
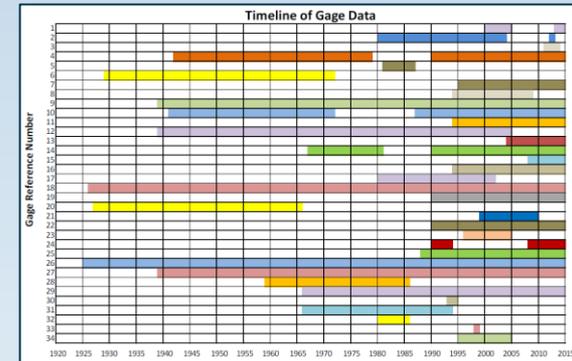
UNIMPAIRED FLOWS (UIF)

UIF Definition and Uses

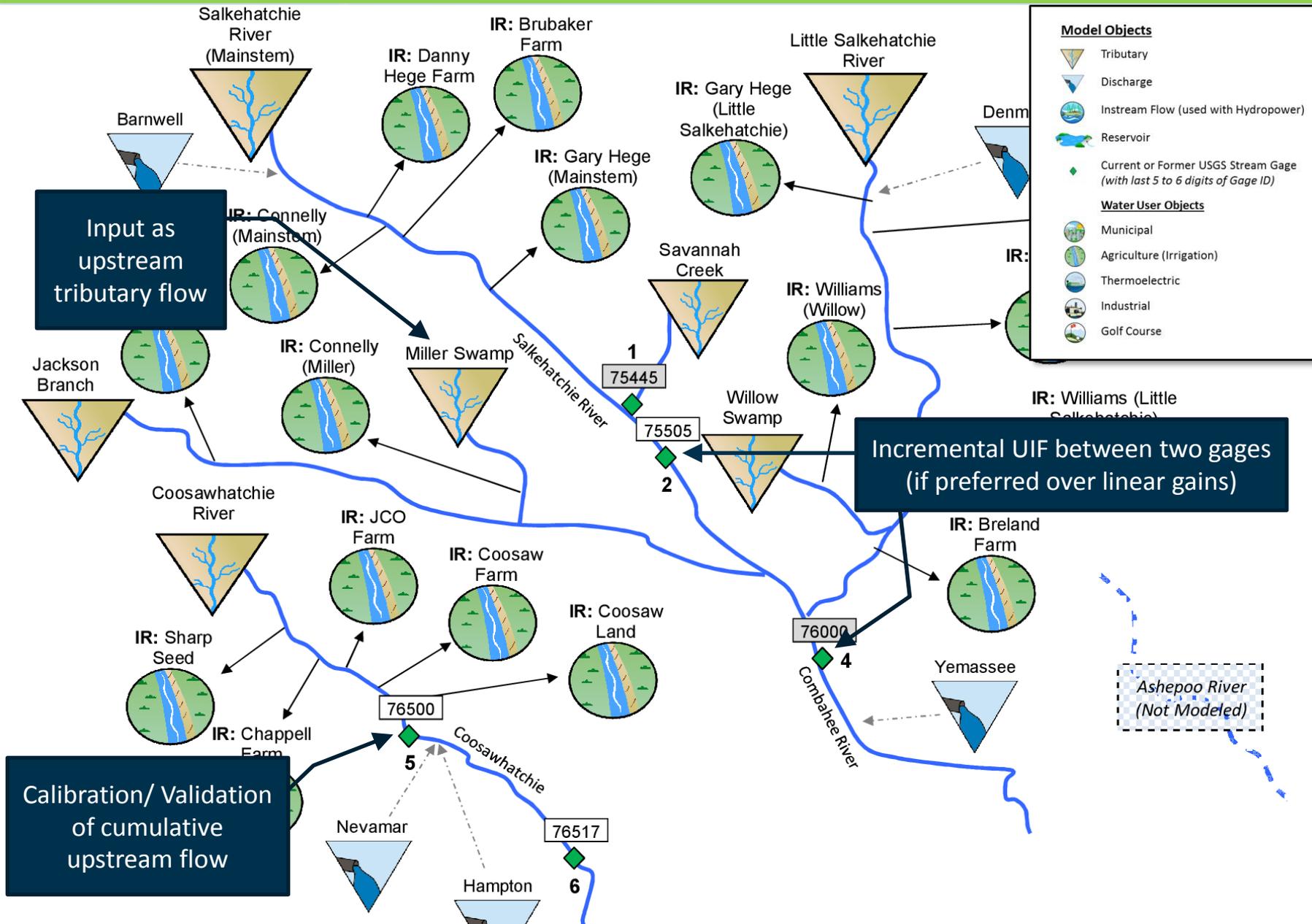
- **Definition:** Estimate of natural historic streamflow in the absence of human intervention in the river channel:
 - Storage
 - Withdrawals
 - Discharges and Return Flow
- ***Unimpaired Flow*** =
Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Discharge to Reservoirs – Return Flow + 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



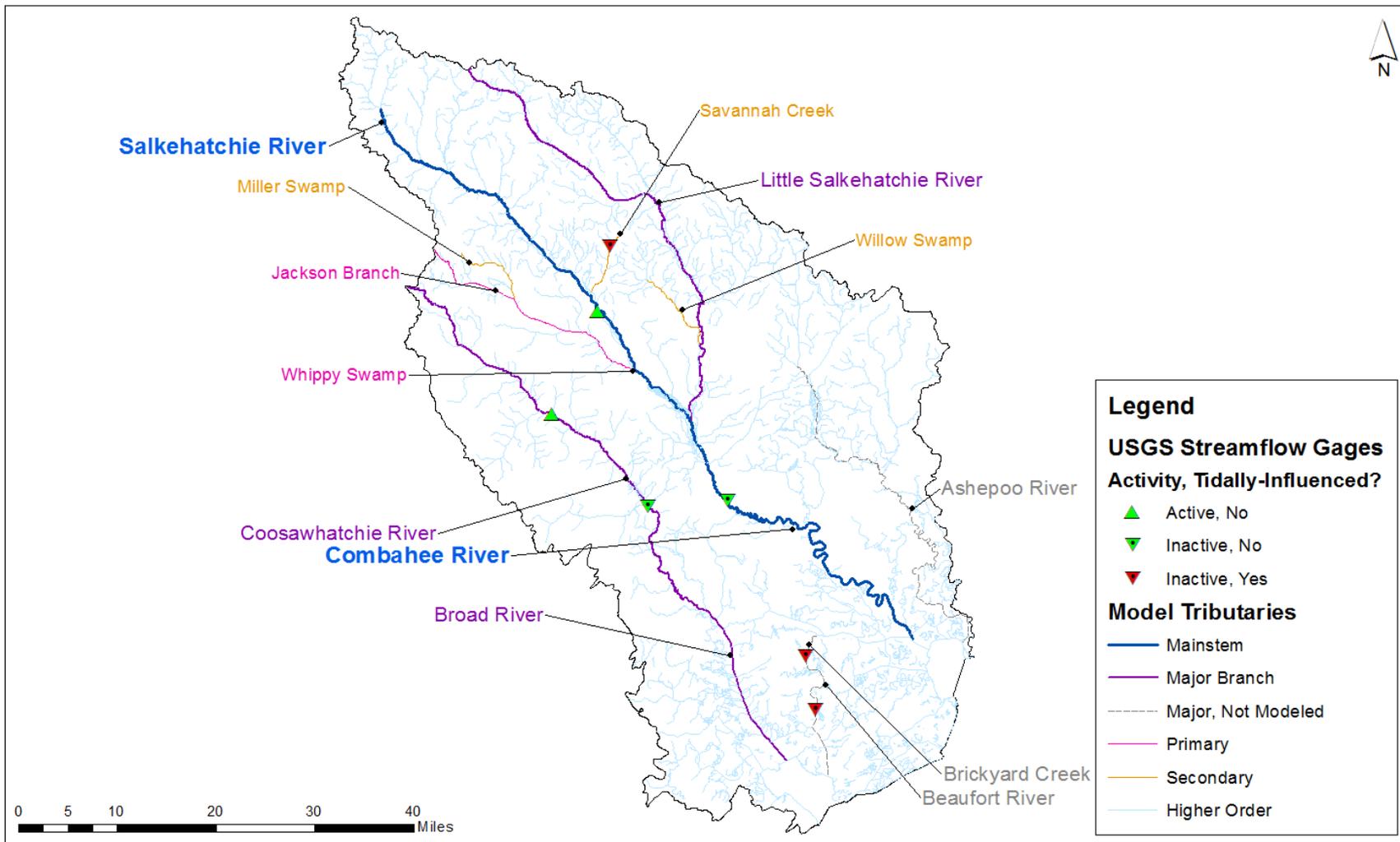
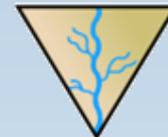
How UIFs are Used in SWAM



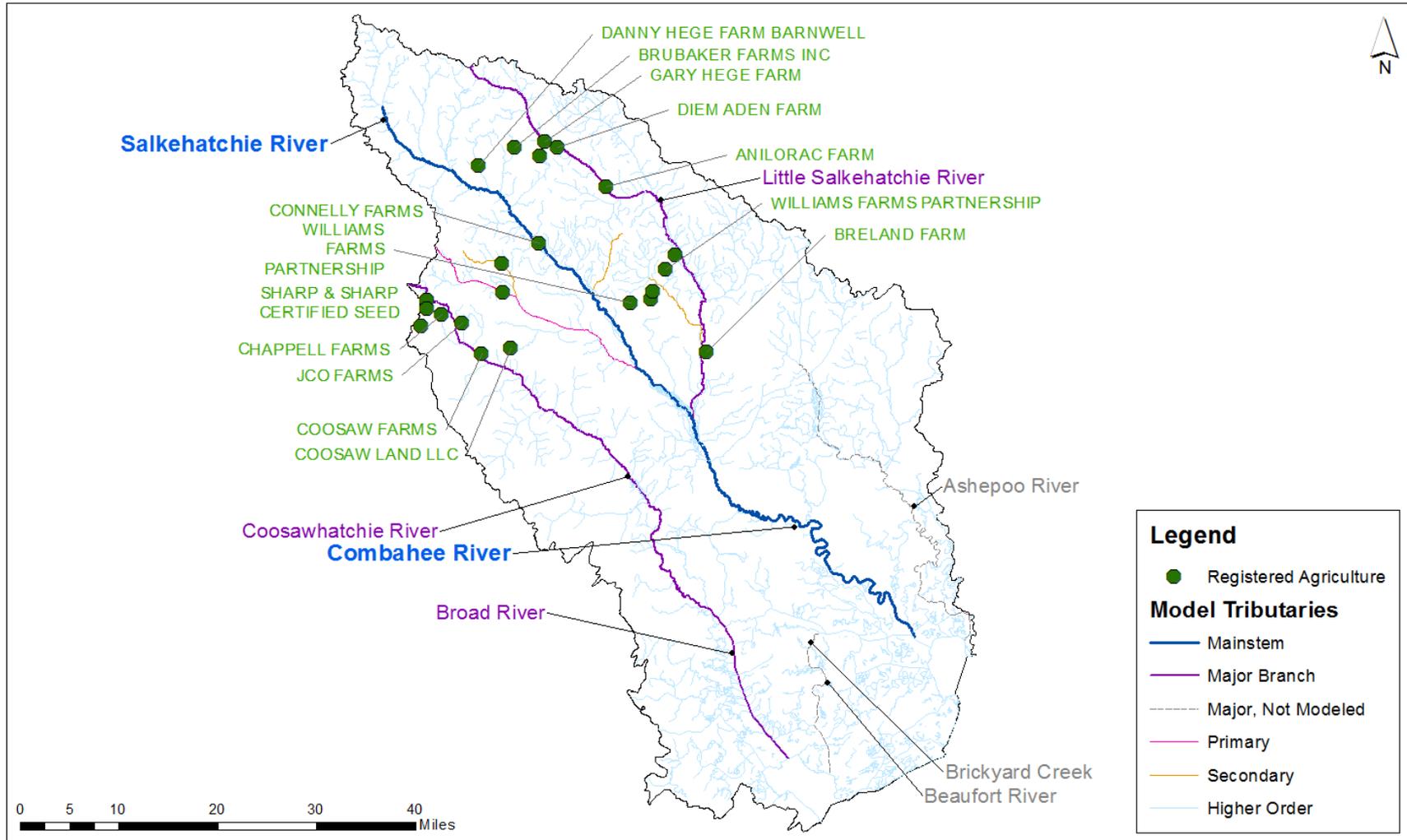
Salkehatchie River Basin

OVERVIEW OF MODEL FRAMEWORK

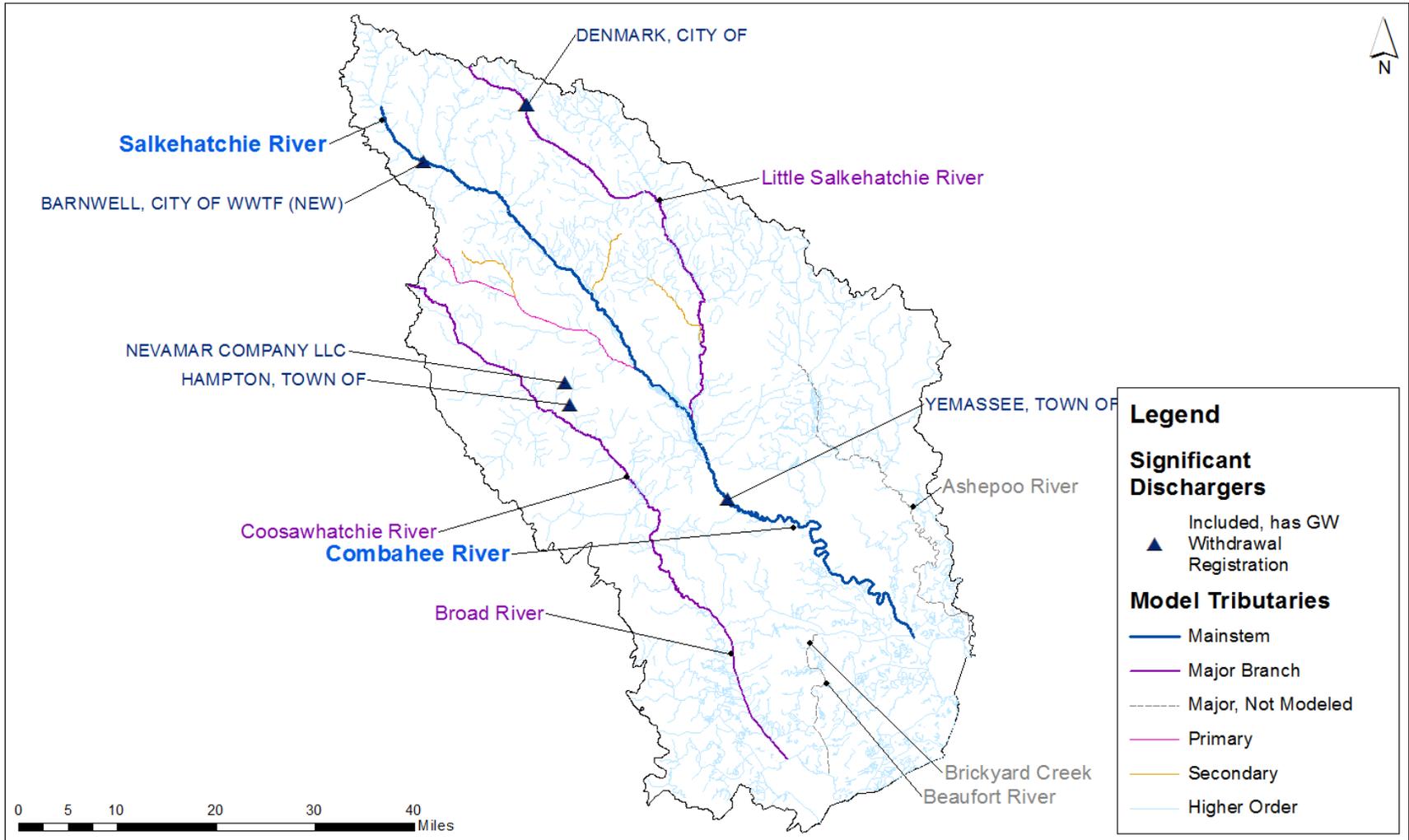
Salkehatchie Basin – Model Tributaries



Agriculture Surface Water Withdrawals



Discharges to Surface Water



Salkehatchie Basin – SWAM Framework

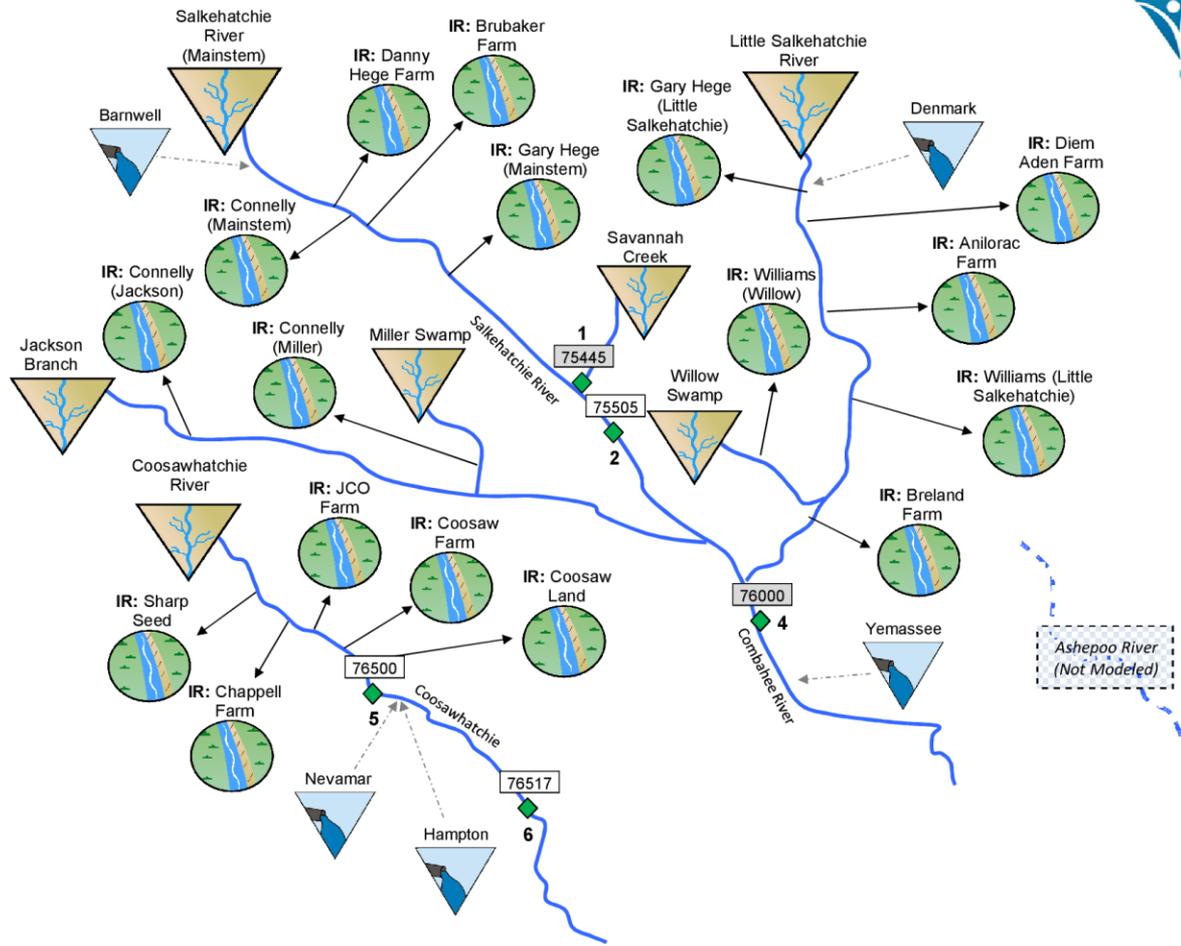


Simplified Water Allocation Model (SWAM)

| Simulation Period | | Simulation Type | |
|-----------------------------------|---------------------------------|--|---|
| Start Date (MM/DD/YYYY) | End Date (MM/DD/YYYY) | <input checked="" type="checkbox"/> Monthly Planning | <input type="checkbox"/> Prior Appropriations |
| 01/01/1983 | 12/31/2013 | <input type="checkbox"/> Daily Planning | <input checked="" type="checkbox"/> Riparian Water Rights |
| | | <input type="checkbox"/> Short Term Forecasting | |
| | | <input type="checkbox"/> Firm Yield Calculator | |

Input Summaries and Outputting

| | | | | |
|---------------------------------------|--|---|---------------------|--|
| Node Priorities | Node Locations | Reservoir Accounts | Output Specs | |
| Input & Output Units | | | | |
| <input type="checkbox"/> AF, AFM, AFD | <input checked="" type="checkbox"/> MG, MGD, CFS | <input type="checkbox"/> m3, m3/d, m3/s | | |



Salkehatchie River Basin

MODEL SETUP

Tributary Input Form



Simplified Water Allocation Model (SWAM)

Simulation Period Start Date (MM/DD/YYYY): 01/01/1983

Tributary

Tributary Name: [Dropdown] **Delete Tributary** **Headwater Flows**

Confluence Stream: [Dropdown] **Confluence Location (mi):** 0

Spatial Flow Changes

| Subbasin Flow Factor (unitless) | Reach Length (mi) |
|---------------------------------|-------------------|
| 1 | 10 |

Comments: [Text Area] **Save** **Close**

Map labels: Salkehatchie River (Mainstem), Barnwell, IR: Connelly (Mainstem), IR: Connelly (Jackson), Jackson Branch, Coosawhatchie River, IR: Sharp Seed, IR: Chappell Farm, Nevamar, Hampton, Coosawhatchie, 76500, 76517, 5, 6, [Not Modeled]

Input Summaries and Outputting

Node Priorities **Node Locations** **Reservoir Accounts** **Output Specs**

Input & Output Units

AF, AFM, AFD MG, MGD, CFS m3, m3/d, m3/s

Agricultural Water User Input Forms

Agricultural Water User [X]

Main | Source Water | Return Flows

User Name: [Dropdown]

Delete Node

Supplemental Supply/Demand Alternatives

Transbasin Import

Groundwater

Comments:

Agricultural Water User [X]

Main | Water Usage | Source Water | Return Flows

Blaney Criddle ET

Original

Modified

| | | | | |
|------------------------|-----------------------|----------------------------------|----------------------------|------------------------|
| Irrigated Acres | Ditch Loss (%) | Irrigation Efficiency (%) | Elevation (ft absl) | Latitude (degr) |
| 0 | 10 | 90 | 0 | 40 |

Crops

| Edit Coeffs | % of Total Acreage | Start Month |
|-------------|--------------------|-------------|
| [Dropdown] | 0 | 5 |

Climate

| | Temp. (F) | Precip. (in.) |
|-----|-----------|---------------|
| Jan | 30 | 0.5 |
| Feb | 35 | 0.6 |
| Mar | 45 | 1.2 |
| Apr | 55 | 1.6 |
| May | 75 | 2.3 |
| Jun | 80 | 1.6 |
| Jul | 80 | 1.9 |
| Aug | 80 | 1.4 |
| Sep | 65 | 1.1 |
| Oct | 50 | 1.0 |
| Nov | 45 | 0.8 |
| Dec | 40 | 0.5 |

Calculated River Headgate Demand

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Tot. |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(AFM)

Calculated Potential Consumptive Use of Irrigation Water

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Tot. |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(AFM)

Save / Calculate

Close

Input Summaries and Outputting

Output Specs

Output Units: [Dropdown] m3, m3/d, m3/s



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**

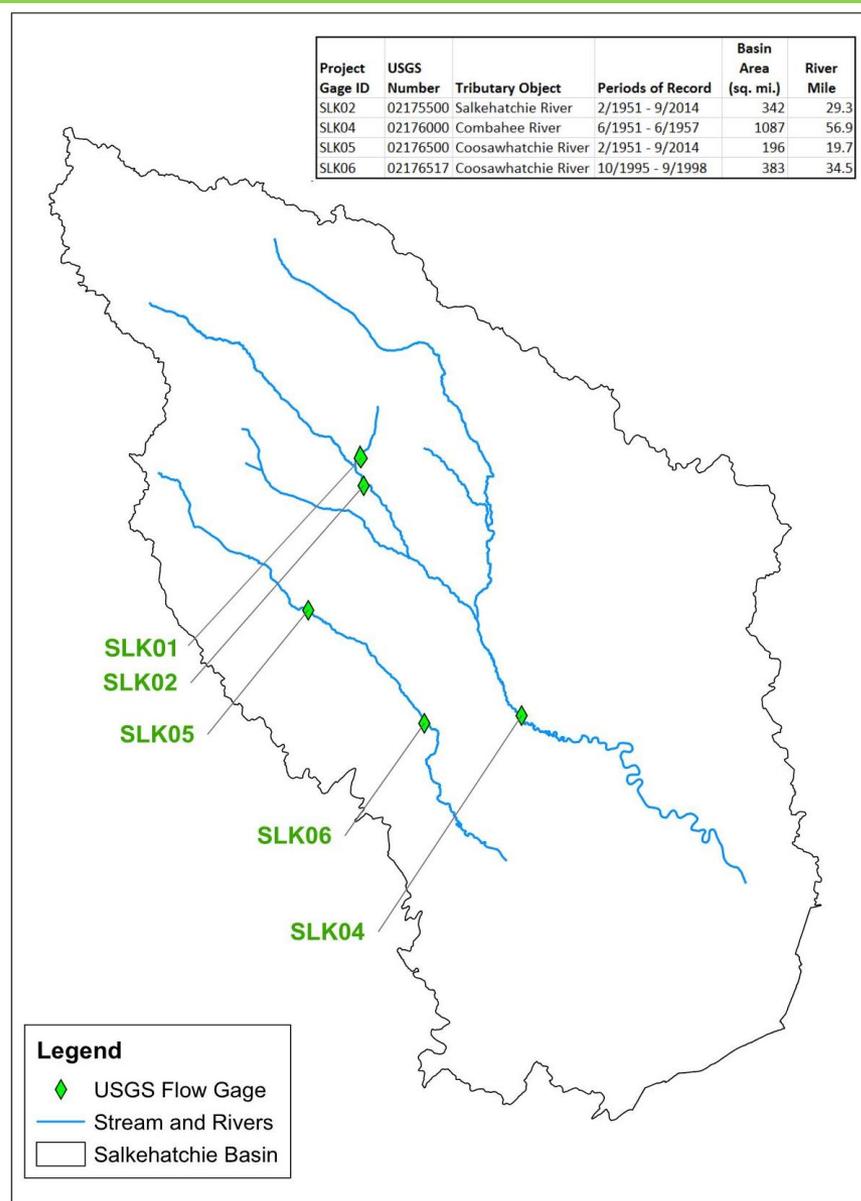
Calibration/Validation General Approach

- 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)

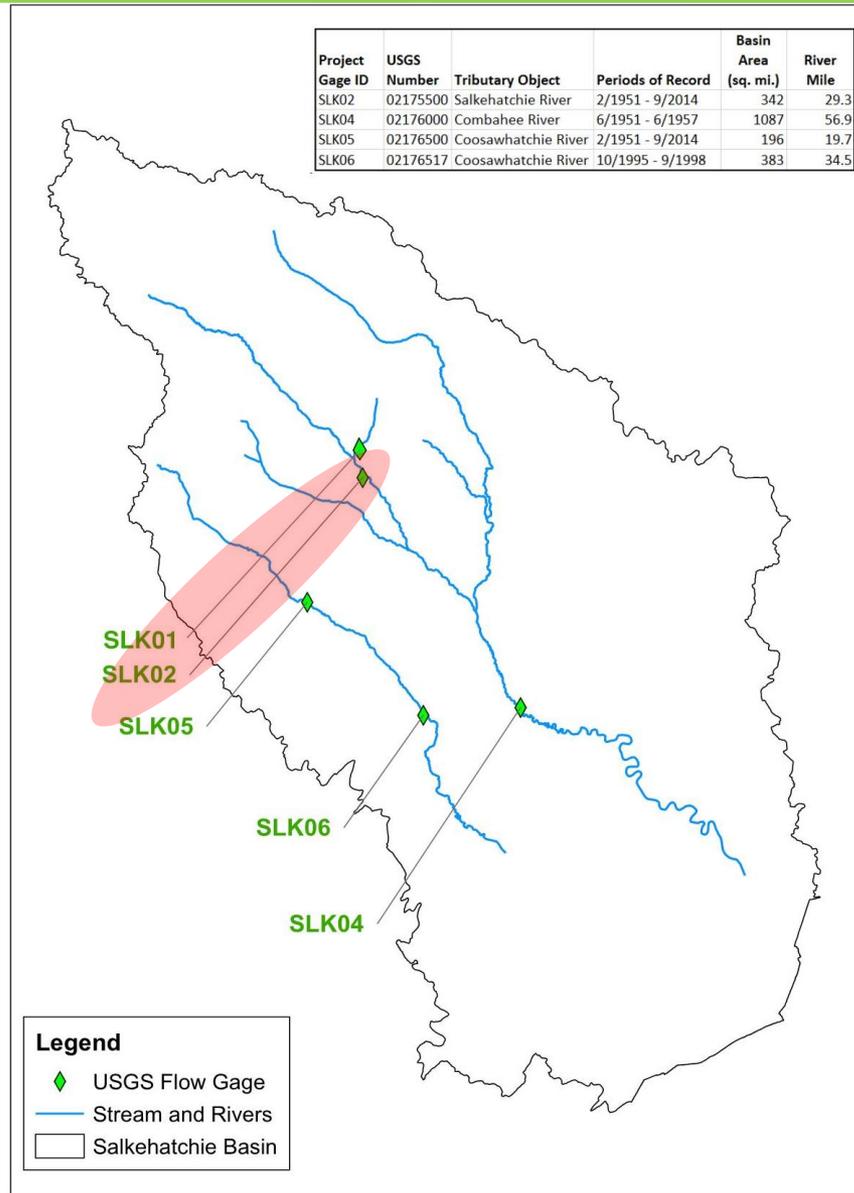
Potential Sources of Model Error and Uncertainty

- Gaged flow data ($\pm 20\%$)
- Gaged reservoir levels ($\pm ?\%$)
- 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

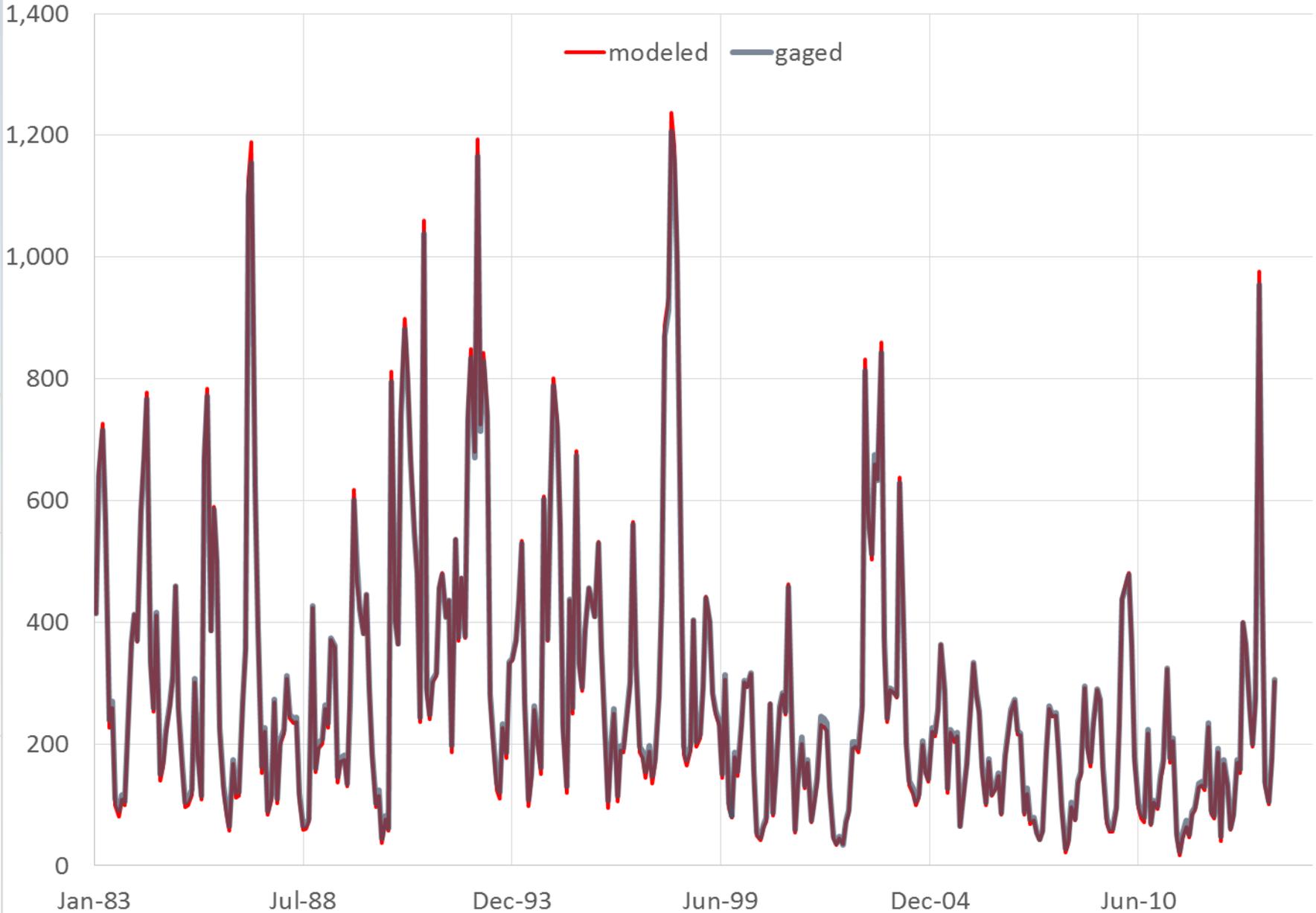


Calibration/Validation Locations



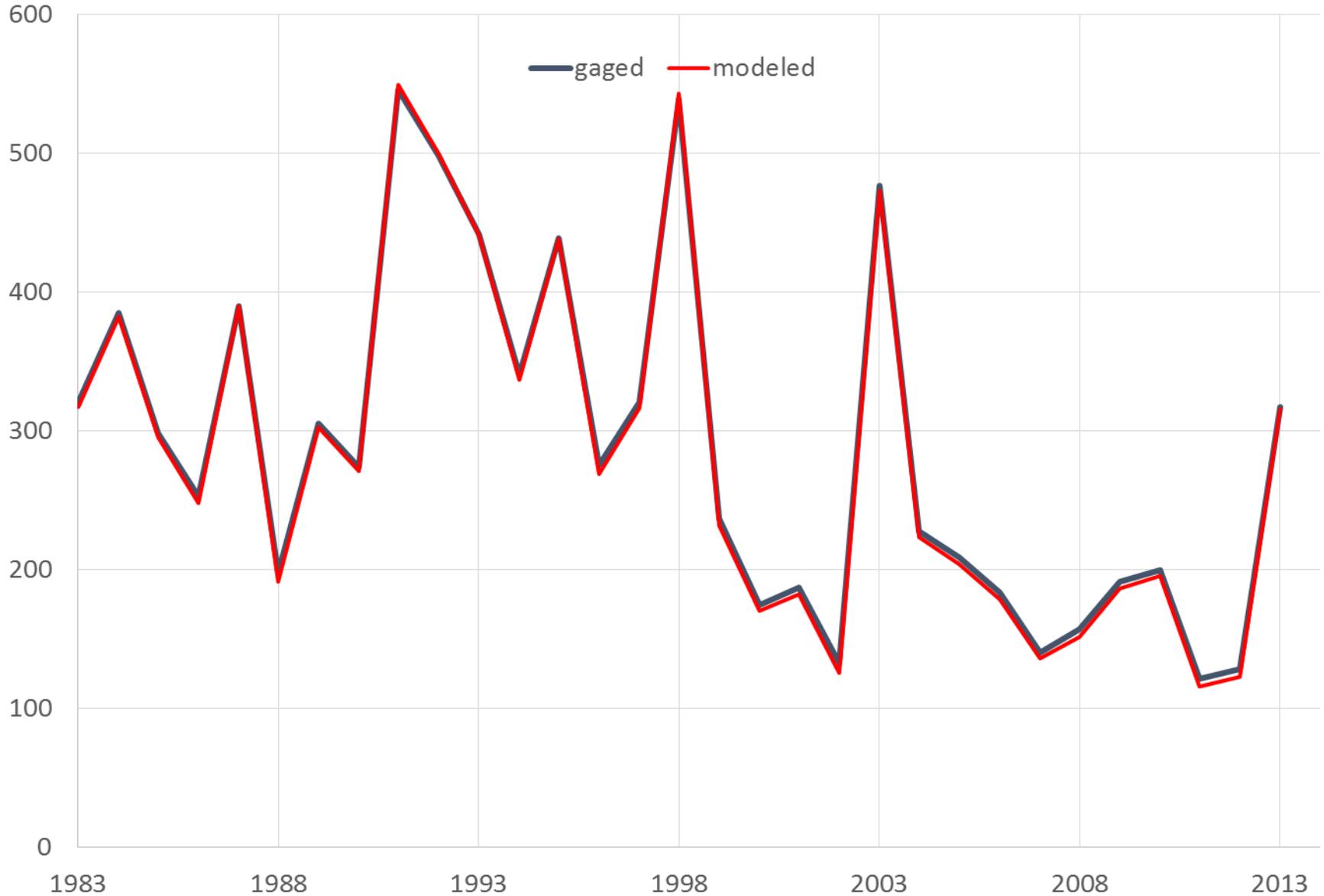
Monthly Flow Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY (CFS)



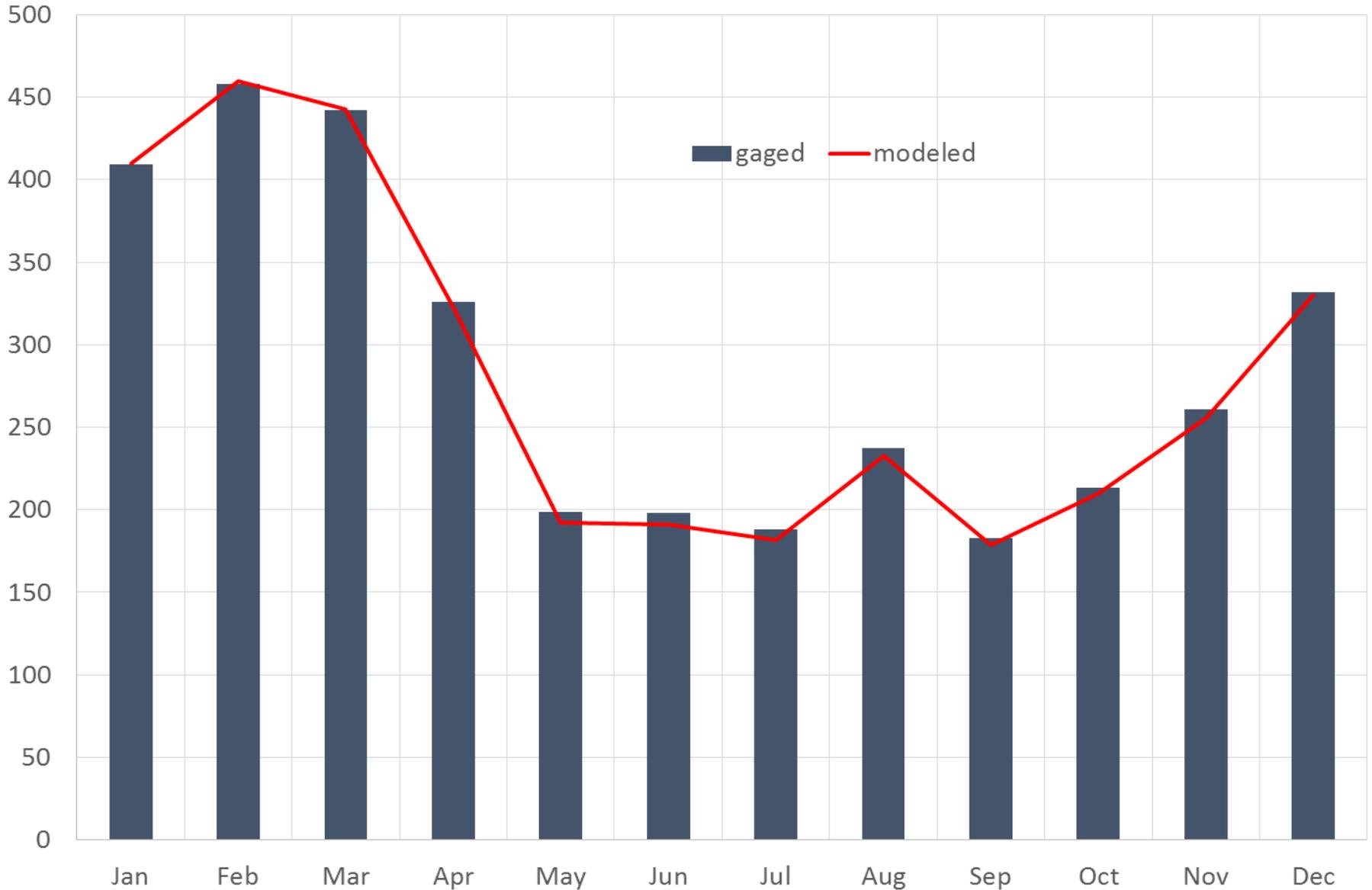
Annual Average Flow Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY (CFS)
Annual Average Flow



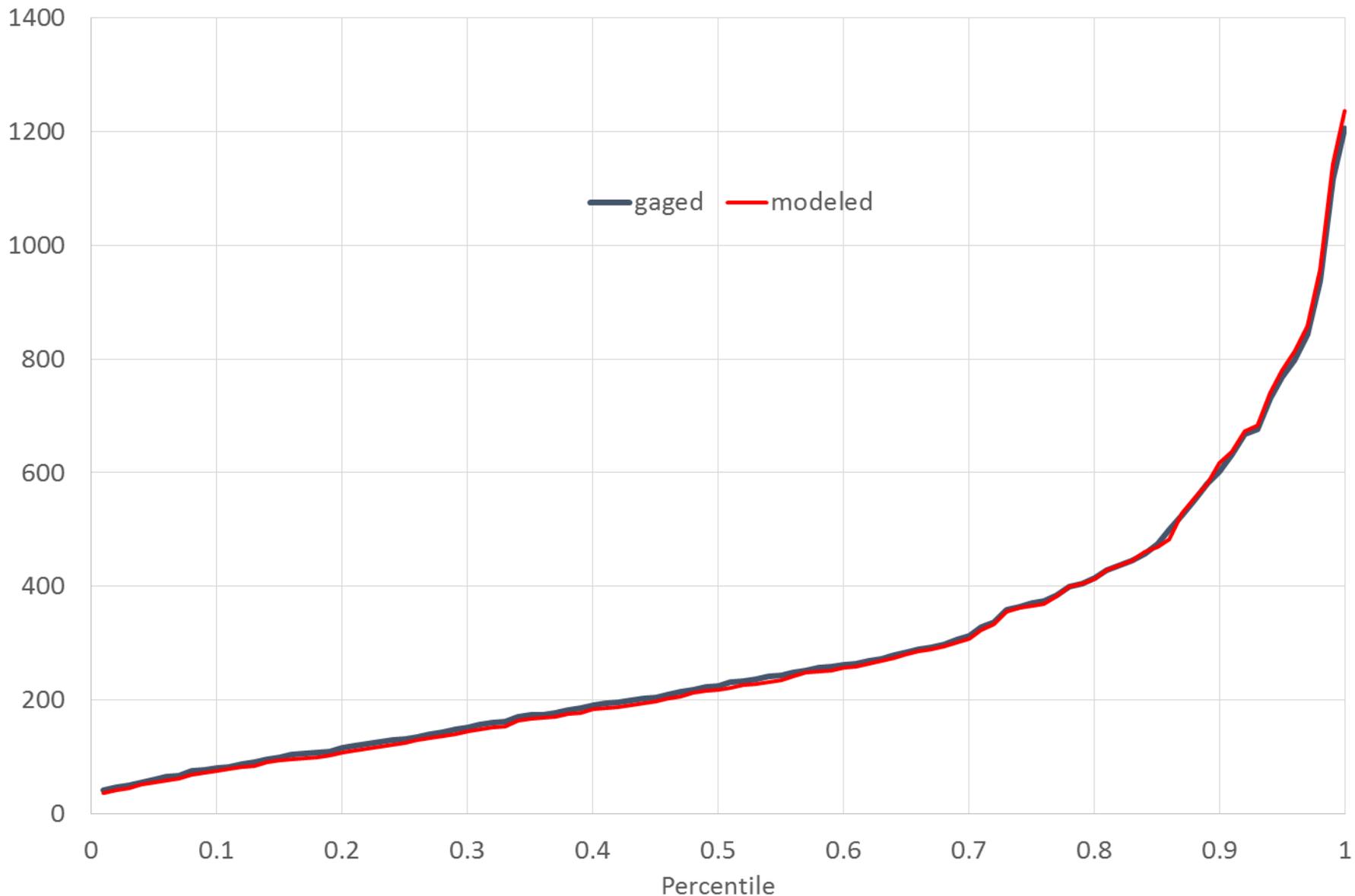
Monthly Mean Flow Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY
Monthly Mean Flow (CFS)



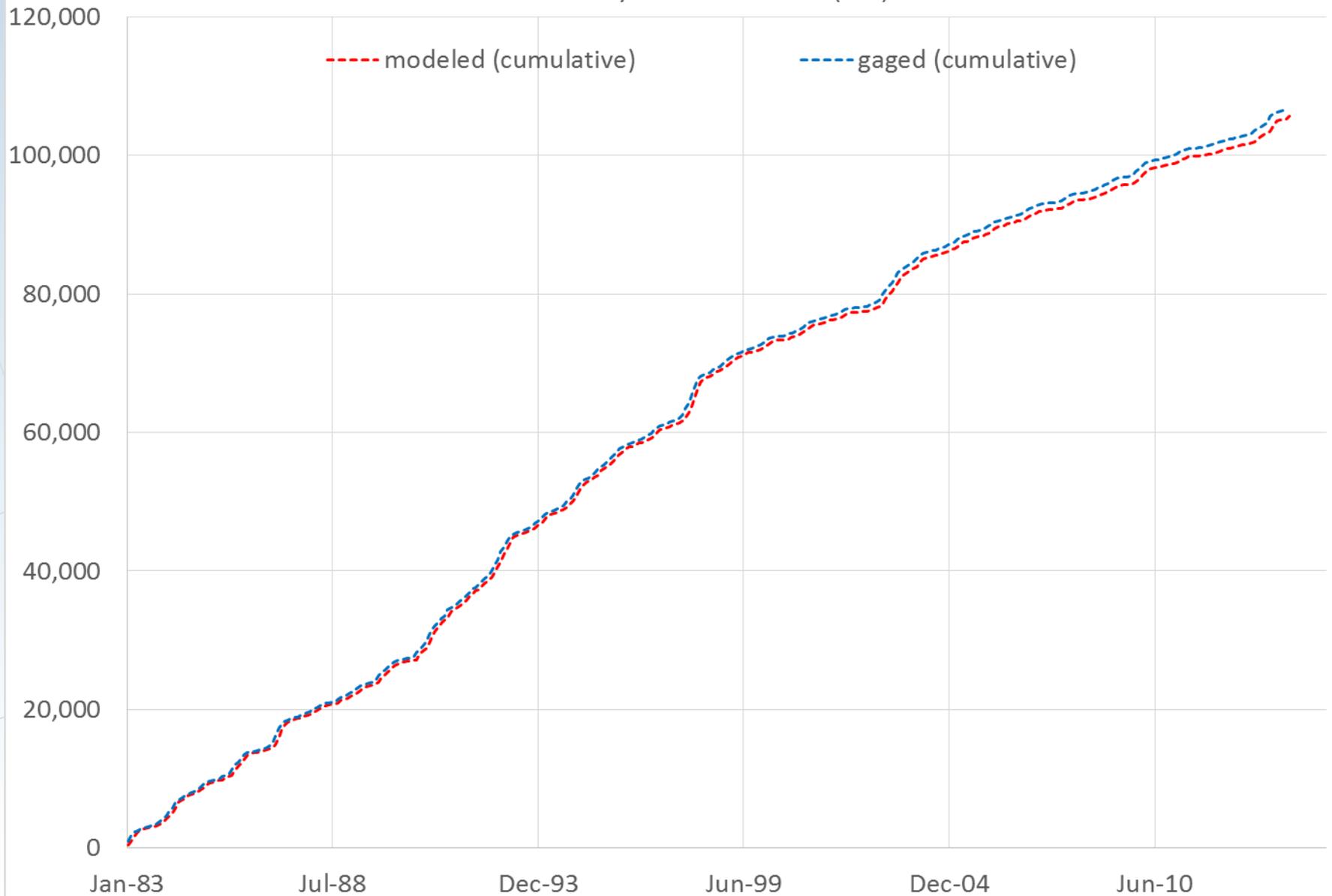
Monthly Flow Percentiles Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY
Monthly Flow Percentiles (CFS)



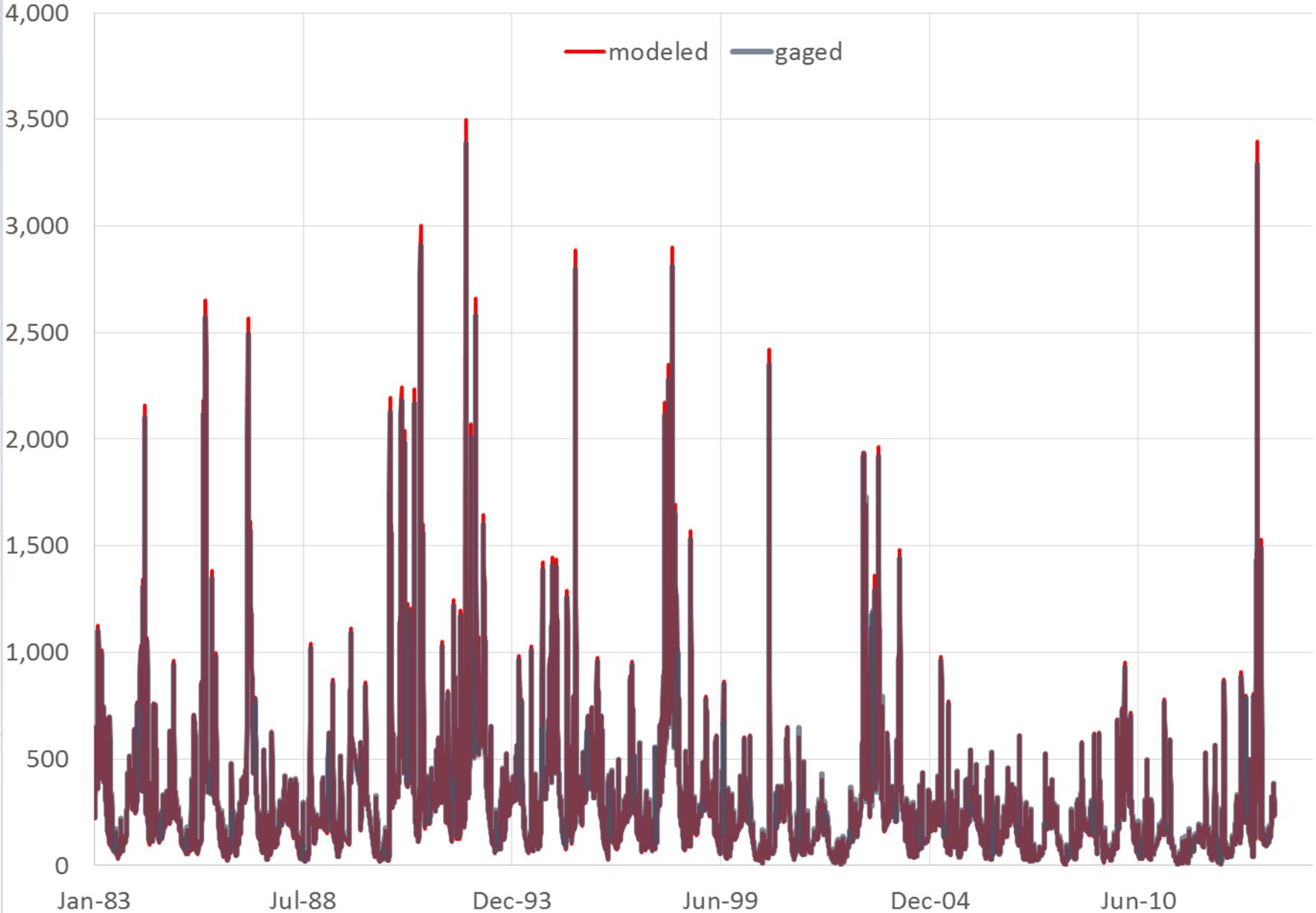
Cumulative Flow Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY (CFS)
Monthly Cumulative Flow (CFS)



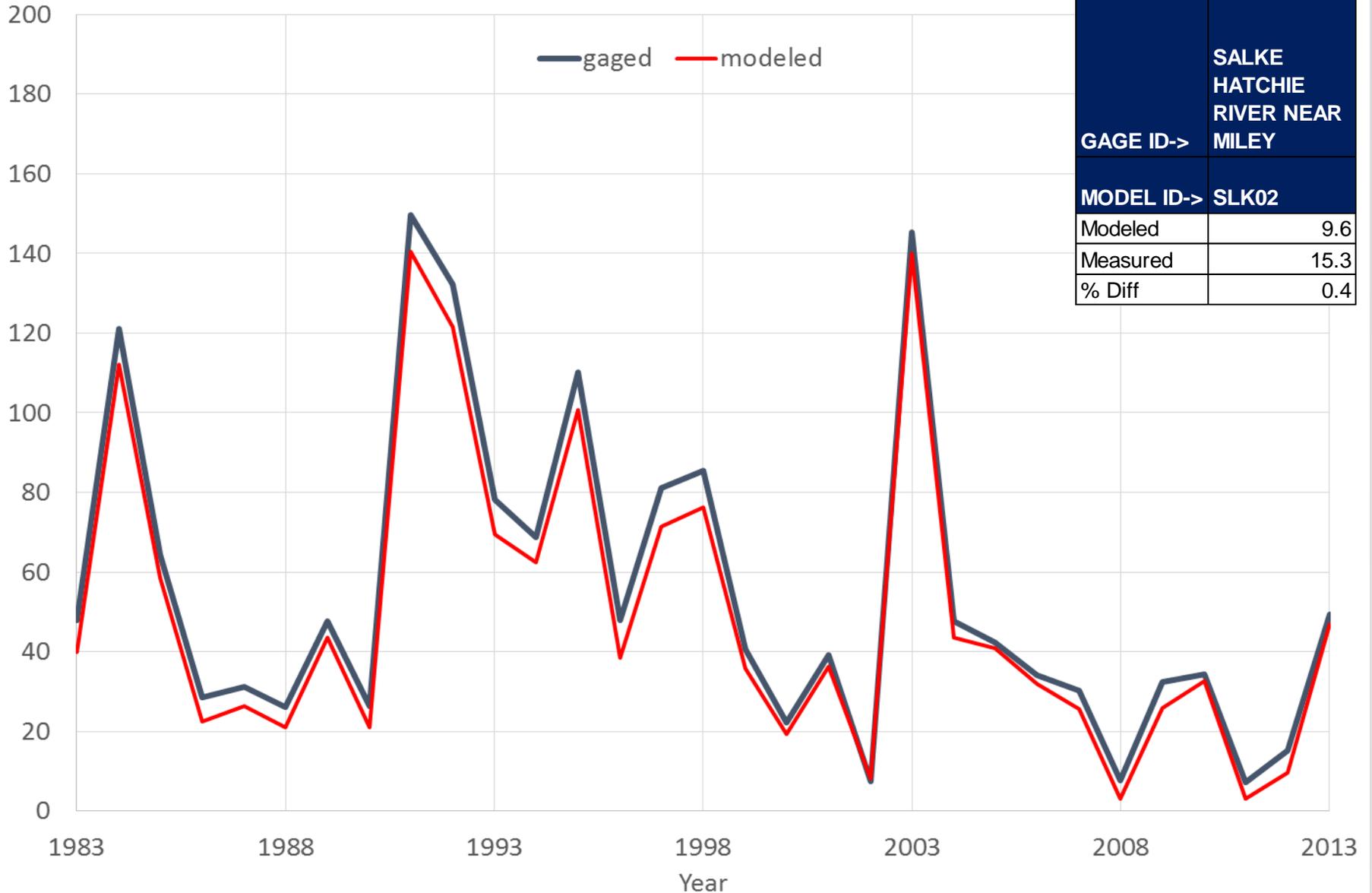
Daily Flow Comparison

SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY (CFS)



Annual 7 Day Low Flows

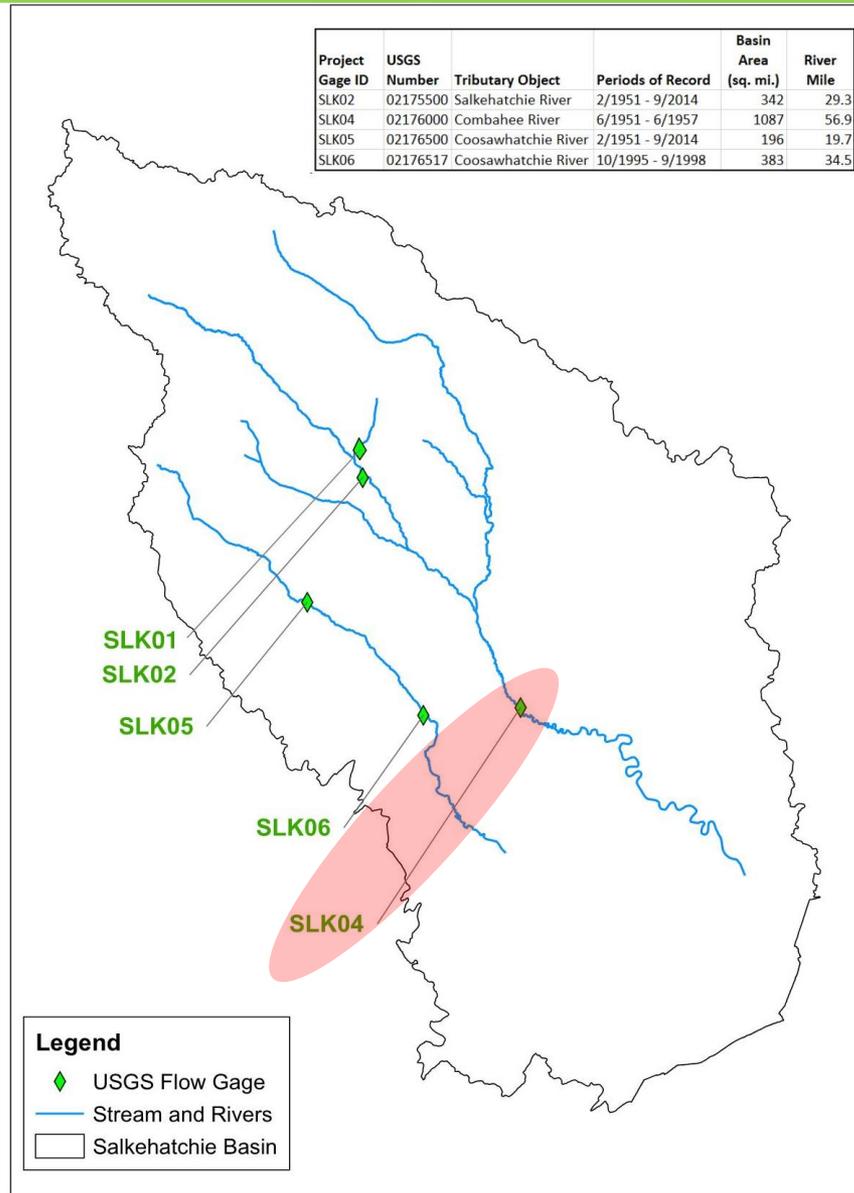
SLK02 (02175500) SALKEHATCHIE RIVER NEAR MILEY
Annual 7-day Low Flow (CFS)



7Q10 Comparison

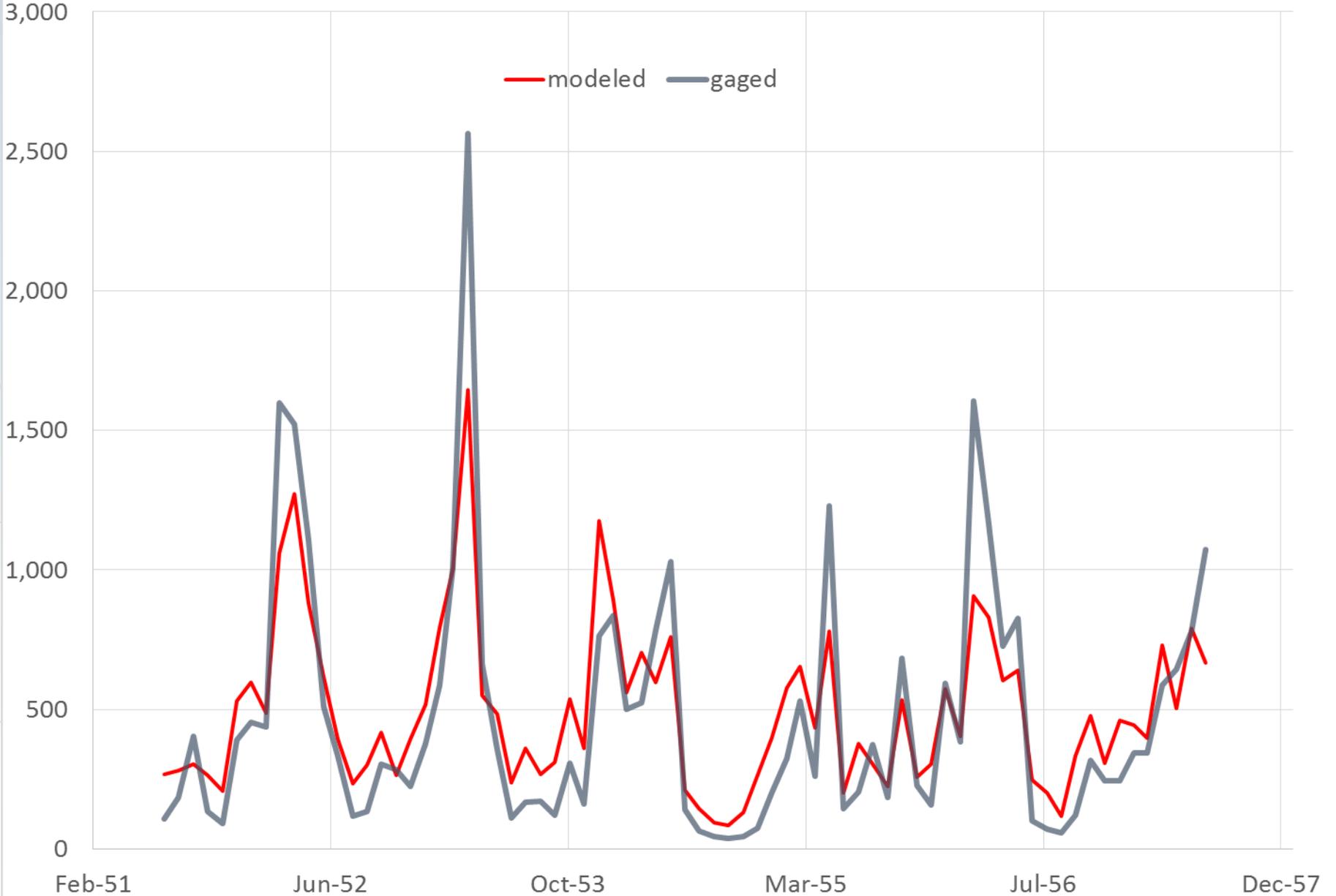
| SALKE HATCHIE RIVER NEAR MILEY | |
|--------------------------------|-------|
| GAGE ID-> | SLK02 |
| MODEL ID-> | SLK02 |
| Modeled | 9.6 |
| Measured | 15.3 |
| % Diff | 0.4 |

Calibration/Validation Locations



Monthly Flow Comparison

SLK04 (02176000) COMBAHEE RIVER NEAR YEMASSEE (CFS)



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 | } 5% or less diff. |
| SLK05 | COOSAWHATCHIE RIVER NEAR HAMPTON | 138 | 139 | -0.5% | 12 | |
| SLK01 | SAVANNAH CREEK AT EHRHARDT | 4 | 4 | -0.1% | 21 | } 1% or less difference |
| 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. |

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