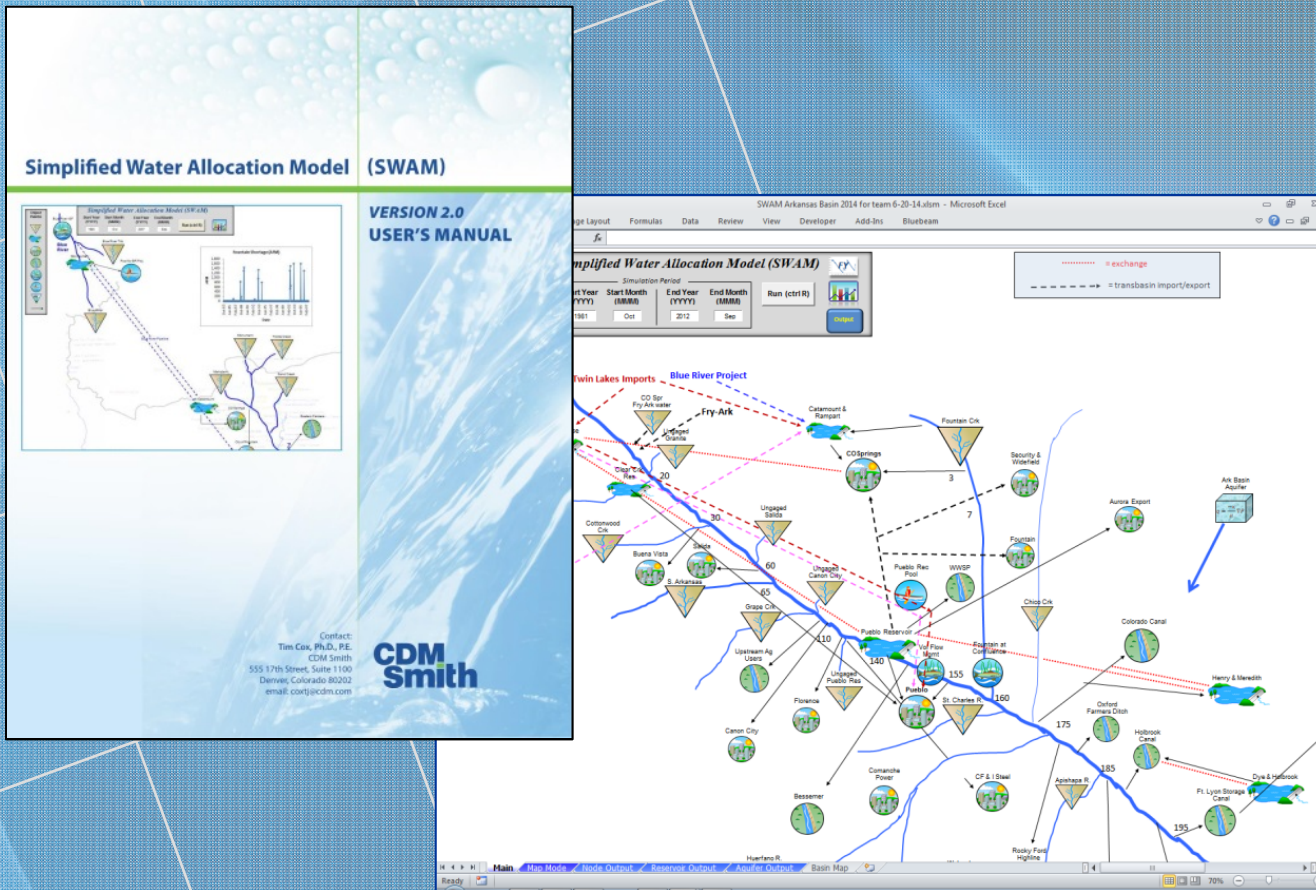


# South Carolina Surface Water Quantity Modeling Project

Edisto Basin Meeting No. 1 – Model Framework

Kirk Westphal, PE  
John Boyer, PE, BCEE

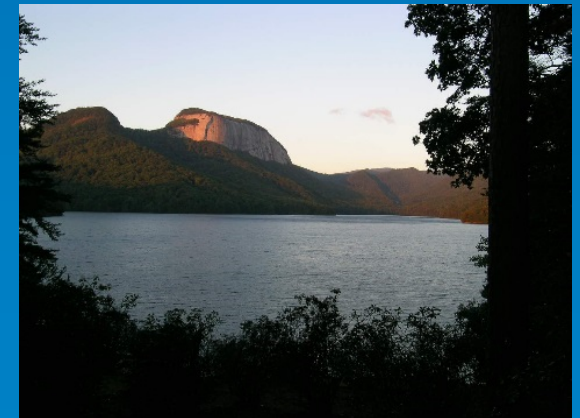
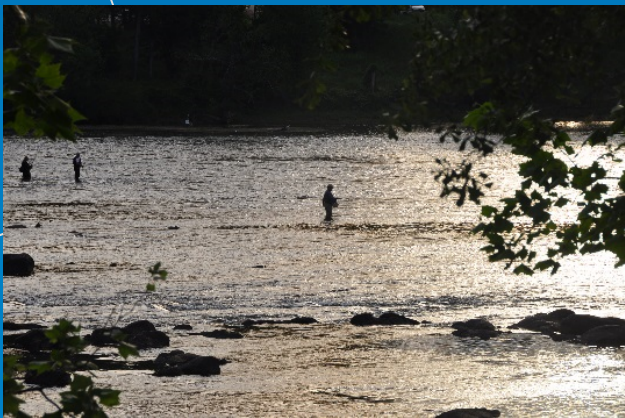
June 18, 2015



**CDM  
Smith**

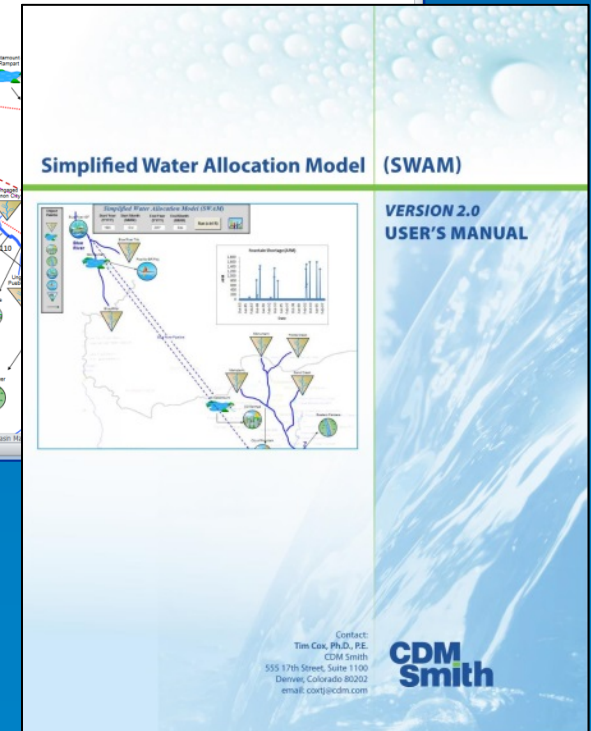
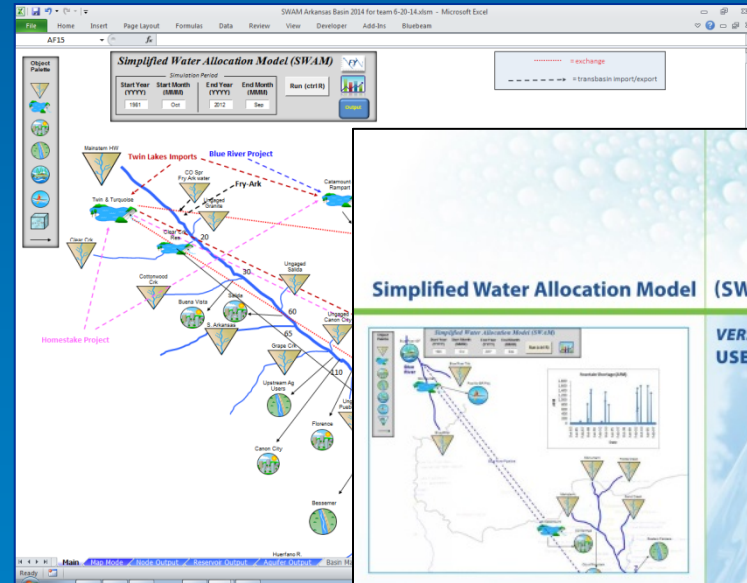
# Project Purpose

- 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.



# 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

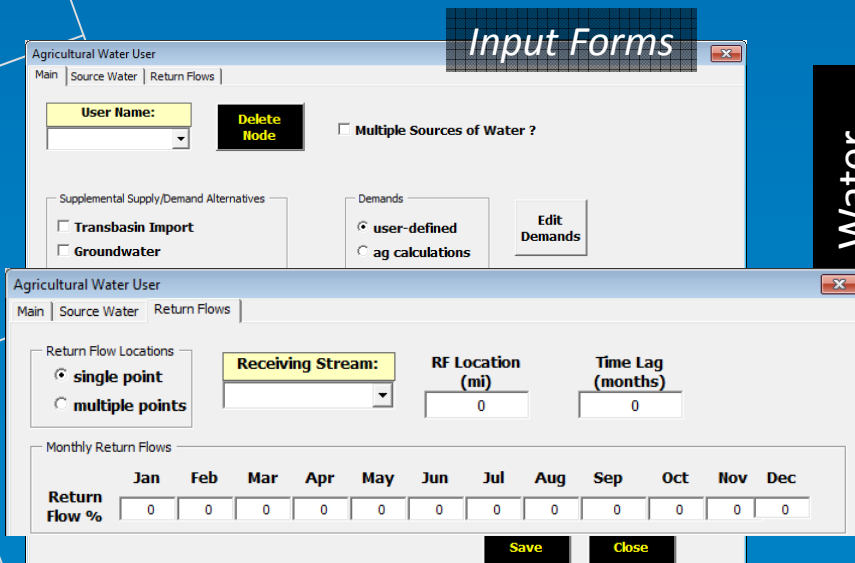
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

### RiverWare

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

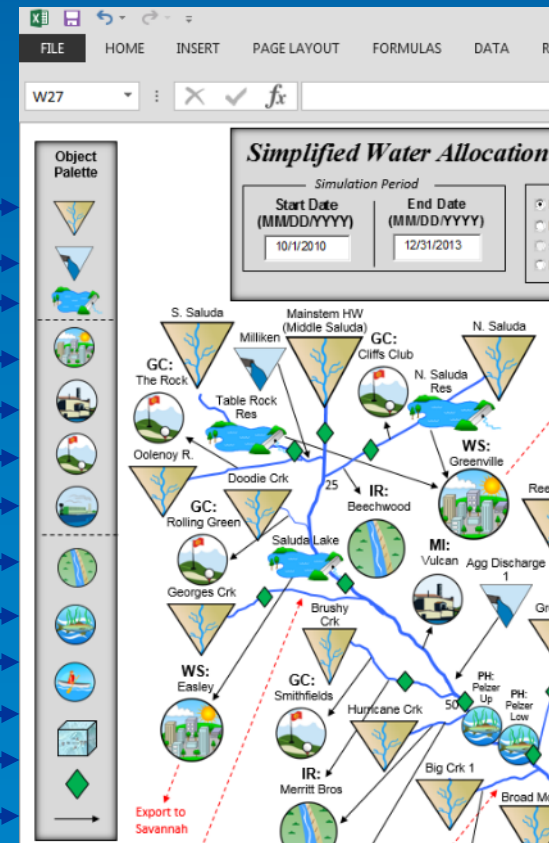
# Simplified Water Allocation Model (SWAM)

- 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



**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 configuration:

- Reservoir Name:** A text input field with a dropdown arrow.
- Delete Node:** A black button with yellow text.
- Storage Capacity (AF):** A text input field.
- Initial Storage (AF):** A text input field.
- Offline/Online:** Radio buttons for 'Offline' (selected) and 'Online'.
- Evaporation:** Radio buttons for 'Inches/day' (selected), '% Volume', and 'Input Timeseries'.
- Reservoir Releases:** Radio buttons for 'Simple' (selected) and 'Advanced'. Below it is a 'Receiving Stream:' dropdown and a 'Release Location (mi)' input field.
- Monthly Rates:** A table with columns for 'Month' and 'Evap. Rates (in./day)'. The months listed are Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep.
- Area-Capacity Table:** Radio buttons for 'Simple' (selected) and 'Detailed'. Below it is a table with columns for 'Volume (AF)' and 'Area (ac)'. The months listed are Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep.
- User Defined Releases:** A table with columns for 'Month', 'Min. Release (AFM)', and '(CFS)'. The months listed are Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep.

# SWAM Model Main Screen

### Simplified Water Allocation Model (SWAM)

**Simulation Period**

Start Date (MM/DD/YYYY): 01/01/2000  
 End Date (MM/DD/YYYY): 12/31/2013

**Simulation Type**

Monthly Planning  
 Daily Planning  
 Short Term Forecasting  
 Firm Yield Calculator

Prior Appropriations  
 Riparian Water Rights

**Run (ctrl R)**

### Input Summaries and Outputting

Node Priorities  
 Node Locations  
 Reservoir Accounts  
 Output Specs

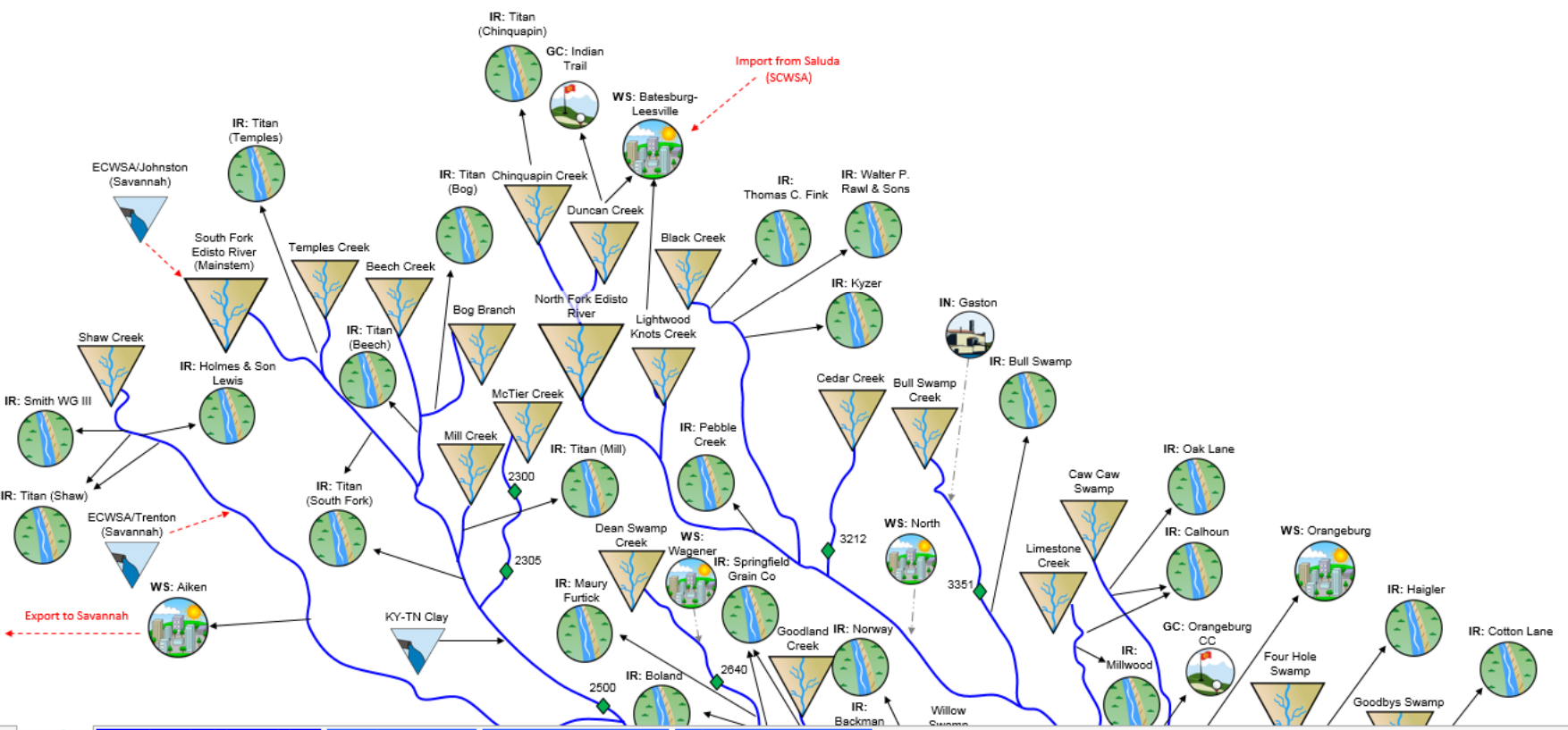
**Input & Output Units**

AF, AFM, AFD  
 MG, MGD, CFS  
 m8, m3d, m8/s



**Object Palette**

- Water Body
- Reservoir
- Swamp
- Wetland
- Canal
- Creek
- River
- Structure
- Point Source
- Flow Gage
- Priority Node
- Location Node
- Account Node
- Output Node



Main | Node Priorities Table | Node Output | Reservoir Output | Flow Gage Output

Edisto 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
  - Basin slope

Edisto 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

# Primary UIF Data Sources

## **Documented**

- USGS Gage flows
- DHEC records of M&I withdrawals and discharges
- Reservoir operator records of water levels
- Reported agricultural withdrawals
- GIS Data layers

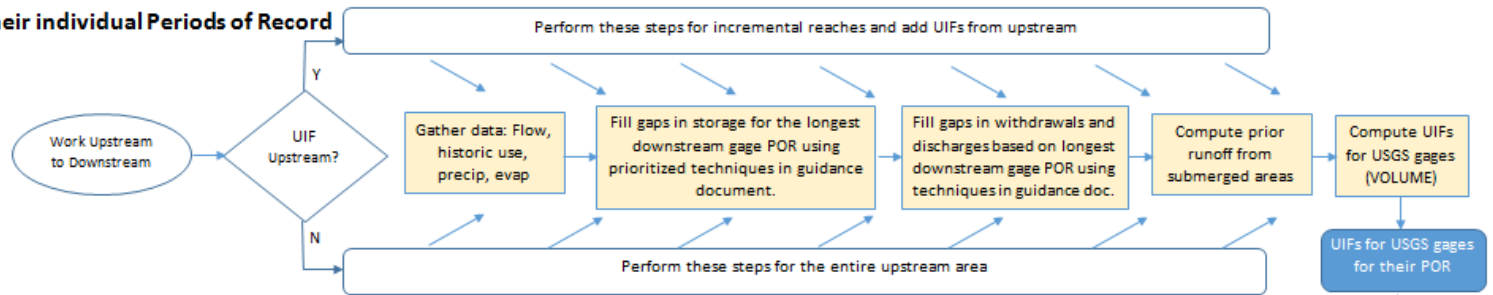
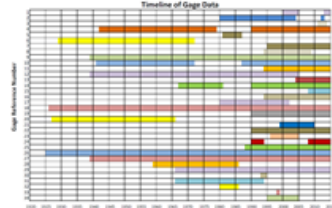
## **Estimated**

- Direct contact with users regarding historic use patterns
- Operational hindcasting
- Agricultural water use modeling

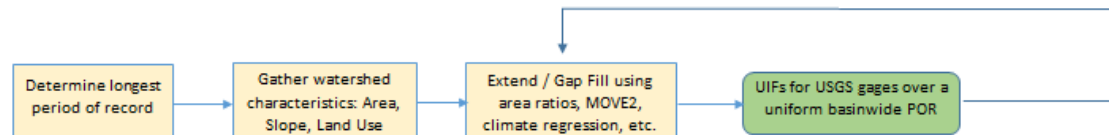
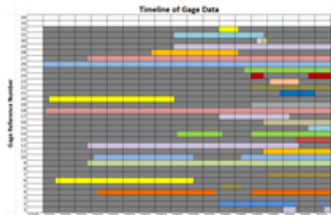
# Basinwide UIF Calculation Process

## Stepwise Procedure for UIF Calculation – Saluda Basin

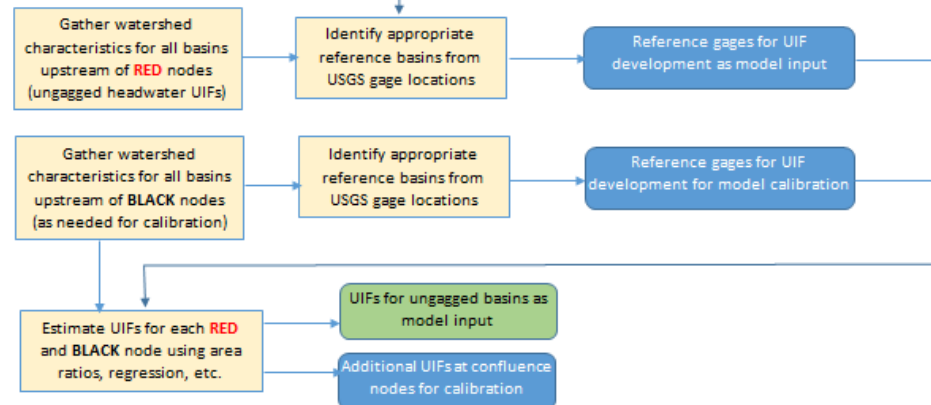
### Step 1: UIFs for USGS Gages for their individual Periods of Record



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



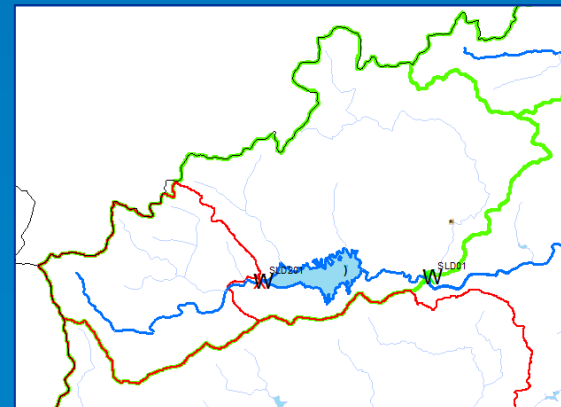
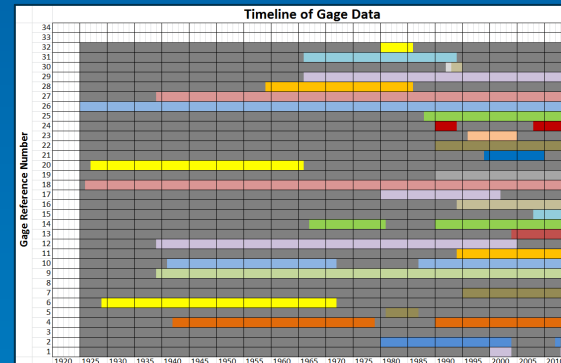
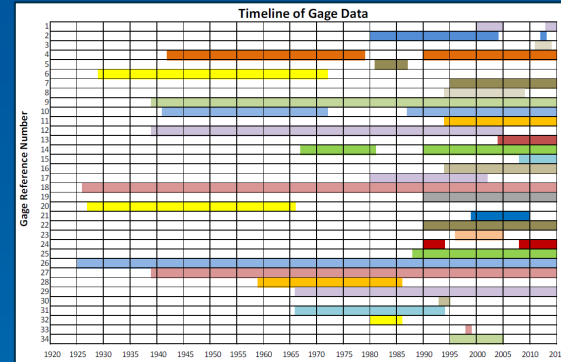
### Step 3: Correlation between Ungaged Basins and Gaged Basins



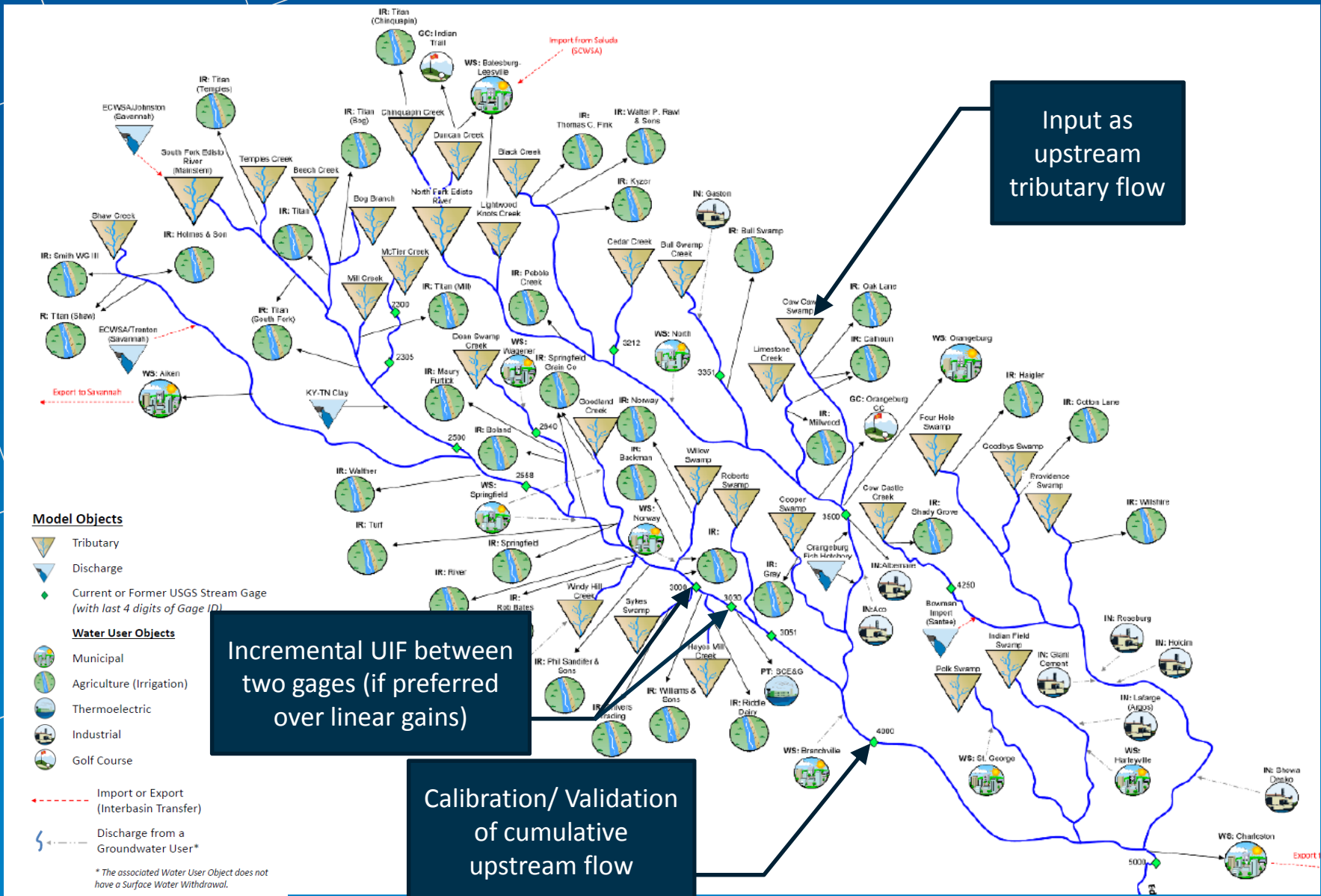
### Step 4: UIFs for Ungaged Basins

# 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

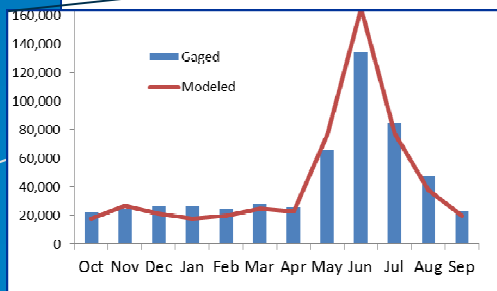
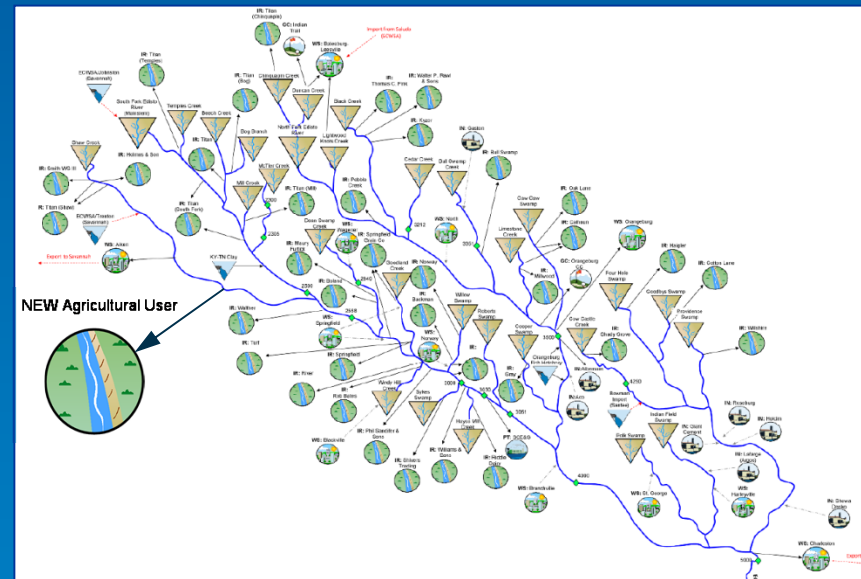
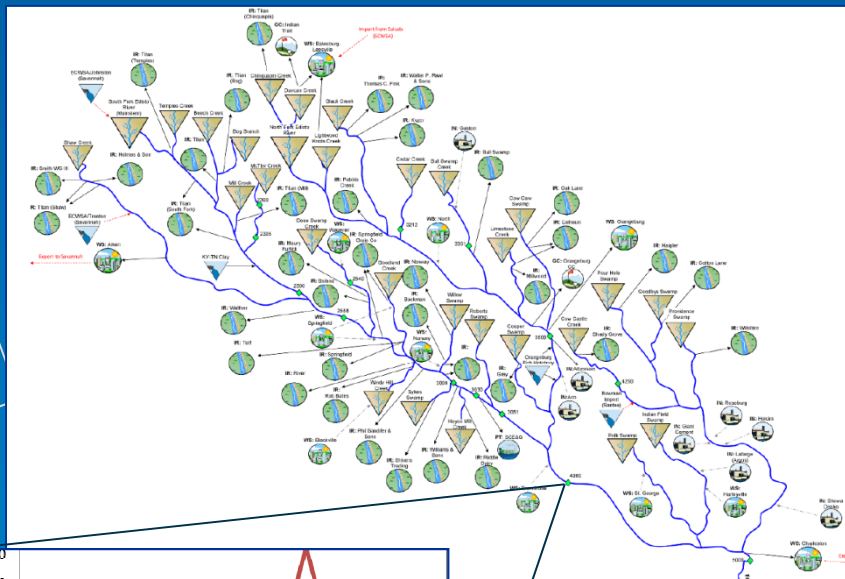




# Two Versions of Every Model

## Calibration with UIFs and Historic Use Records

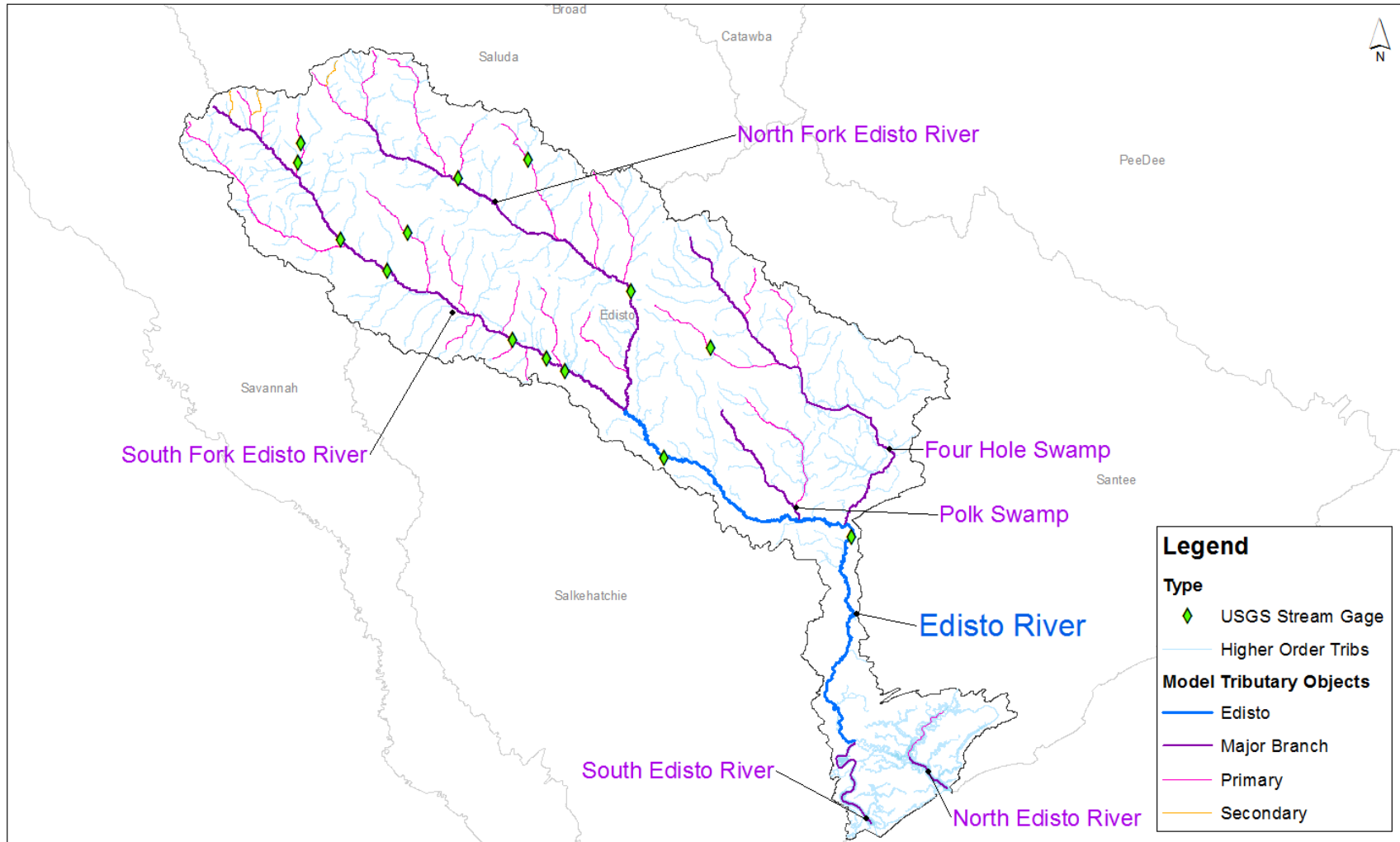
## Planning with UIFs, Current Uses, and User-Defined Future Uses



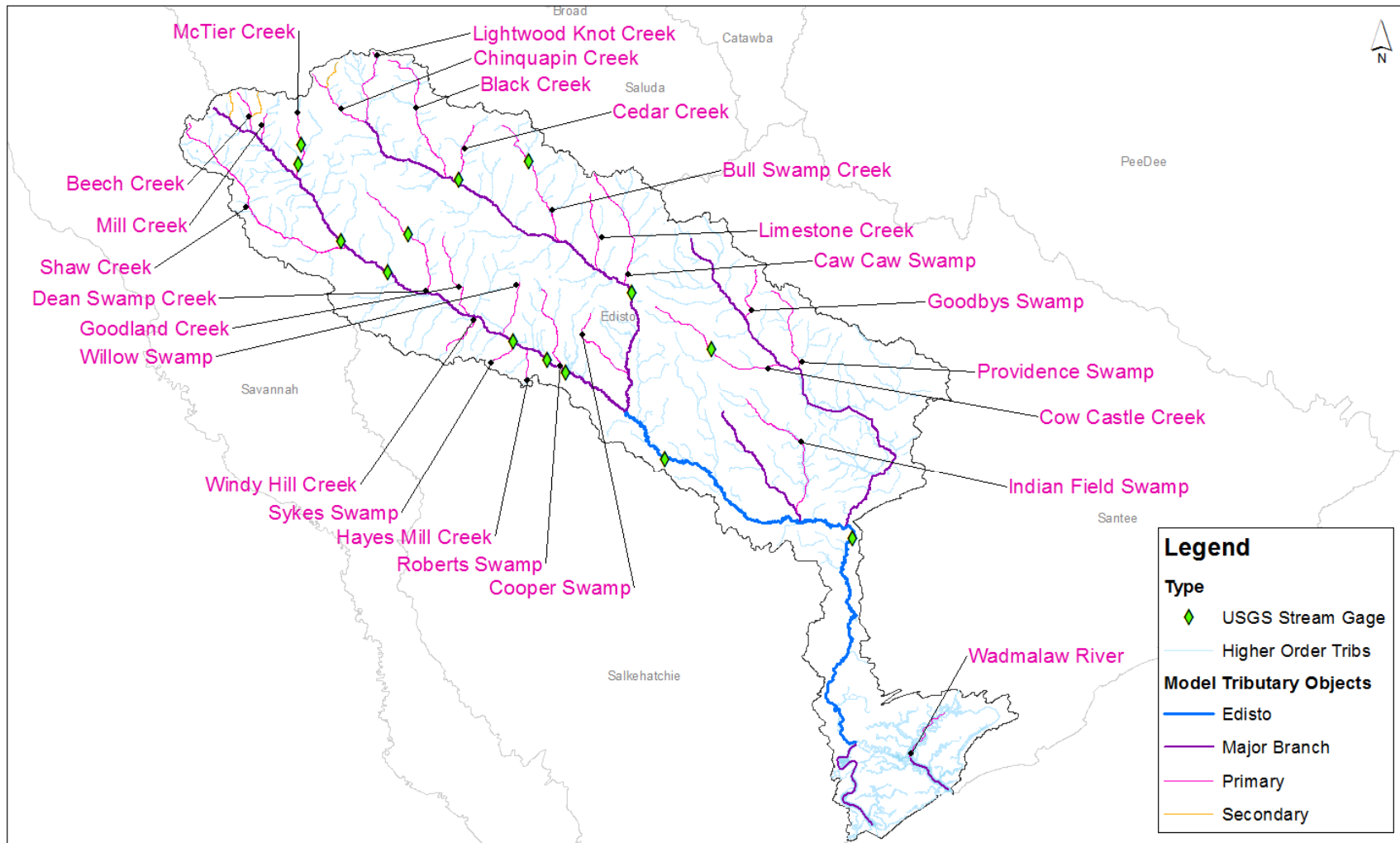
Edisto River Basin

# OVERVIEW OF MODEL FRAMEWORK

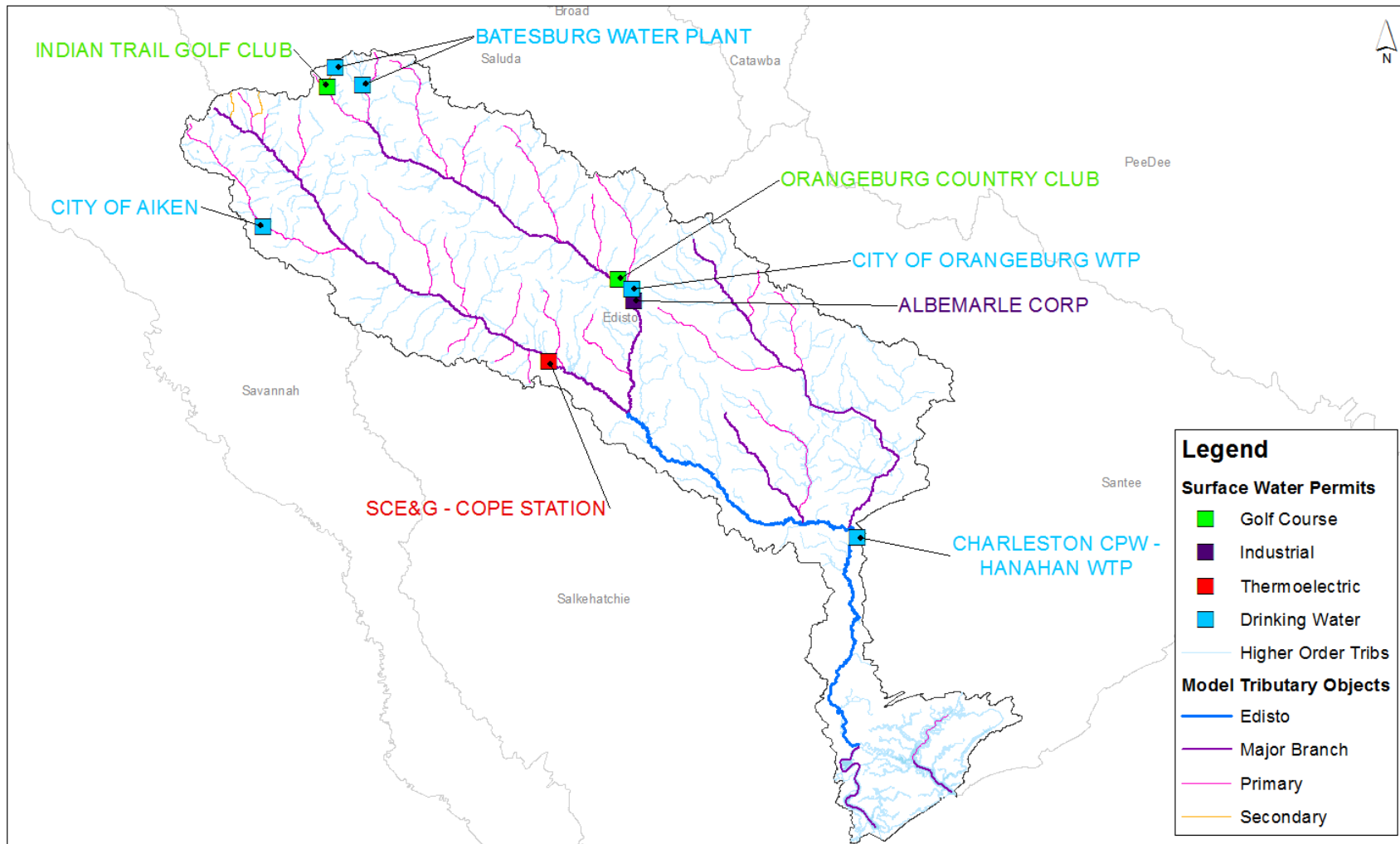
# Edisto Basin – Main and Major Branches



# Edisto Basin – Primary Tributaries

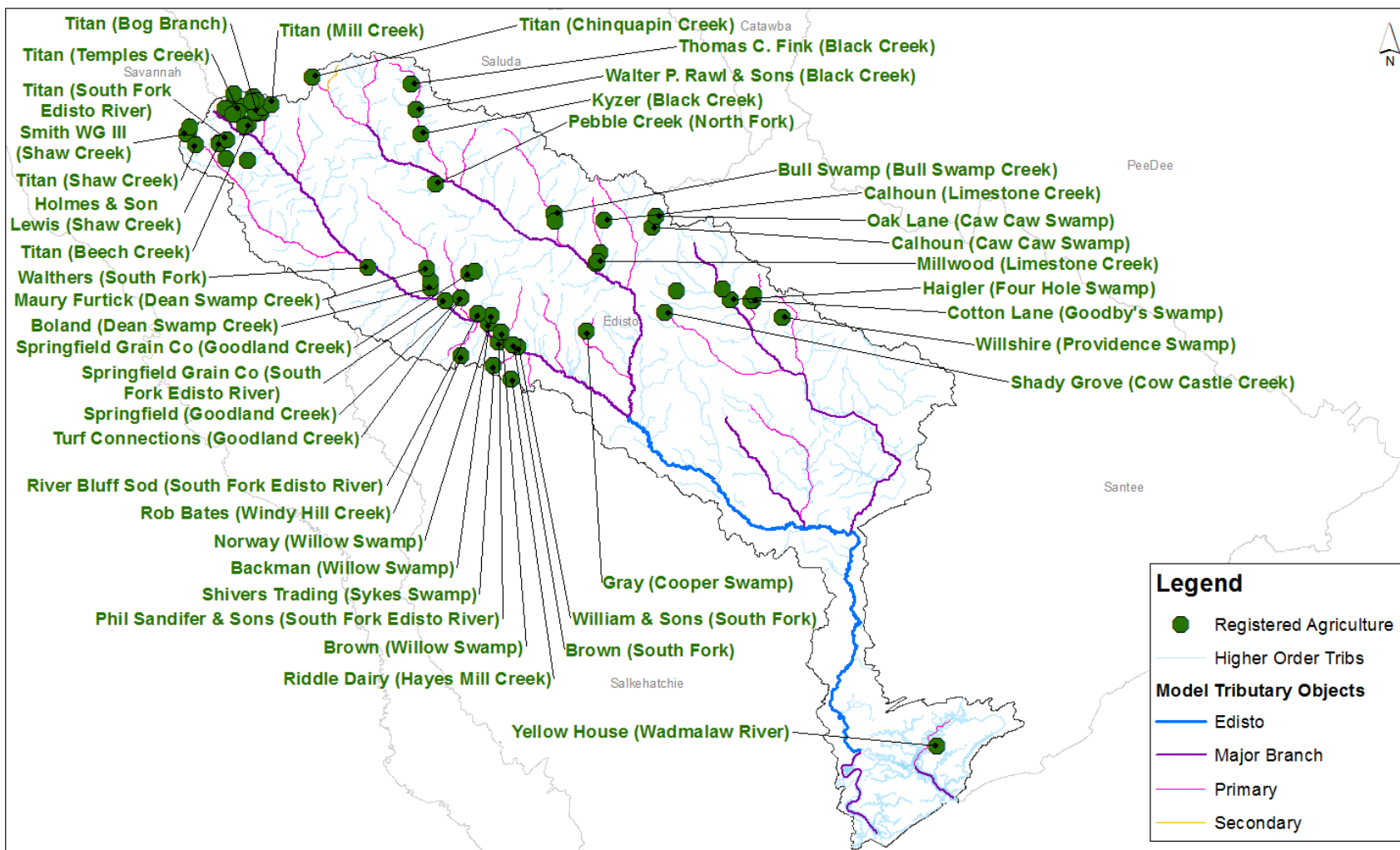


# Edisto Basin Surface Water Withdrawals

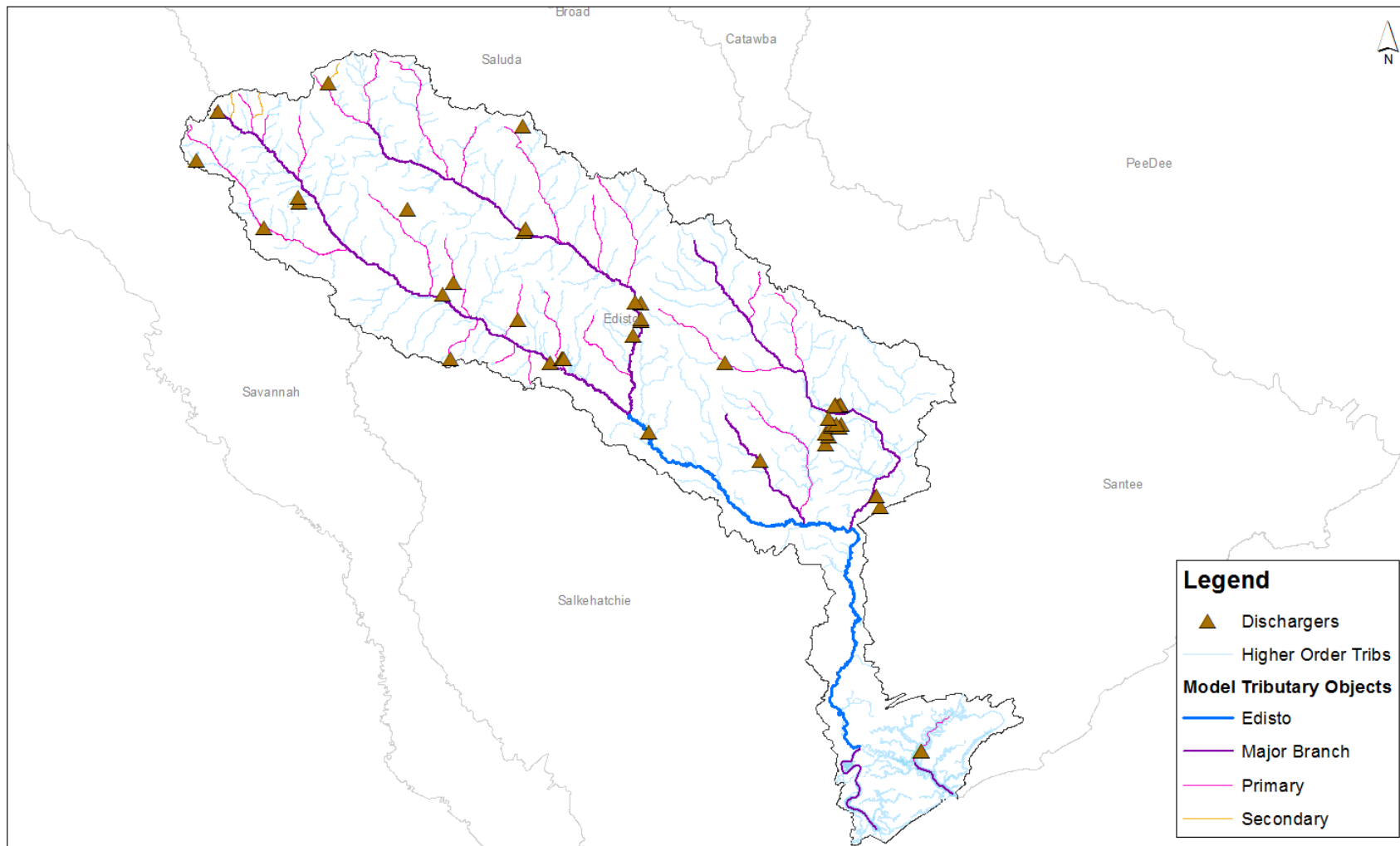




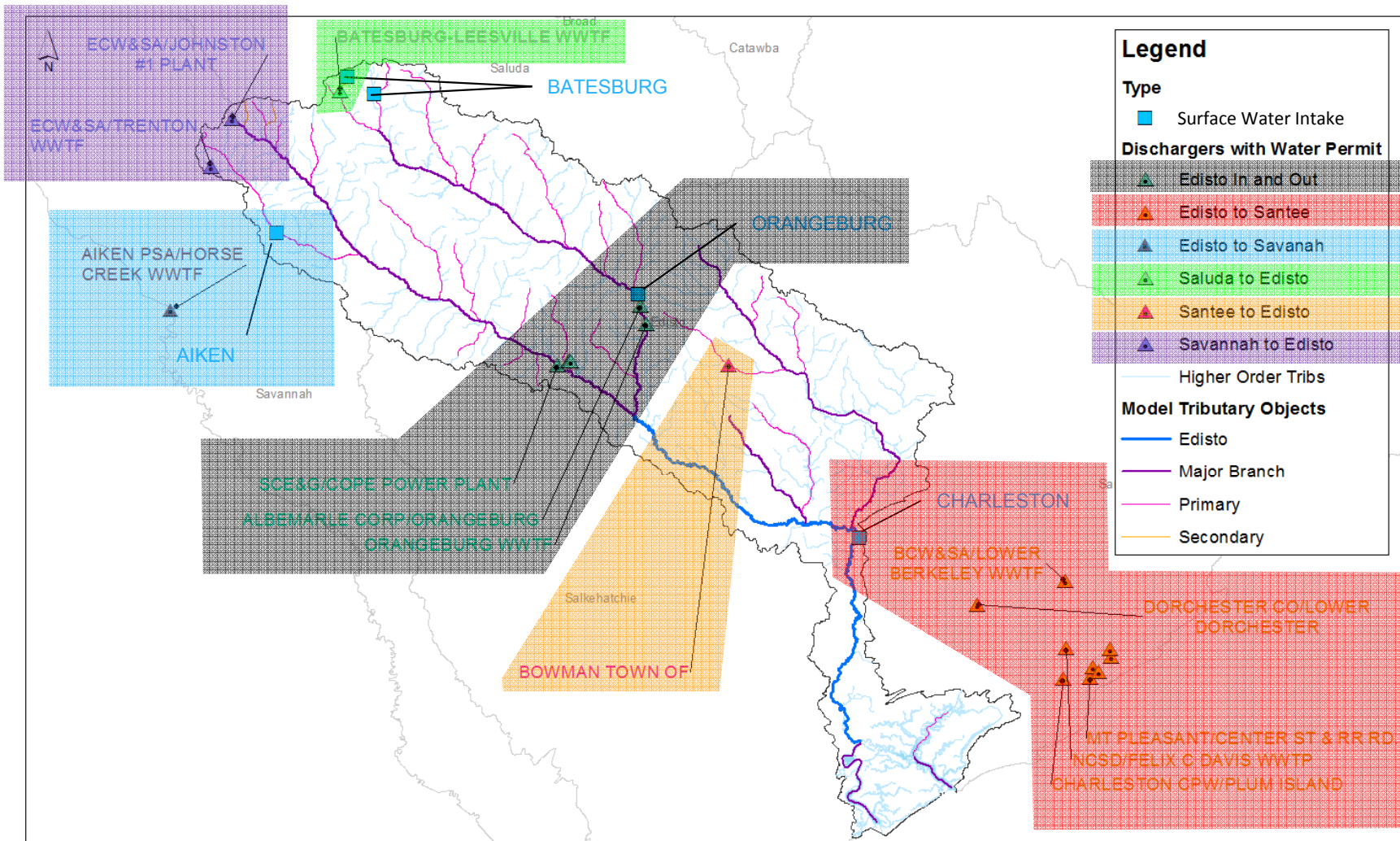
# Edisto Basin Withdrawals – Agriculture



# Edisto Basin Discharges



# Interbasin Transfers





Edisto River Basin

# MODEL SETUP



# Tributary Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

**Simplified Water Allocation Model (SWAM)**

Simulation Period  
Start Year (YYYY): 1981 Start Month (MMM): Oct

**Tributary**

Tributary Name:  **Delete Tributary** **Headwater Flows**

Confluence Stream:  Confluence Location (mi):

Spatial Flow Changes

Subbasin Flow Factor (unitless):  Reach Length (mi):

Comments:

**Save**  
**Close**

..... = exchange

transbasin import/export

Ark Basin Aquifer

Colorado Canal

Henry & Meredith

Holbrook Canal

Dye & Holbrook

Ft. Lyon Storage Canal

Apishapa R. 185

195

Huerfano R.

Rocky Ford Highline

Besemer

Comanoha Power

CF & I Steel

Homestake Project

Mainstem HW

Twin Lakes Impo

Twin & Turquoise

Clear Crk Res.

Clear Crk

Cottonwood Crk

Bue

Main

Map Mode

Node Output

Reservoir Output

Aquifer Output

Basin Map

Ready

70%

# Reservoir Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

**Simplified Water Allocation Model (SWAM)**

Simulation Period: Start Year, Start Month, End Year, End Month

..... = exchange  
 -----> = transbasin import/export

**Reservoir**

Main

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

**Evaporation:**  **Inches/day**  **% Volume**  **Input Timeseries**

**Reservoir Releases:** **Receiving Stream:** [Dropdown]  **Simple**  **Advanced**

**Release Location (mi)** [Input: 0]

**Area-Capacity Table:**  **Simple**  **Detailed**

Month	Evap. Rates (in./day)	Volume (AF)	Area (ac)
Jan			
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Oct			
Nov			
Dec			

Month	Min. Release (AFM)	(CFS)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

**Comments:** [Text Area]

**Save** **Close**

Homesta

Huerfano R. Highline

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

# Water User Input Form – Main

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

Water User

Main | Water Usage | Source Water | Return Flows

Water User Name:  **Delete**

Object Palette

Supplemental S...

Cons

Reca

Ag T

Comments:

Monthly User Distribution

Manual

M&I

Agriculture

Monthly Baseline Usage

Month	Mont Usa
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	

(AFM)

Annual Baseline Usage

Input Format

Total Use

Source Stream:

Source Water Type

Direct River

Reservoir

Groundwater

Downstream Location (mi)

Priority Date

Ditch Capacity  (AFM)

Permit Limit  (AFM)

Seasonal Permit

Storage Withdrawal Permit

**Save**

**Close**

Storage

Reservoir Name:

(AF) Storage Capacity

(AFY) Storage Right

Water Year Start Mo. (1 - 12)

Carry Over Rule

Identifying Notes:

Home

Main | Map Mode | Node Output | Reservoir Output

Ready

70%

# Agricultural Water User Input Forms

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

**Agricultural Water User**

Main Source Water Return Flows

User Name:  **Delete Node**

Supplemental Supply/Demand Alternatives

Transbasin Import

Groundwater

Comments:

**Agricultural Water User**

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
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	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**

Huerfano R. Highline

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

# Instream Flow Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

**Simplified Water Allocation Model (SWAM)**

**Instream Flows**

Water Right

**Instream Flow Name:** [Dropdown] **Delete Node** **Target Stream:** [Dropdown] **Downstream Location (mi)** [Text: 0]

**Priority Date** [Text: 1/1/2007]

**Rules**

- Seasonal WR**
- TNC IHA Methodology**

**Avg. Monthly Flow Rights**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]	[Text]

(CFS)

**Comments:** [Text Area]

**Save** **Close**

Object Palette

Mainstem H

Twin & T

Clear Crk

Ark Basin Aquifer

Henry & Meredith

Dye & Harbrook

Lyon Storage Canal

Huerfano R. Rocky Ford Highline

Homestake Project

Ready

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

70%

Edisto River Basin

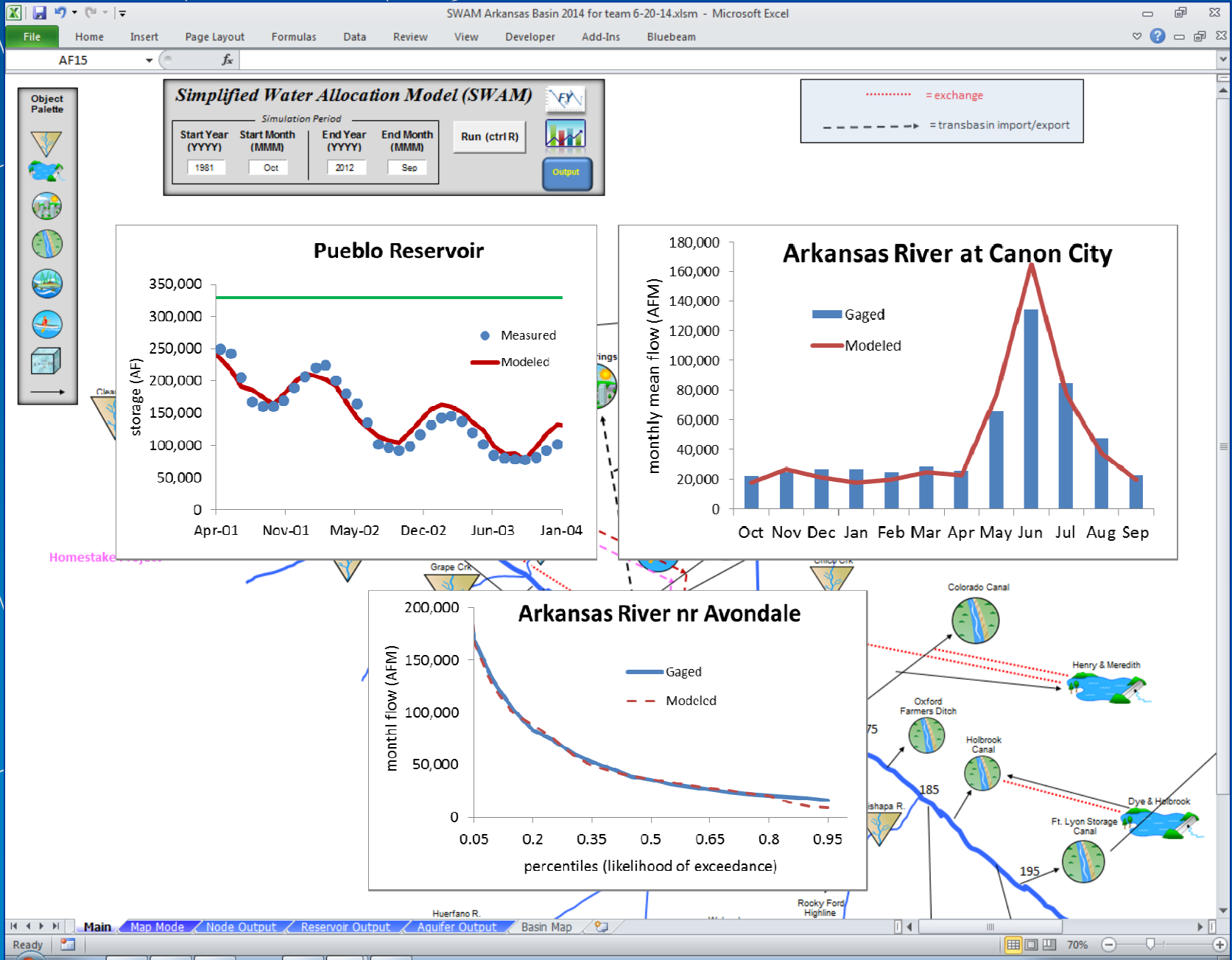
# MODEL VALIDATION

# SWAM Calibration/Validation

- Calibration targets = downstream flow gage records
- Calibration parameters =
  - reach gains/losses,
  - ungedged 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)
  - Reservoir storage timeseries



# Calibration Result Graphs



Edisto River Basin

THANK YOU