

South Carolina Surface Water Quantity Modeling Project

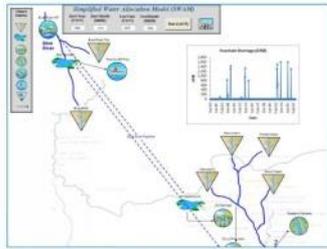
Broad River Basin Meeting No. 1 – Model Framework

Kirk Westphal, PE
John Boyer, PE, BCEE

August 5, 2015

Simplified Water Allocation Model (SWAM)

VERSION 2.0
USER'S MANUAL



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

**CDM
Smith**

Water Allocation Model (SWAM)

Simulation Type: Model Planning Prior Appropriations
 Daily Planning Seasonal Water Rights
 Global Water Allocation Firm Yield Calculator

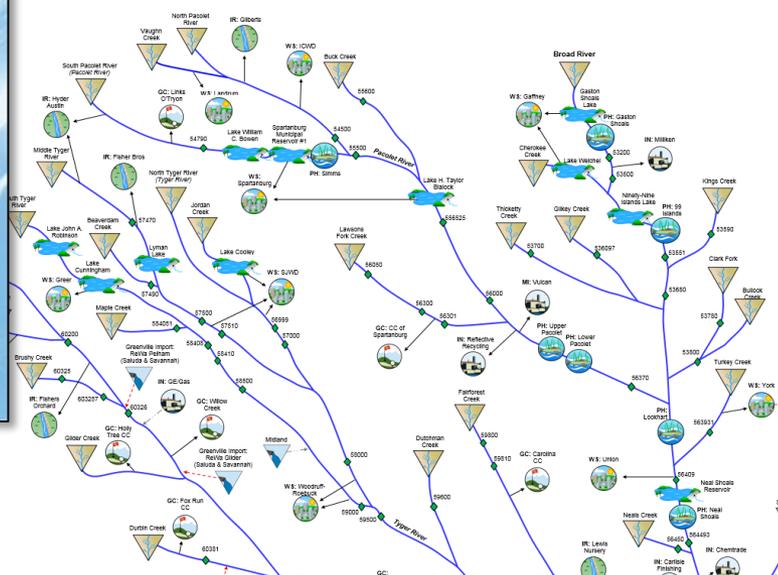
End Date (MM/DD/YYYY): 03/02/15

Run (ctrl R)

Input Summary and Outputting

input & output

AP: AP1 AP2 P: 10, 100, 0.5 P: 10, 100, 10.1



**CDM
Smith**

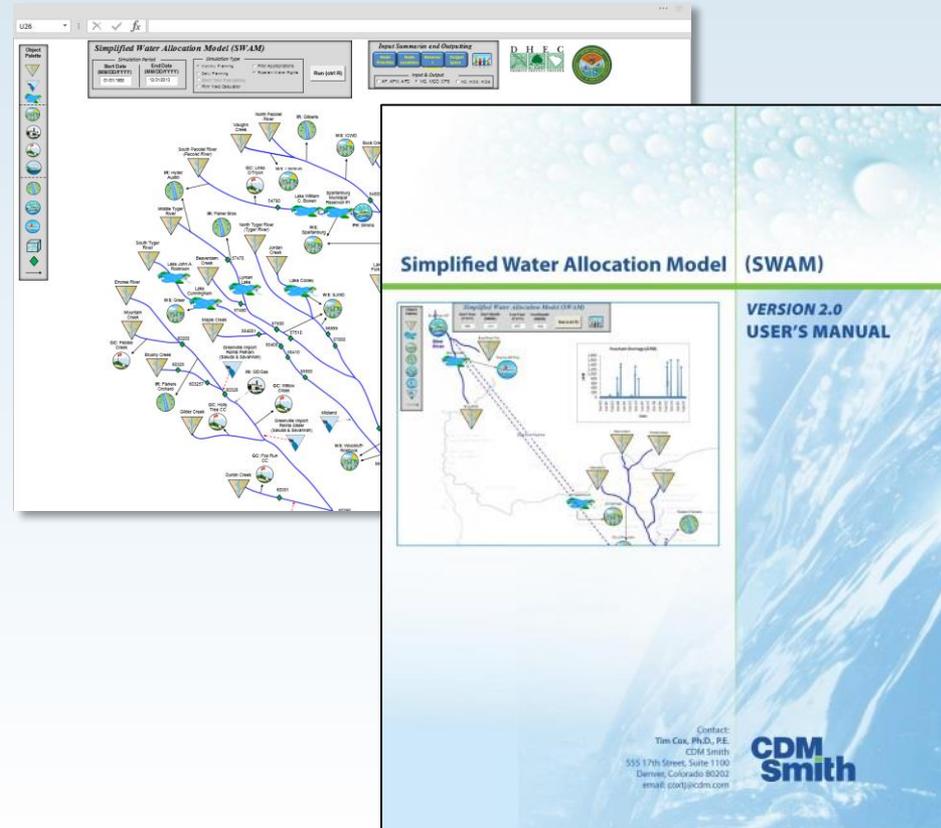
Project Purpose

- 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 a 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)

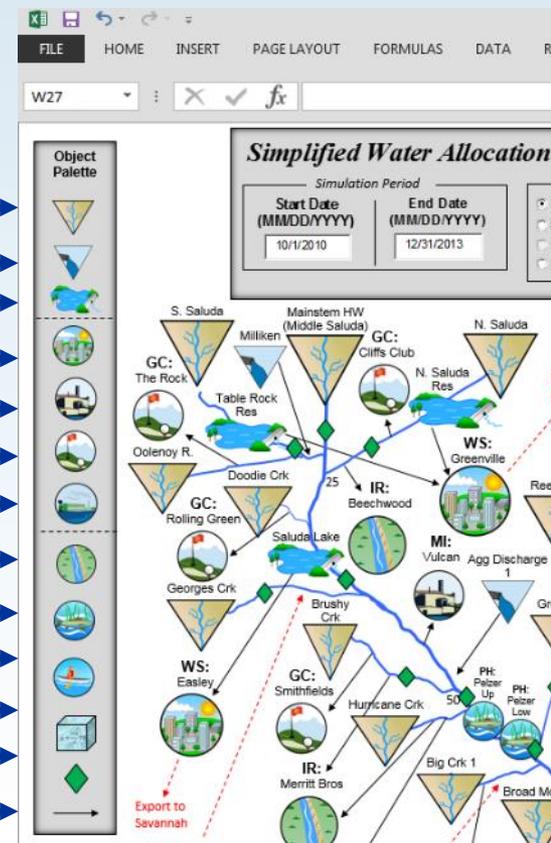
- Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities
- Resides within Microsoft Excel
- Point and click setup and output access

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)

- Intuitive & Transparent** Resides within and interfaces directly with Microsoft Excel
- Ease-of-Use** Point-and-click setup and output access
- Simple & Robust** Mass balance calculations, but handles operating rules, use priorities, etc.

Input Forms

The input forms are designed for user configuration within the SWAM model. They include fields for user identification, source water characteristics, and return flow parameters.

Node Output

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

	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
Output							Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AE)	
1			Priority Rank	Reach (mi)	Location					
2		Pueblo4	32	Mainstem	136		1,000,000	5,000		
3		Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)	GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)
4		Min	1,200	0	0	0	0	0	0	0
5		Max	423,253	420	420	5,000	0	0	0	0
6		Avg	44,588	117	33	4,340	0	0	0	0
7		Oct-81	14,837	0	0	0	0	0	0	0
8		Nov-81	23,186	0	0	0	0	0	0	0
9		Dec-81	24,424	0	0	0	0	0	0	0
10		Jan-82	17,870	0	0	0	0	0	0	0
11		Feb-82	16,694	0	0	0	0	0	0	0
12		Mar-82	25,120	0	0	0	0	0	0	0
13		Apr-82	11,977	0	0	0	0	0	0	0
14		May-82	35,025	0	0	0	0	0	0	0
15		Jun-82	146,407	0	0	0	0	0	0	0
16		Jul-82	97,301	0	0	0	0	0	0	0

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 input fields and tables for configuring a reservoir object.

Reservoir Name: [dropdown] **Delete Node** Storage Capacity (AF) [input] Initial Storage (AF) [input] 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] Simple Advanced

Release Location (mi) [input]

User Defined Releases

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

SWAM Model Main Screen

U26



Simplified Water Allocation Model (SWAM)

Simulation Period
Start Date (MM/DD/YYYY): 01/01/1983
End Date (MM/DD/YYYY): 12/31/2013

Simulation Type
 Monthly Planning
 Daily Planning
 Short Term Forecasting
 Firm Yield Calculator

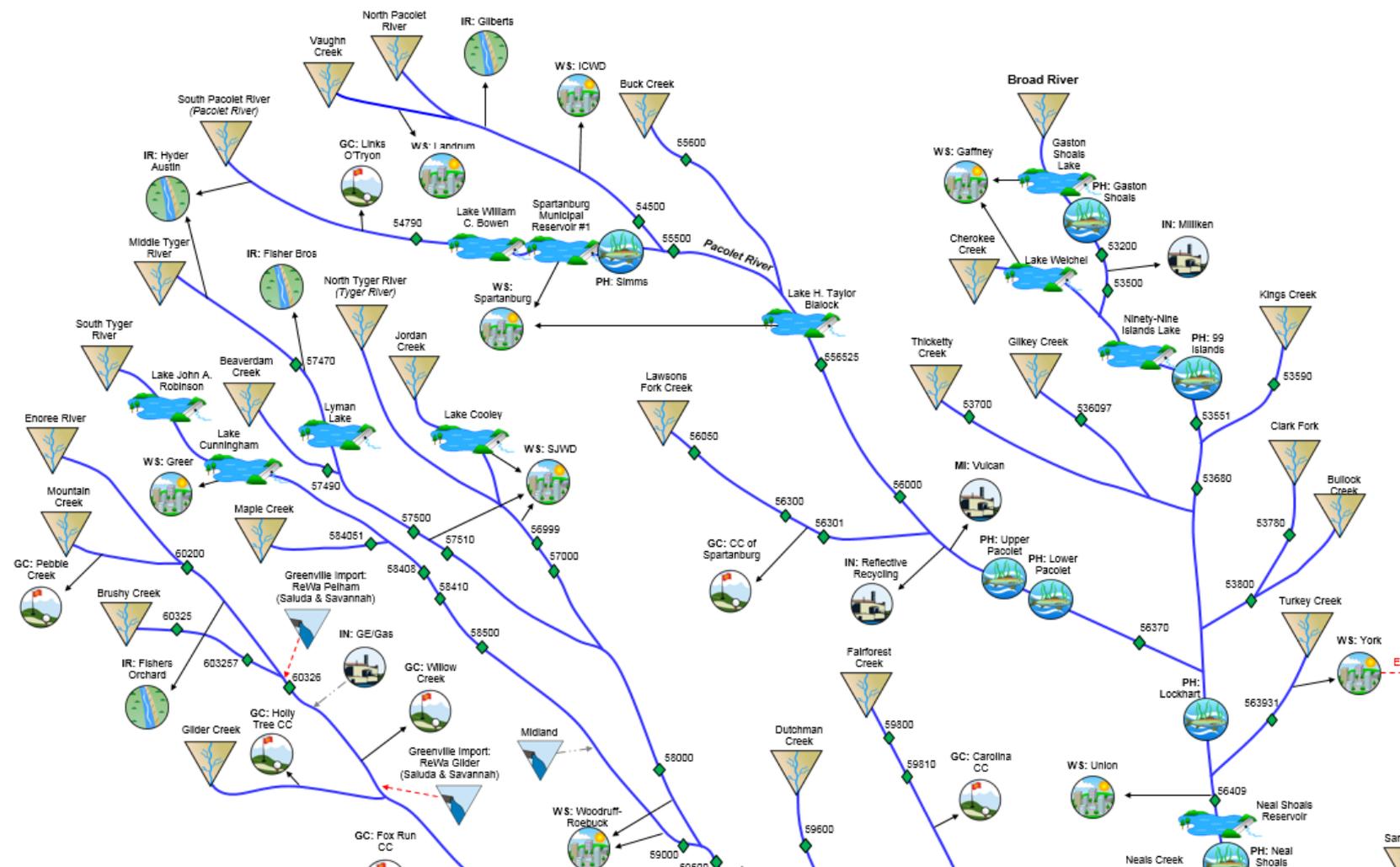
Prior Appropriations
 Riparian Water Rights

Run (ctrl R)

Input Summaries and Outputting

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

Input & Output
 AF, AFM, AFD MG, MGD, CFS m3, m3/d, m3/s



Broad 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

Broad 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

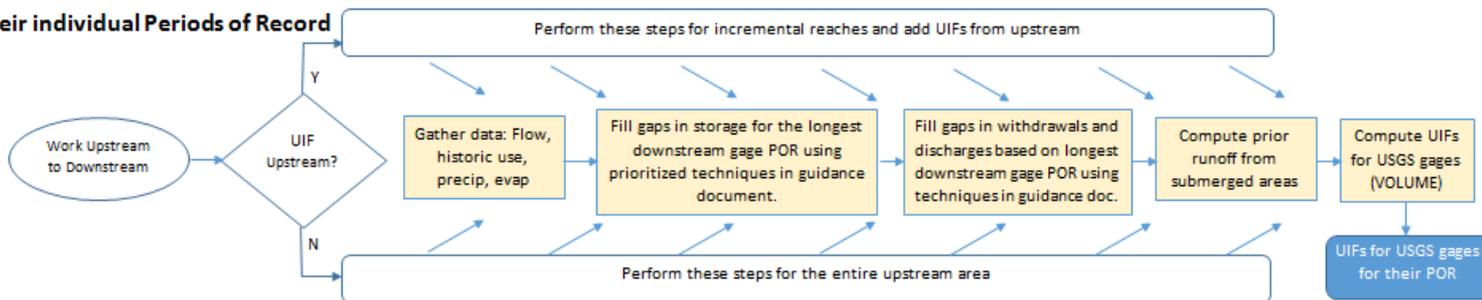
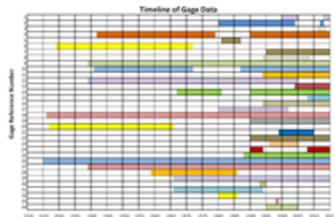
Estimated

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

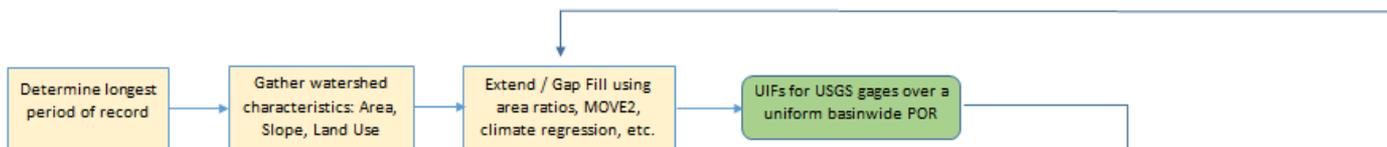
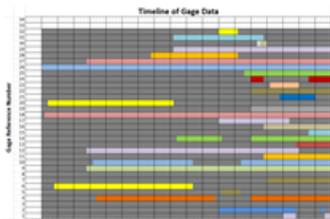
Basinwide UIF Calculation Process

Stepwise Procedure for UIF Calculation – Saluda Basin

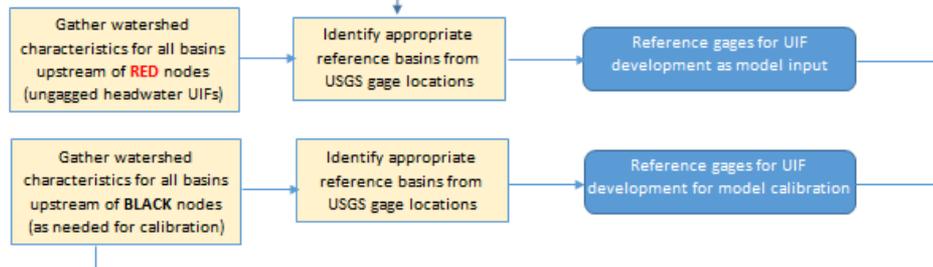
Step 1: UIFs for USGS Gages for their individual Periods of Record



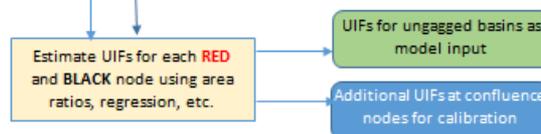
Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record



Step 3: Correlation between Ungaged Basins and Gaged Basins

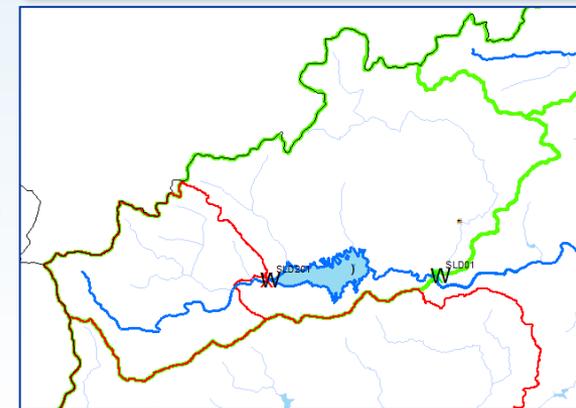
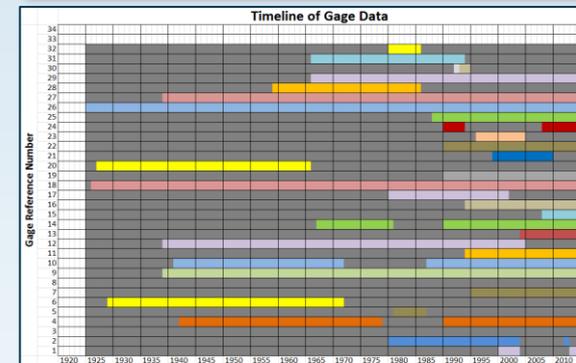
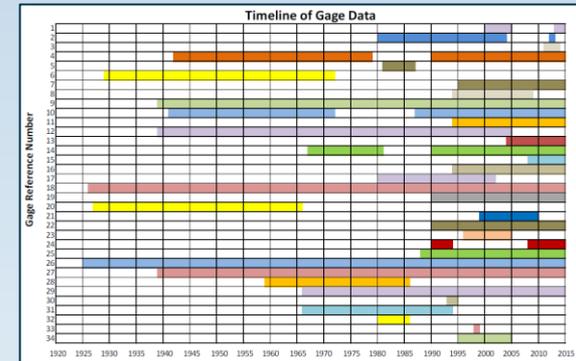


Step 4: UIFs for Ungaged Basins



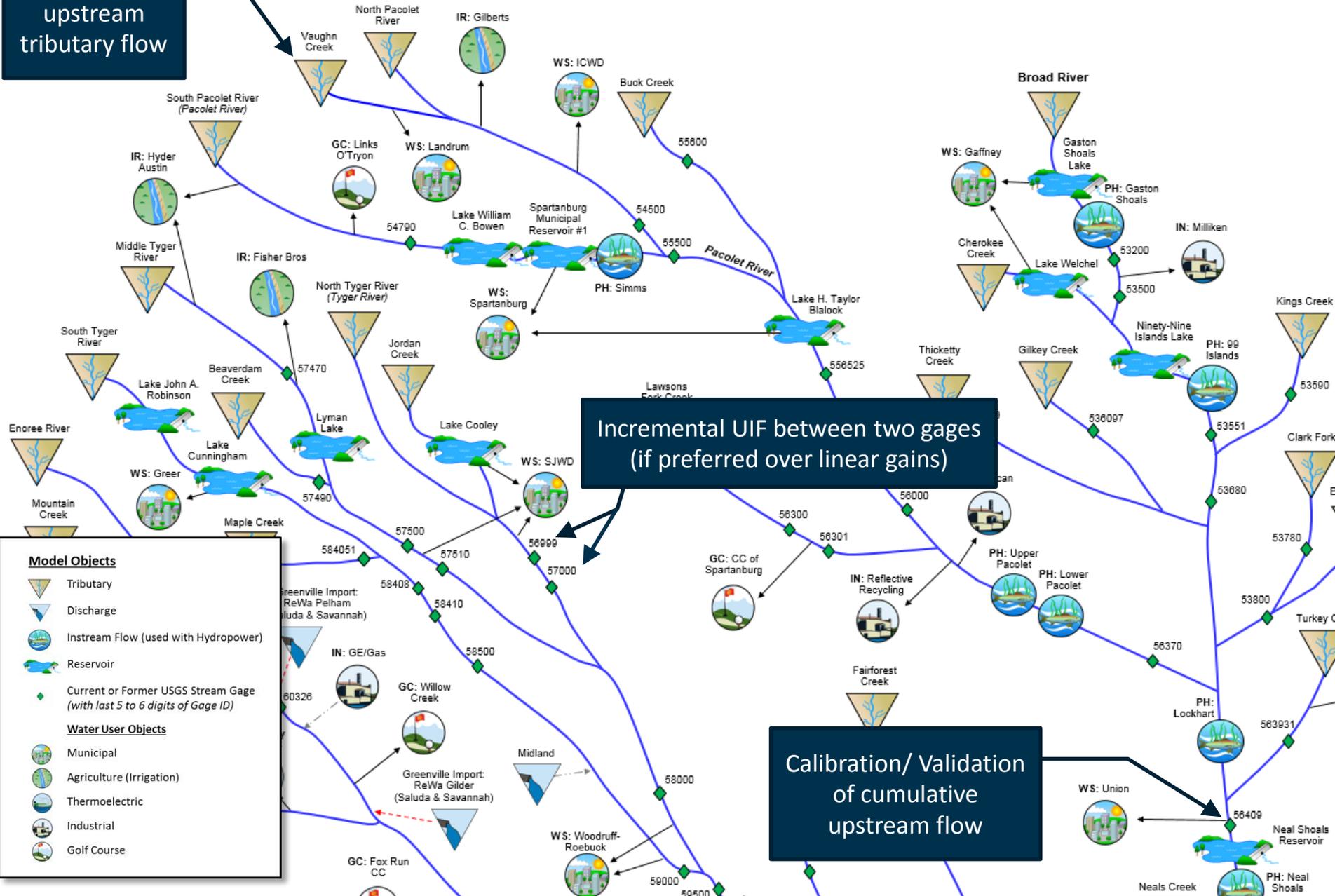
Four Steps in UIF Calculation Process

- **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

Input as upstream tributary flow



Incremental UIF between two gages
(if preferred over linear gains)

Calibration/ Validation
of cumulative
upstream flow

Model Objects

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

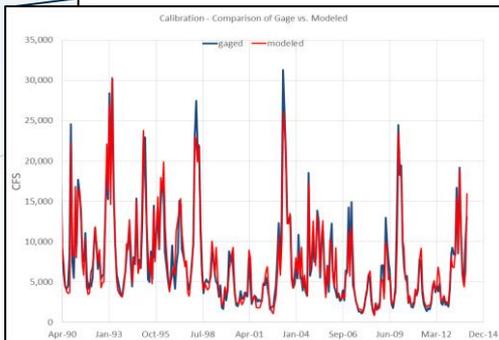
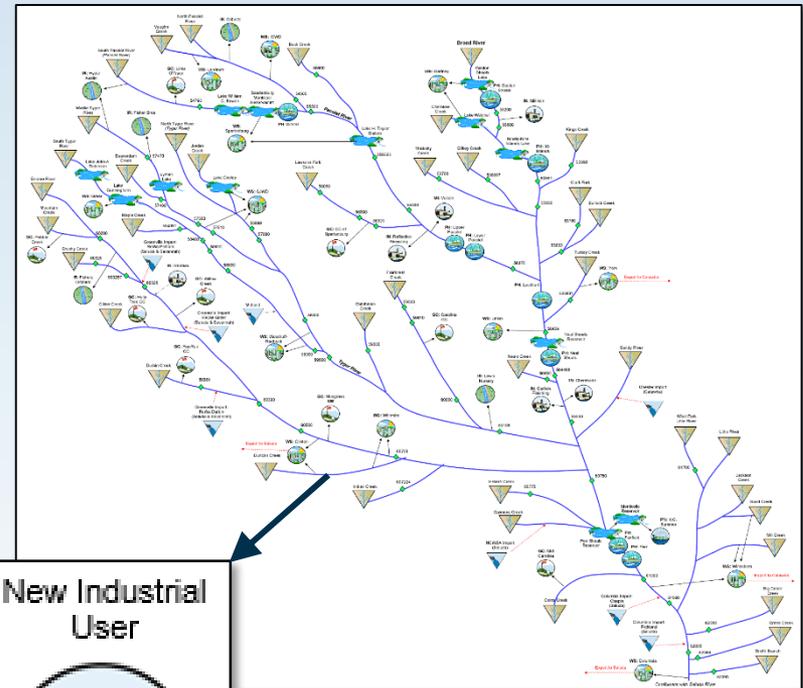
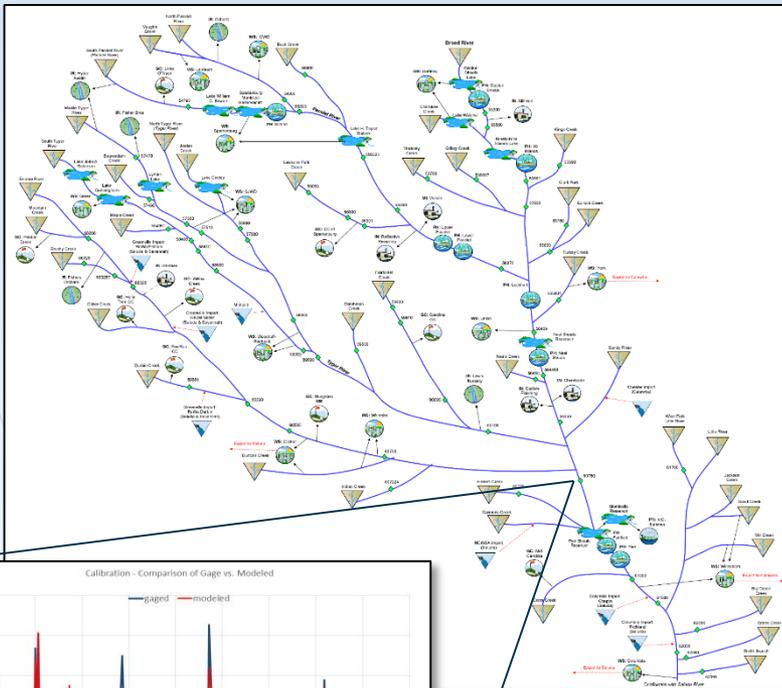
Water User Objects

- Municipal
- Agriculture (Irrigation)
- Thermolectric
- Industrial
- Golf Course

Two Versions of Every Model

Calibration with UIFs and Historic Use Records

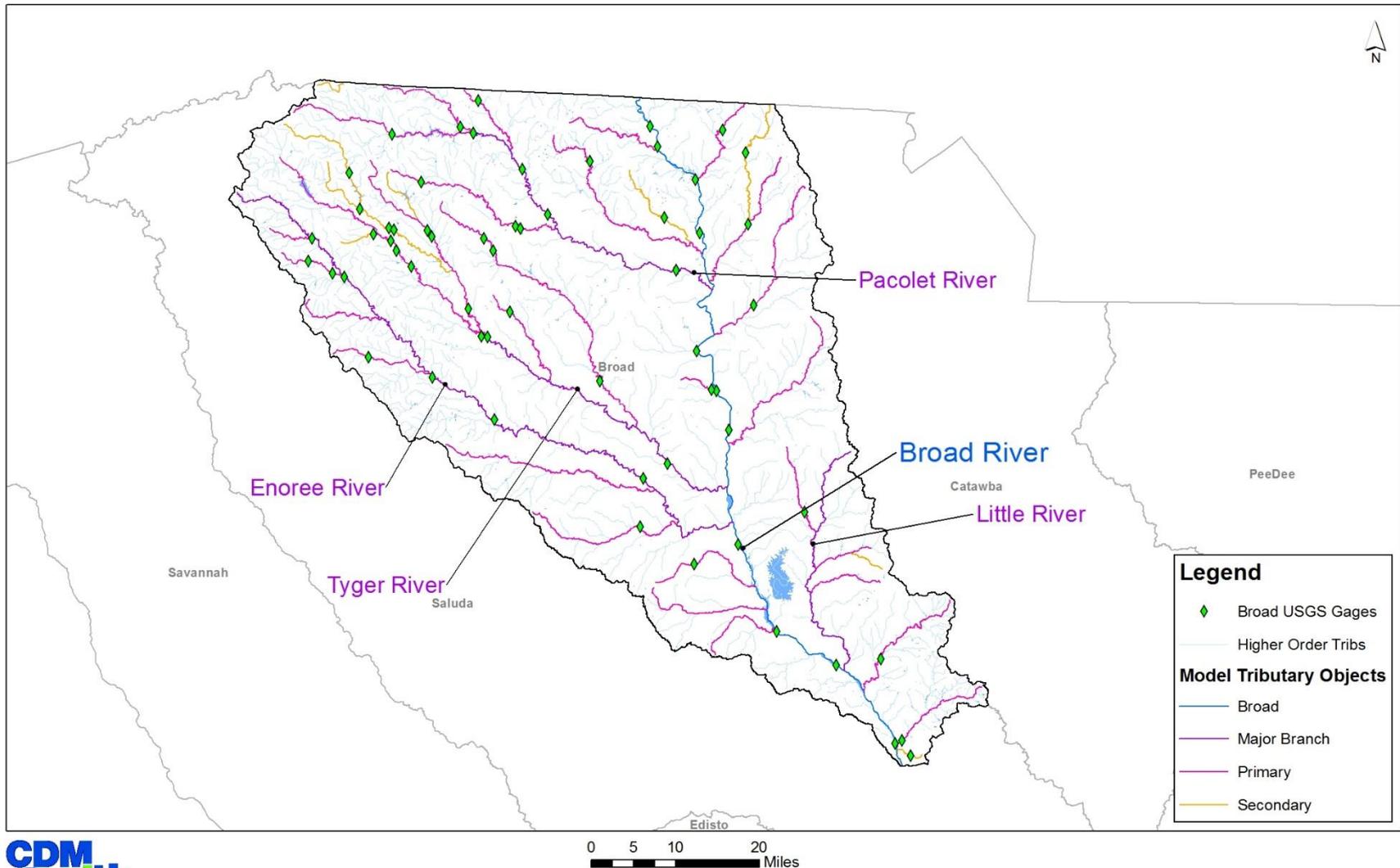
Planning with UIFs, Current Uses, and User-Defined Future Uses



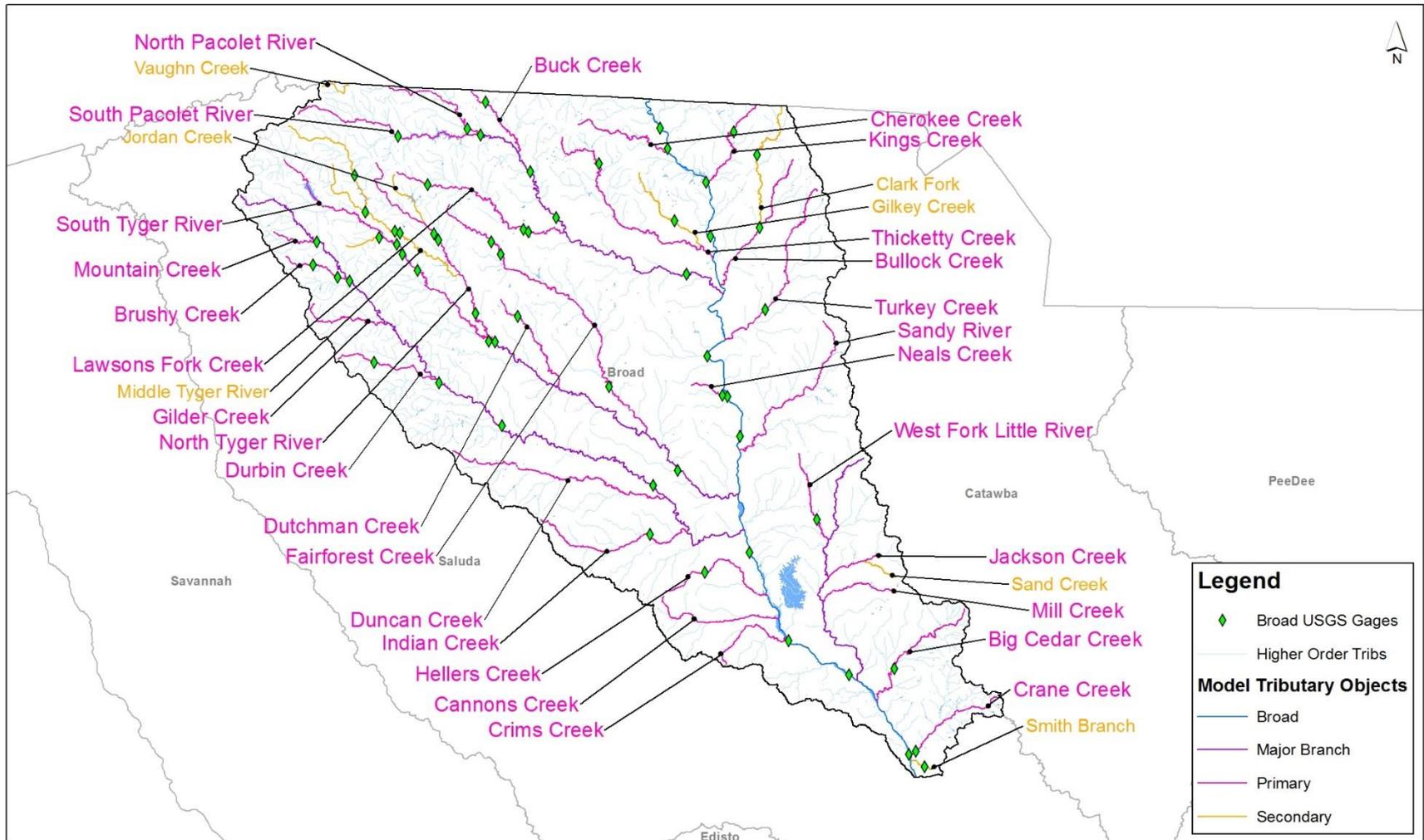
Broad River Basin

OVERVIEW OF MODEL FRAMEWORK

Broad Basin – Main and Major Branches

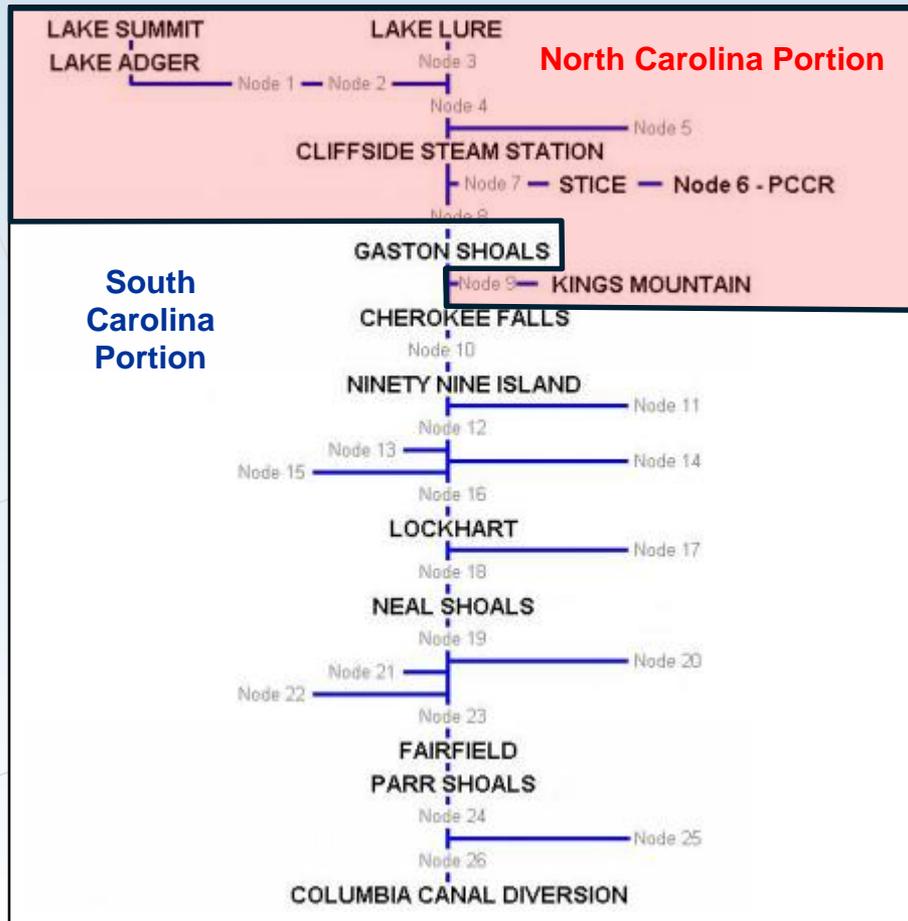


Primary and Secondary Tributaries

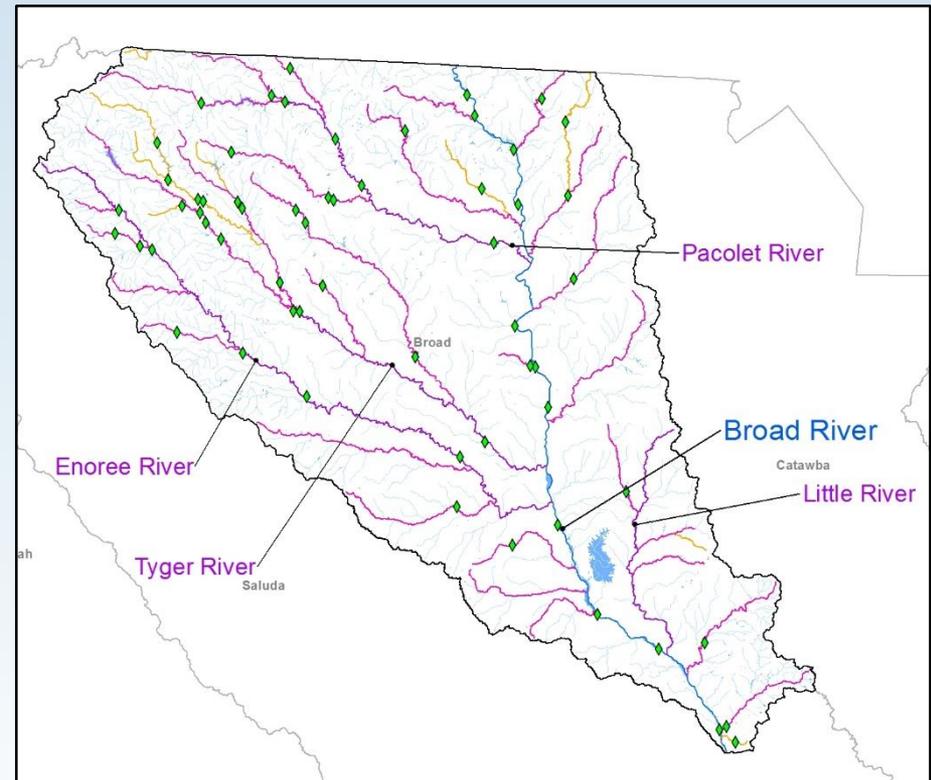


Broad Basin

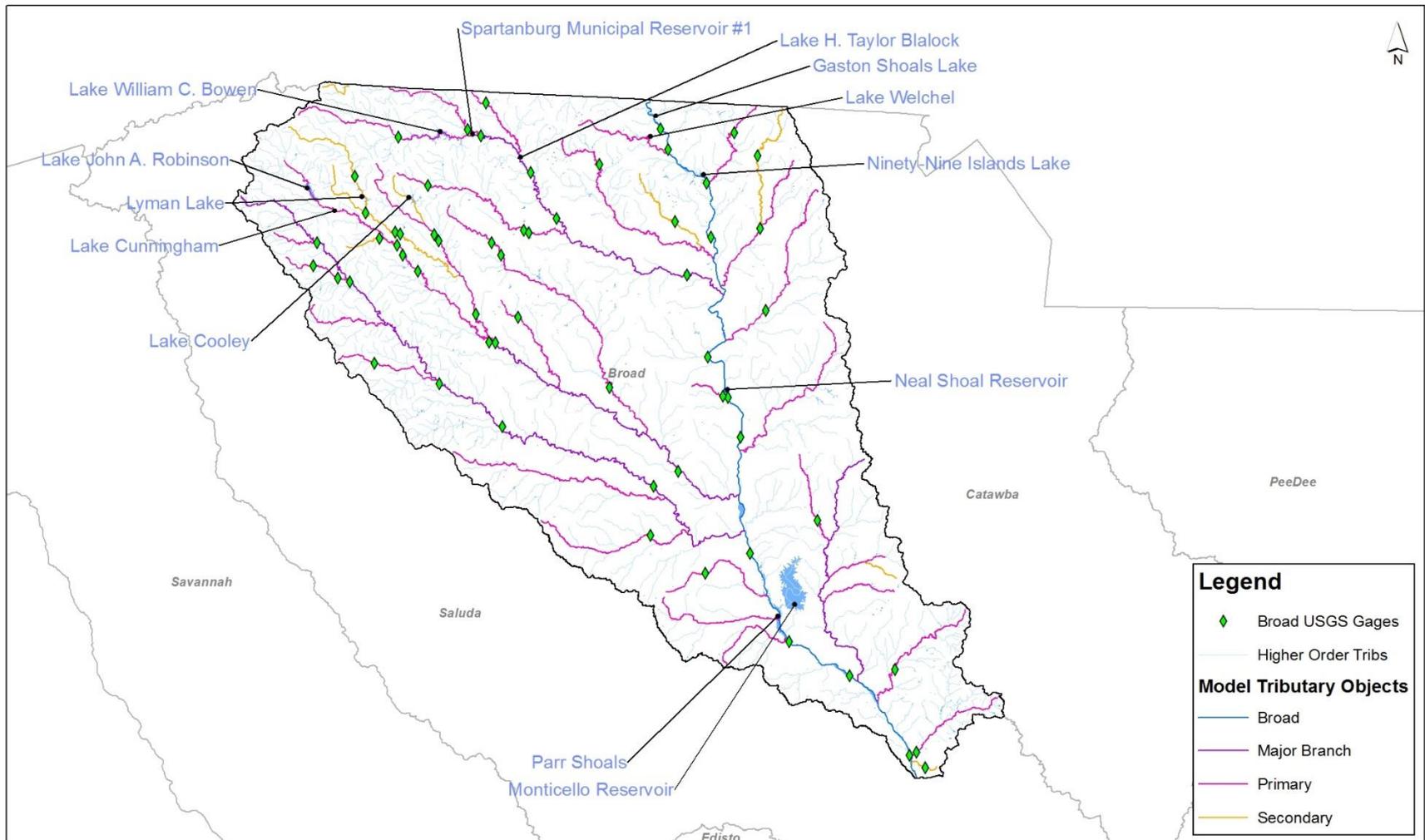
CHEOPS Model Schematic



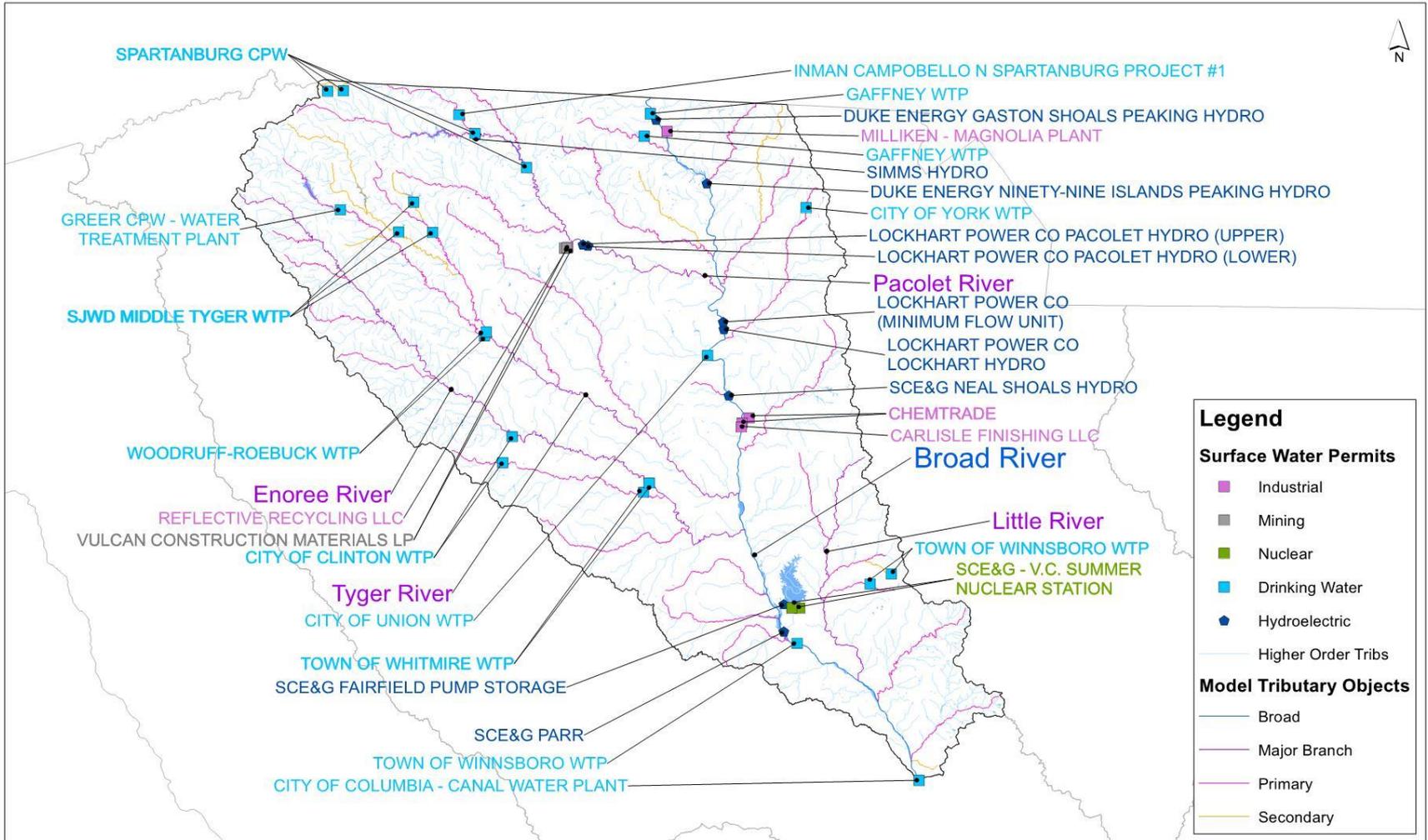
SWAM Model Intended Coverage



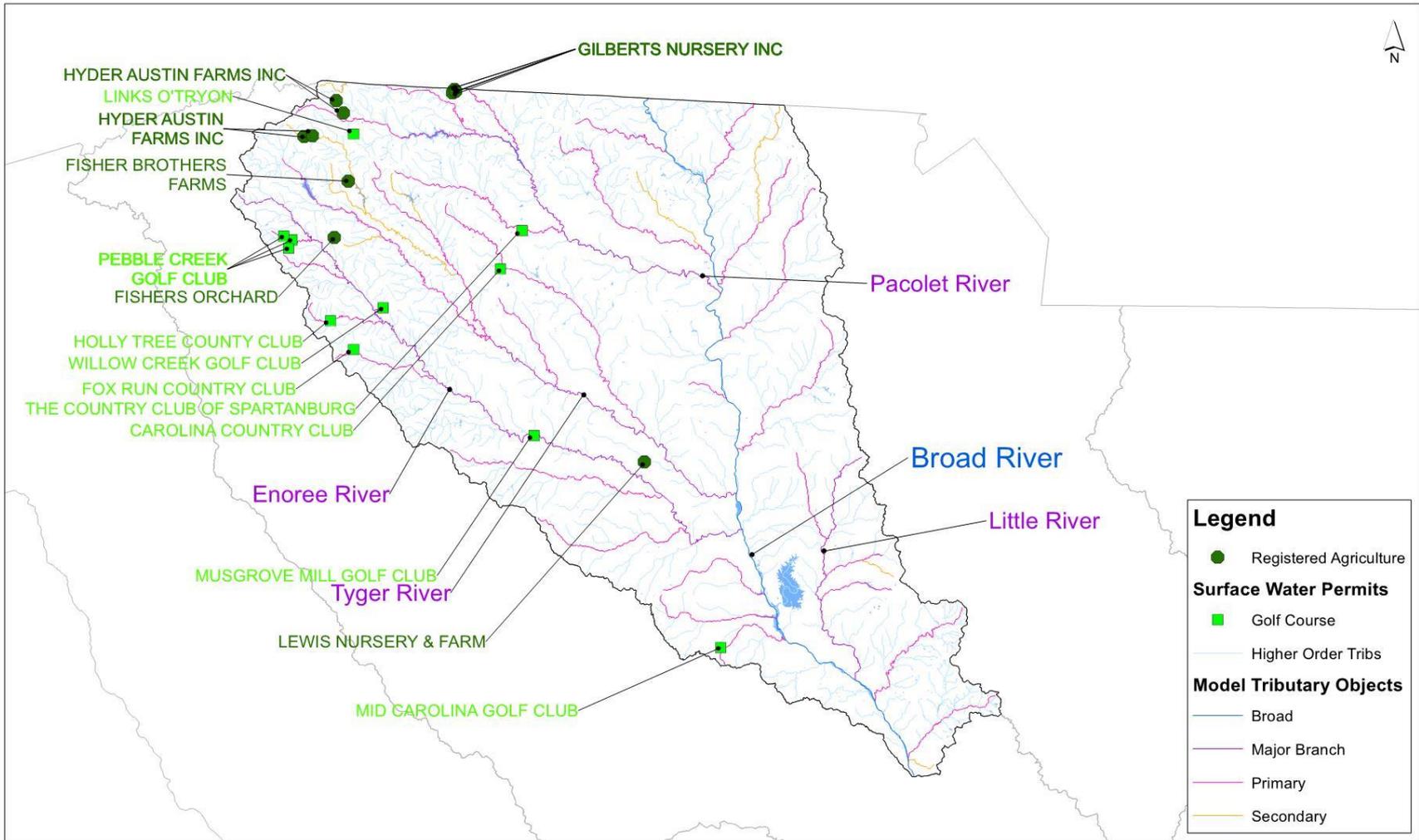
Reservoirs



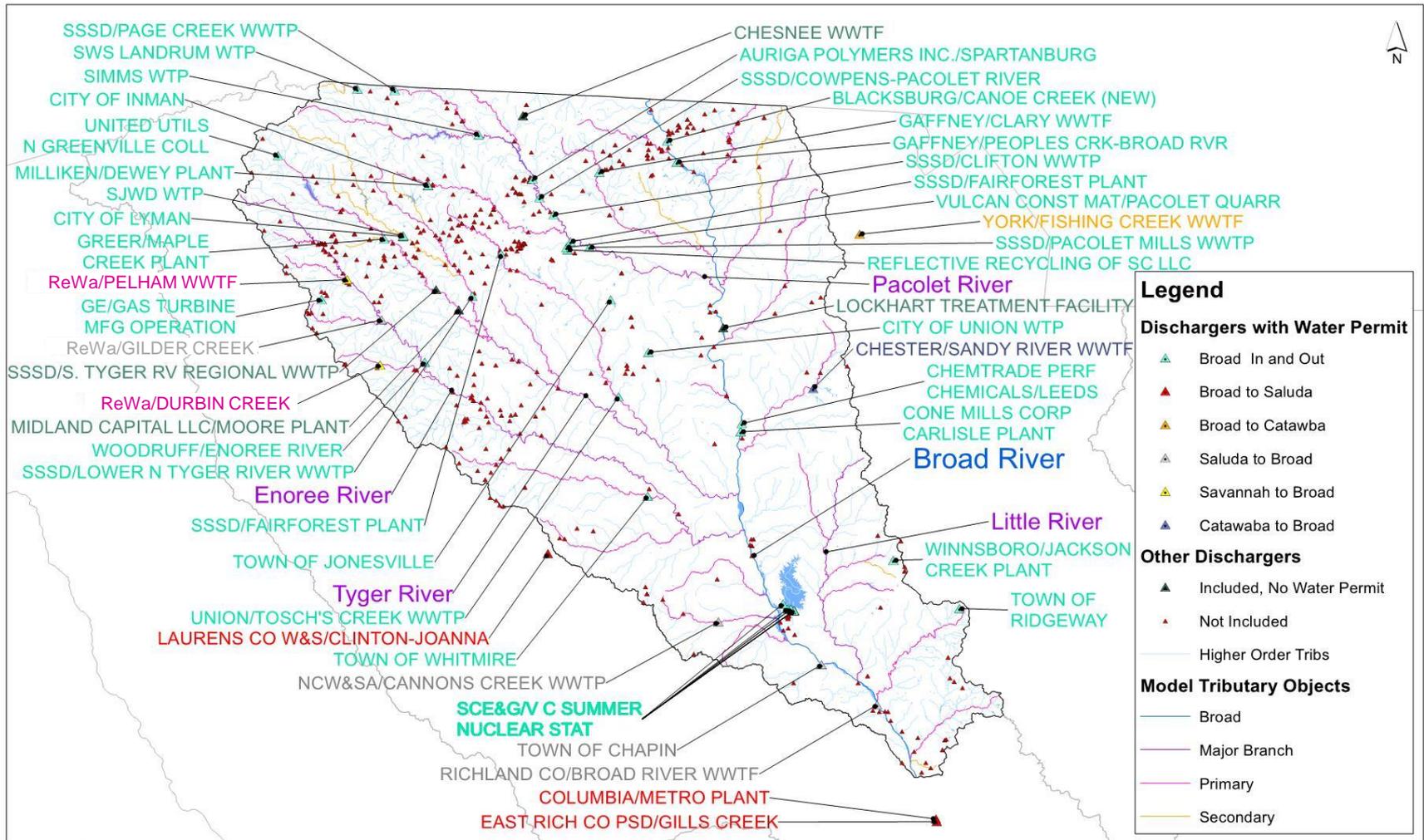
M&I and Energy Surface Water Withdrawals



Surface Water Withdrawals for Irrigation



Discharges to Surface Water



Legend

Dischargers with Water Permit

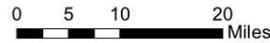
- ▲ Broad In and Out
- ▲ Broad to Saluda
- ▲ Broad to Catawba
- ▲ Saluda to Broad
- ▲ Savannah to Broad
- ▲ Catawaba to Broad

Other Dischargers

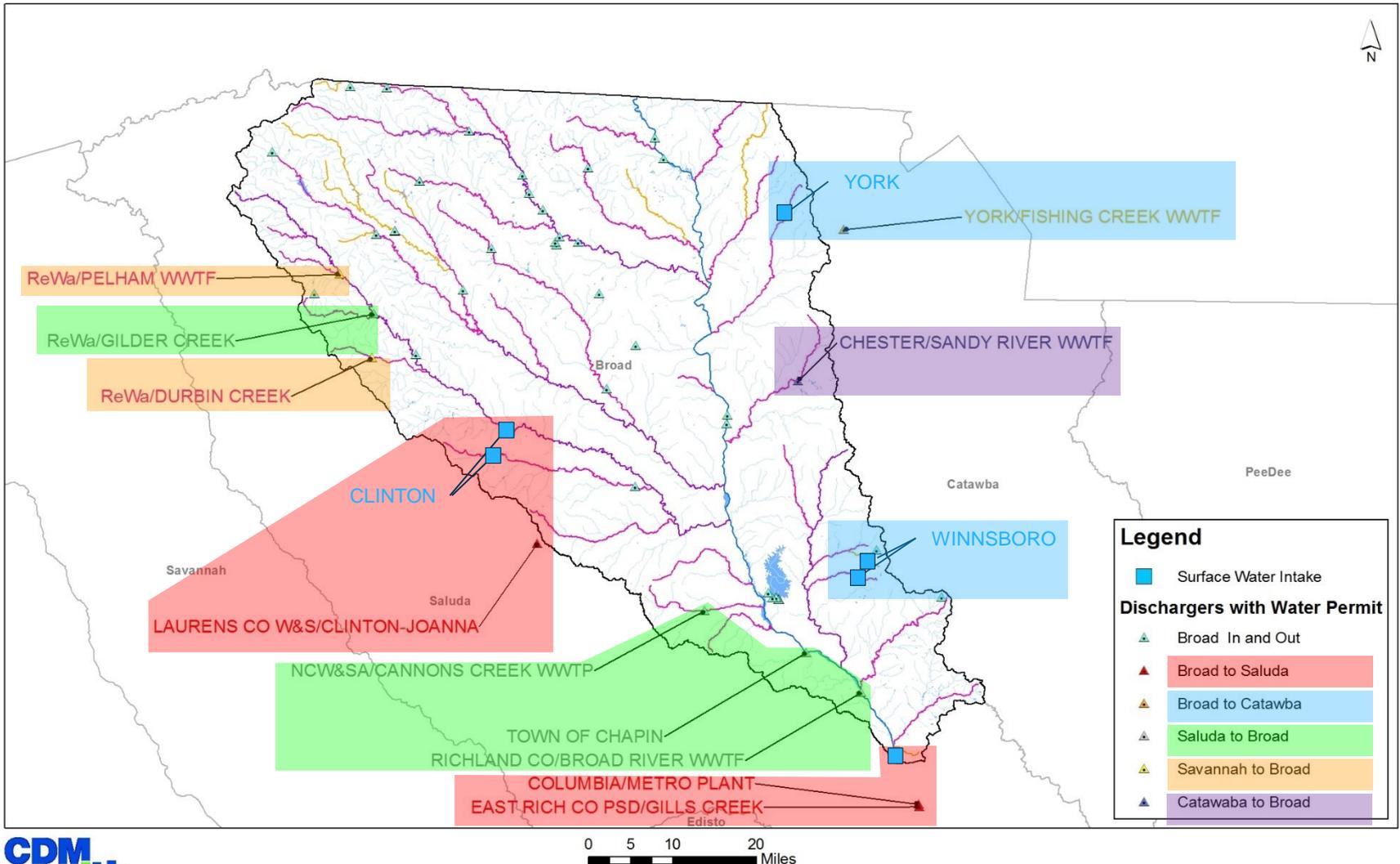
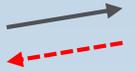
- ▲ Included, No Water Permit
- ▲ Not Included

Model Tributary Objects

- Higher Order Tribs
- Broad
- Major Branch
- Primary
- Secondary



Interbasin Transfers



Broad Basin – SWAM Framework

Model Objects

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

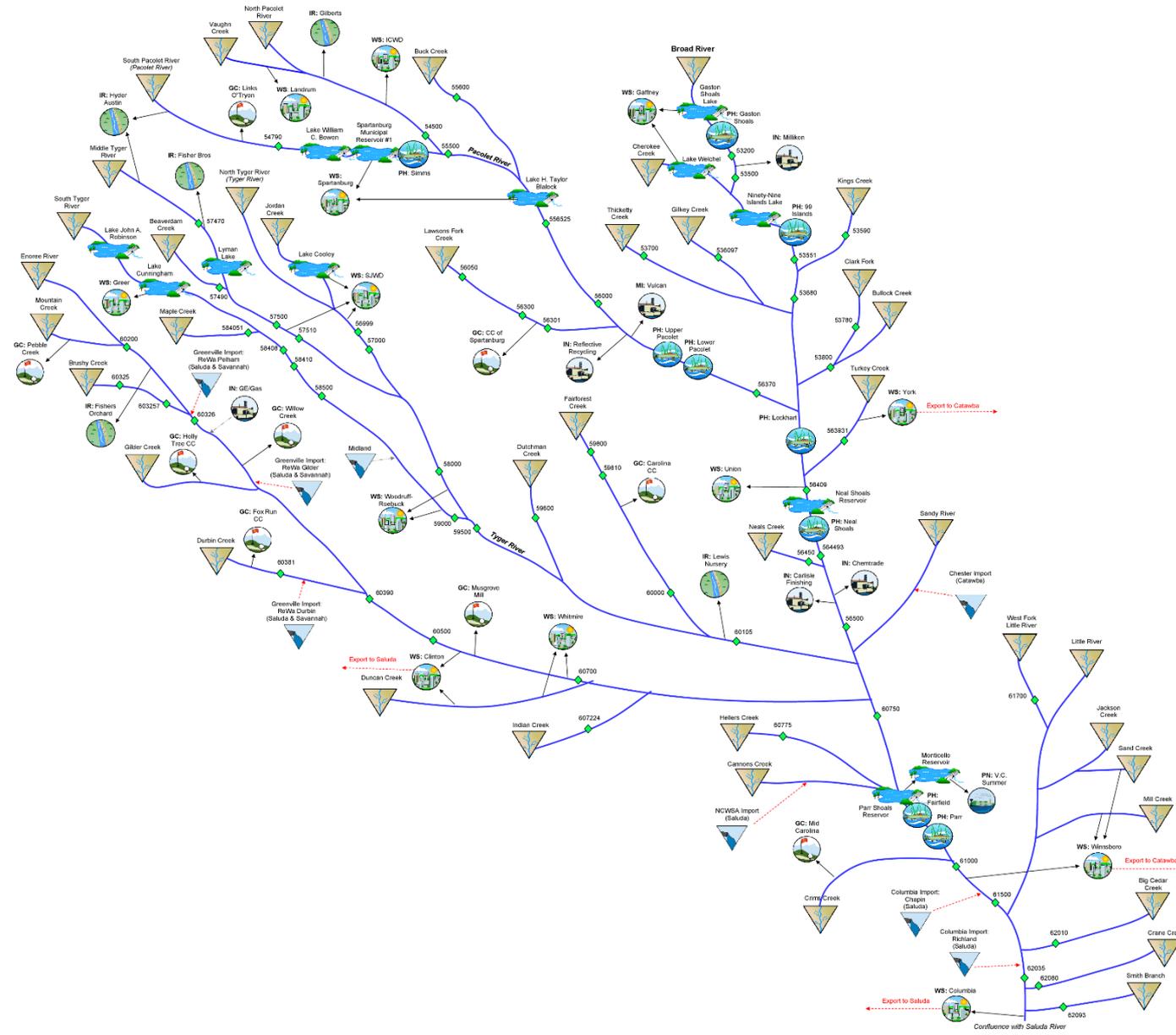
Water User Objects

-  Municipal
-  Agriculture (Irrigation)
-  Thermoelectric
-  Industrial
-  Golf Course

 Import or Export
(Interbasin Transfer)

 Discharge from a
Groundwater User*

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



Broad River Basin

MODEL SETUP

Tributary Input Form

U26

Simplified Water Allocation Model (SWAM) | **Input Summaries and Outputing** | D H E C

Simulation Period
Start Date (MM/DD/YYYY): 01/01/1983 | End Date (MM/DD/YYYY): 12/31/2013



Tributary

Tributary Name:

Delete Tributary **Headwater Flows**

Confluence Stream:

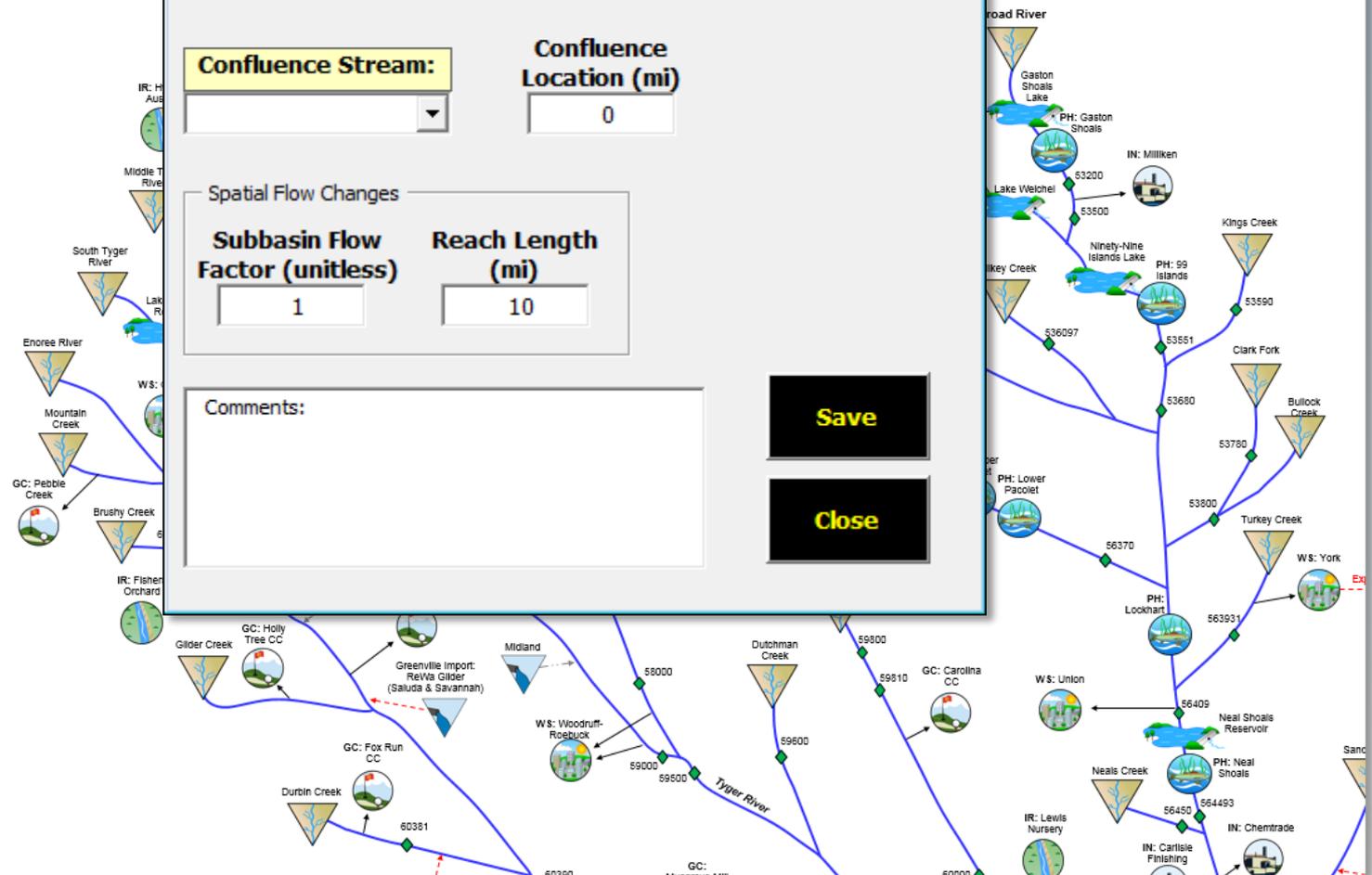
Confluence Location (mi):

Spatial Flow Changes

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

Comments:

Save **Close**



Water User Input Form – Main

U26

Water User

Main | Water Usage | Source Water | Return Flows

Water User Name: **Delete**

Supplemental S...

Cons

Reca

Ag T

Comments:

Water User

Main | Water Usage | Source Water | Return Flows

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

1/1/2008

Ditch Capacity

Permit Limit

(AFM) (AFM)

Seasonal Permit

Storage Withdrawal Permit

Save

Close

Storage

Reservoir Name:

(AF) Storage Capacity

(AFY) Storage Right

Water Year Start Mo. (1 - 12)

1

Carry Over Rule

Identifying Notes:

Object Palette

D H E C

UNIVERSITY OF CALIFORNIA

LOCK

WS: York

60381

Nursery

IN: Chemtrade

IN: Carlisle Finishing

GC:

60380

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Agricultural Water User Input Forms

U26

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

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

Instream Flow Input Form

U26



Instream Flows

Water Right

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

Priority Date [1/1/2007]

Rules

- Seasonal WR**
- TNC IHA Methodology**

Avg. Monthly Flow Rights

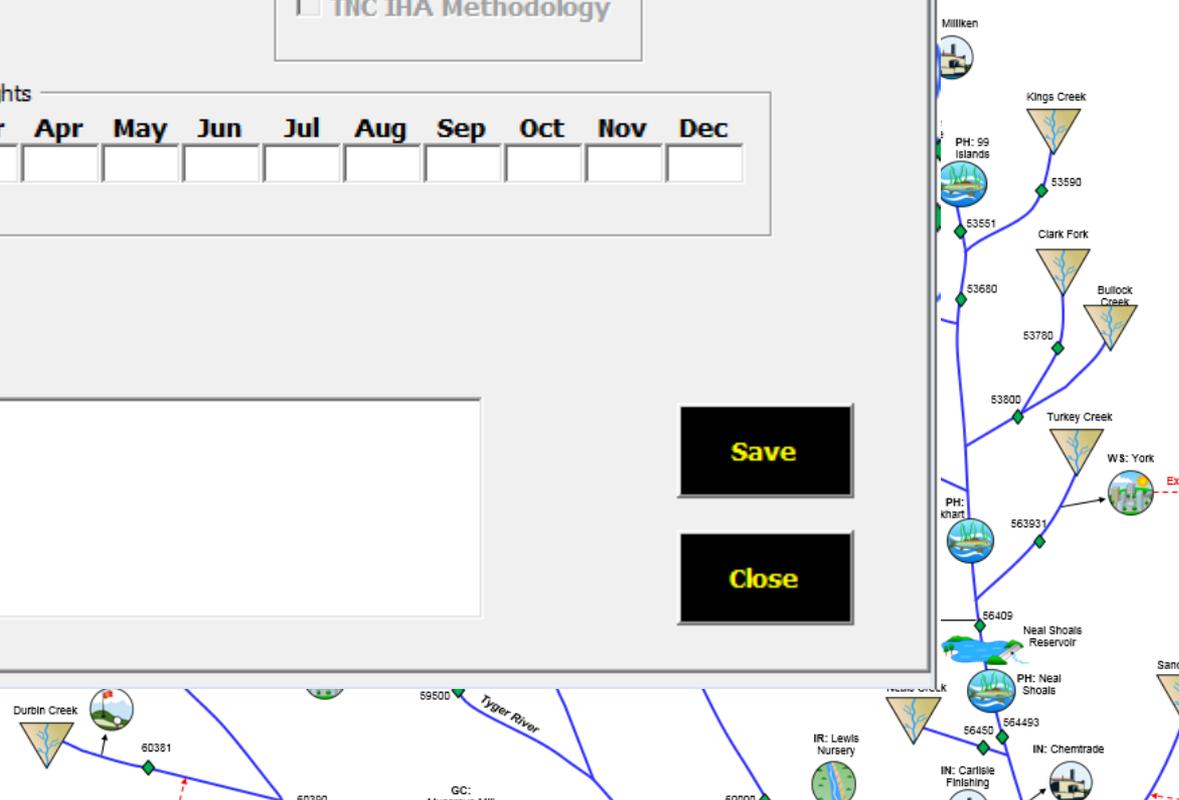
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

(CFS)

Comments: [Text Area]

Save

Close



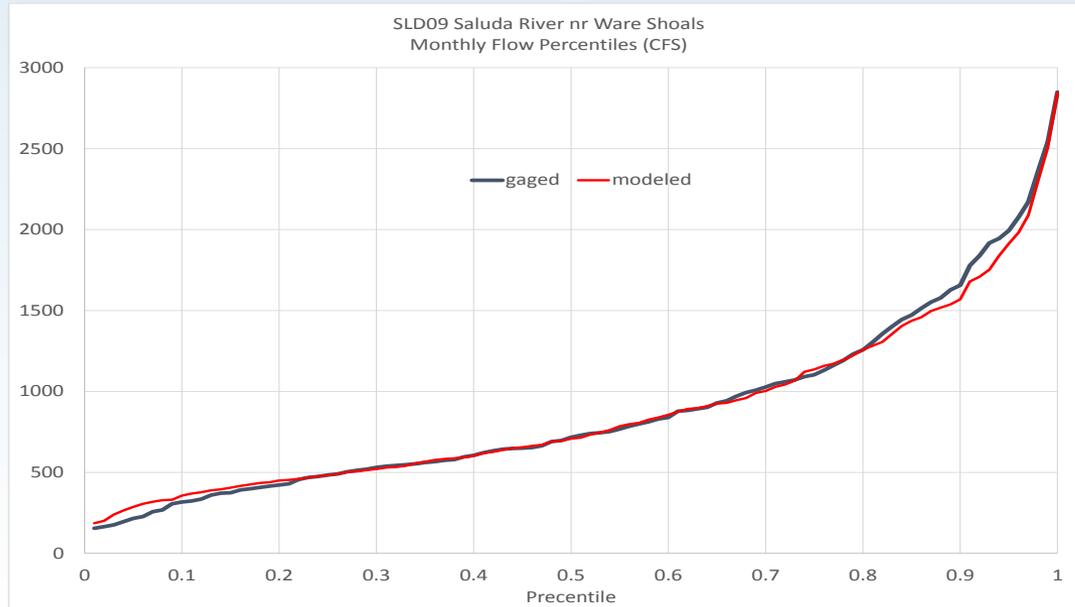
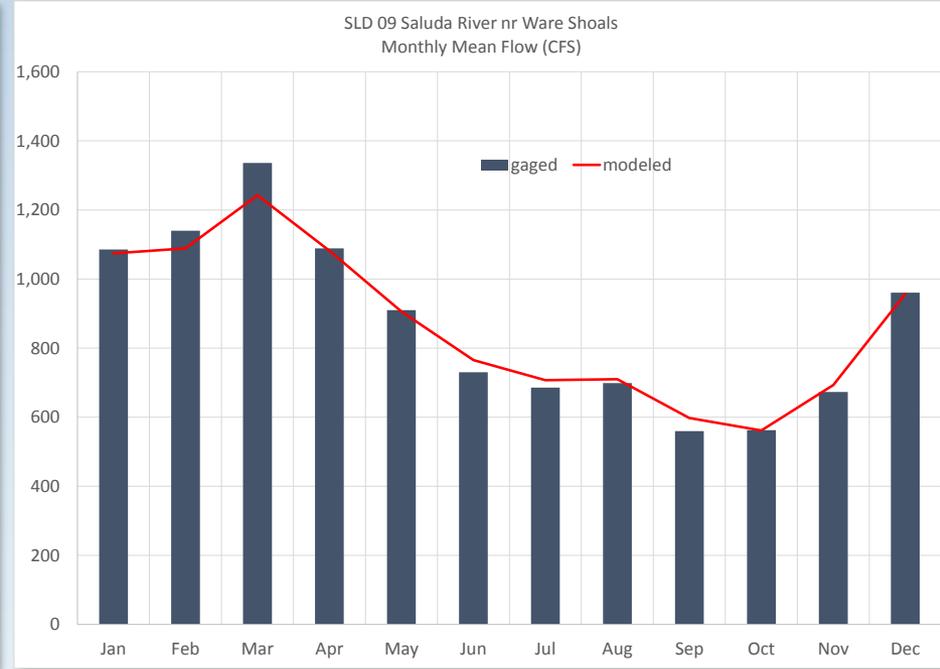
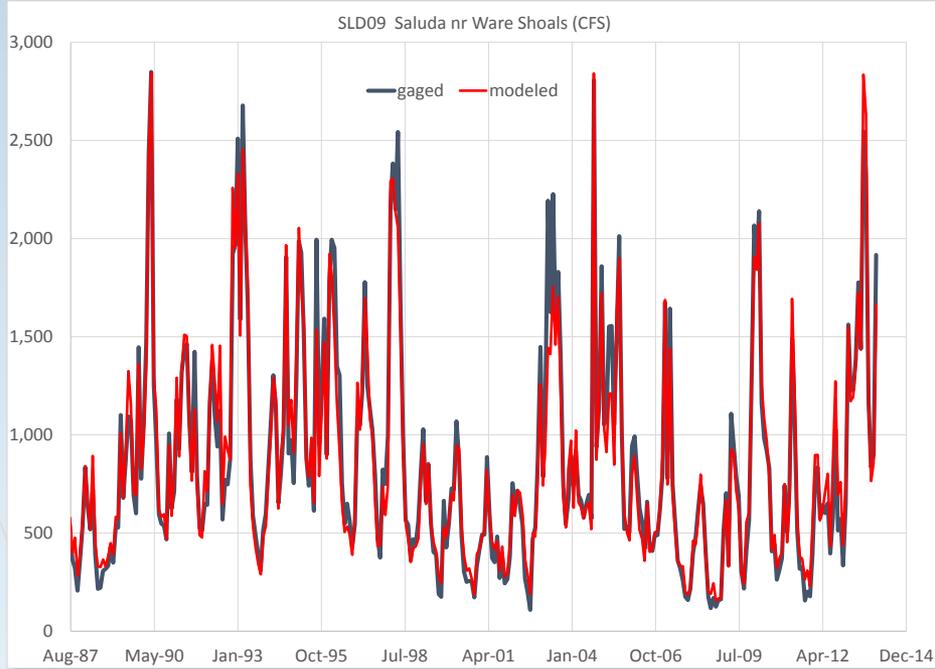
Broad River Basin

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)
 - Reservoir storage timeseries

Calibration Result Graphs



Preliminary
examples
from the
Saluda Basin

Broad River Basin

THANK YOU