

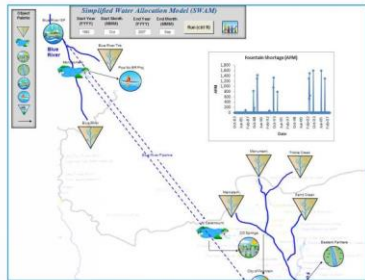
South Carolina Surface Water Quantity Modeling Project

Catawba-Wateree River Basin Meeting No. 1 – Model Framework

Kirk Westphal, PE
John Boyer, PE, BCEE

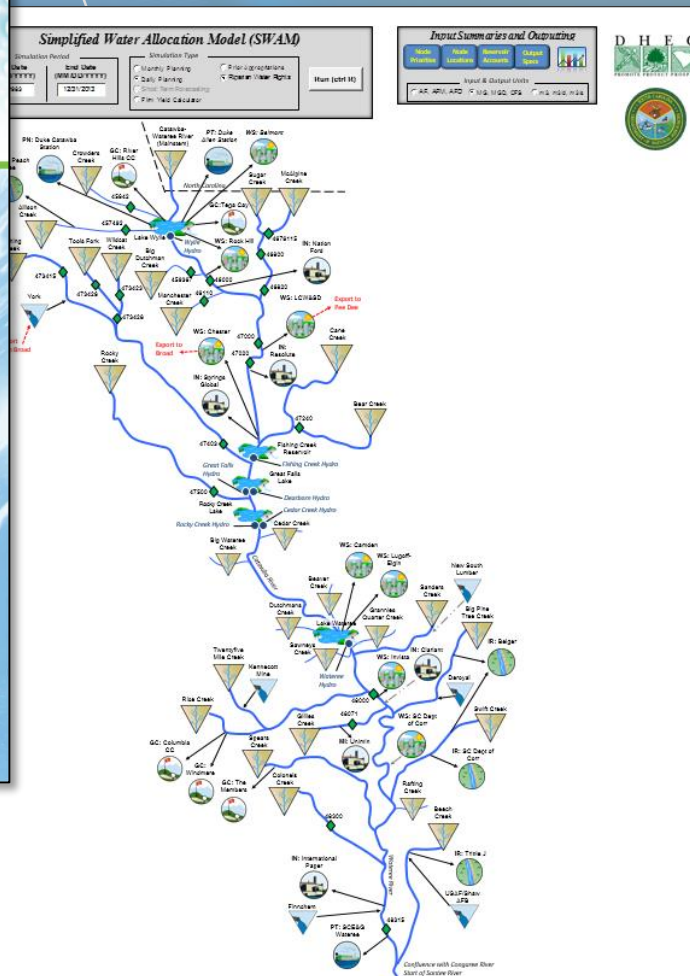
November 4, 2015

Simplified Water Allocation Model (SWAM)



VERSION 3.0
USER'S MANUAL

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



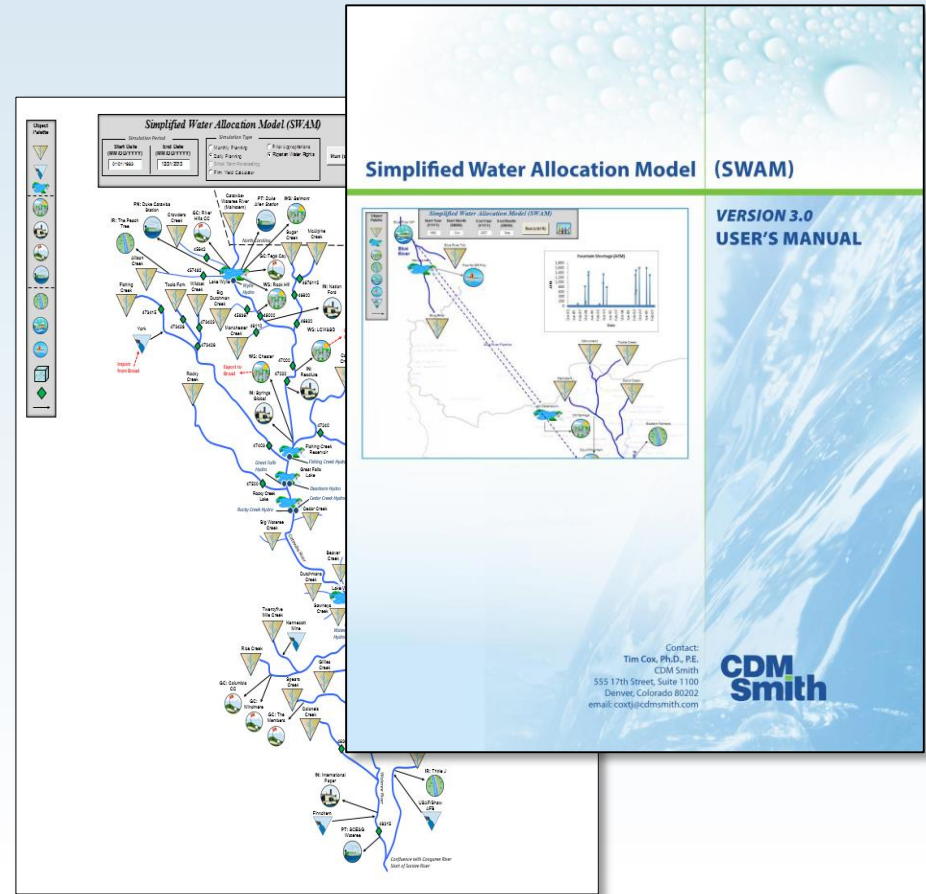
Project Purpose

- 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

Input Forms

Agricultural Water User - Input Form 1

Main | Source Water | Return Flows

User Name: [] **Delete Node** Multiple Sources of Water ?

Supplemental Supply/Demand Alternatives

Transbasin Import Groundwater

Demands

user-defined ag calculations **Edit Demands**

Agricultural Water User - Input Form 2

Main | Source Water | Return Flows

Return Flow Locations

single point multiple points

Receiving Stream: [] RF Location (mi): [0] Time Lag (months): [0]

Monthly Return Flows

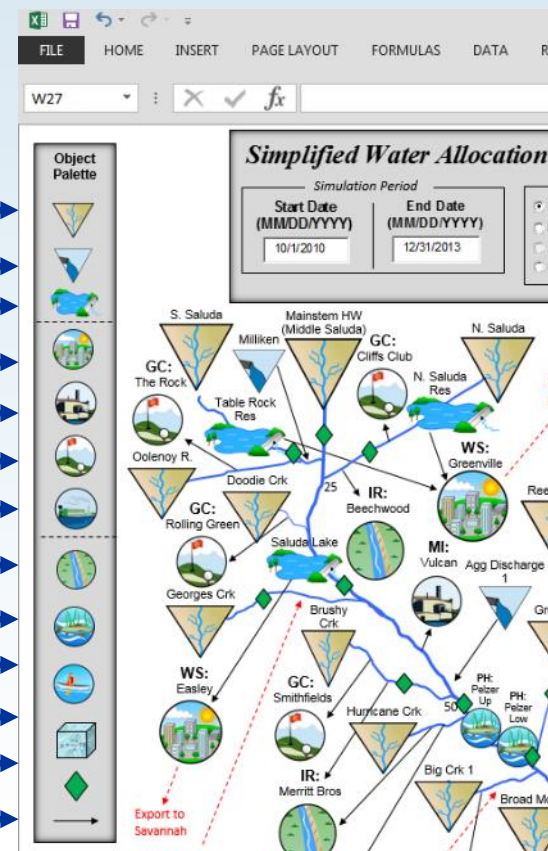
Return Flow %	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0

Save Close

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

Agricultural Water User

Main | Source Water | Return Flows |

User Name: **Delete Node** Multiple Sources of Water ?

Supplemental Supply/Demand Alternatives | Demands

Agricultural Water User

Main | Source Water | Return Flows |

Source Stream: Source Water Type: Direct River Reservoir

Downstream Location (mi) Priority Date

Agricultural Water User

Main | Source Water | Return Flows |

Return Flow Locations: single point multiple points

Receiving Stream: RF Location (mi) Time Lag (months)

Monthly Return Flows

Return Flow %	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0

Node Output

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
C7 1519.40002441406										
	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
	Output			Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AE)	
1										
2			Pueblo4	32	Mainstem	136	420	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

AC36 X ✓ fx

Simplified Water Allocation Model (SWAM)

Simulation Period

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

Simulation Type

<input type="radio"/> Monthly Planning	<input type="radio"/> Prior Appropriations
<input checked="" type="radio"/> Daily Planning	<input type="radio"/> Riparian Water Rights
<input type="radio"/> Short Term Forecasting	
<input type="radio"/> Firm Yield Calculator	

Run (ctrl R)

Input Summaries and Outputting

Node Priorities
Node Locations
Reservoir Accounts
Output Specs

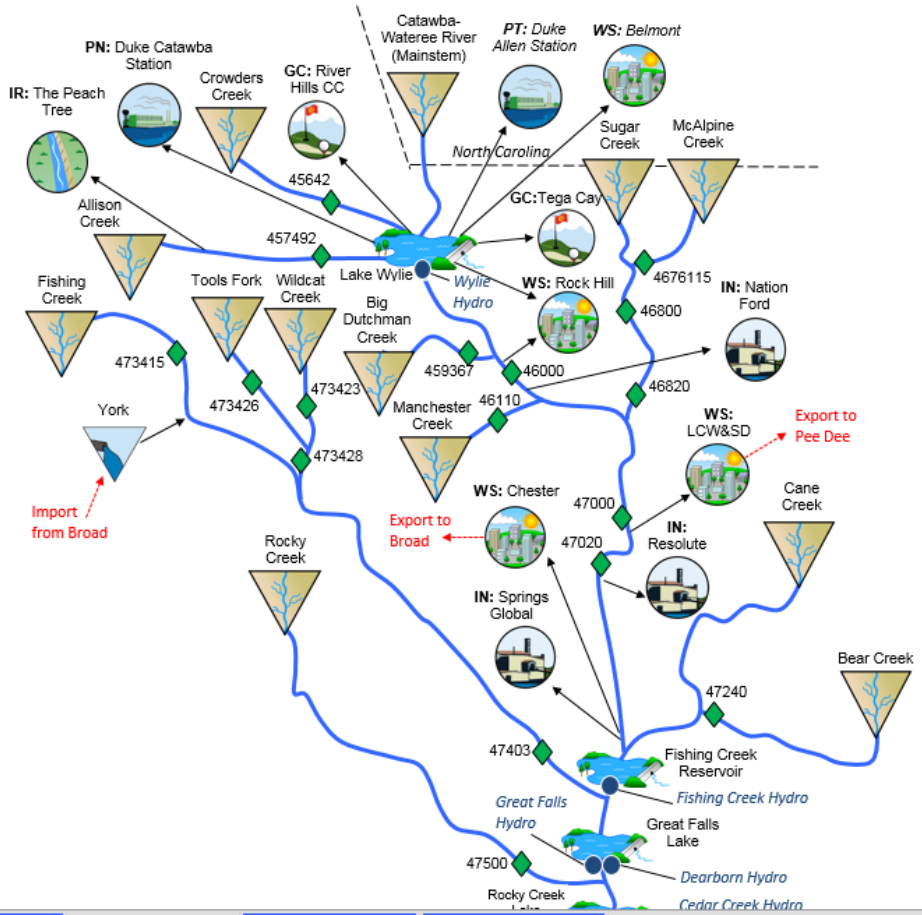
Input & Output

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



Object Palette

-
-
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-



Catawba-Wataree 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
- CWWMG data, studies, and model

Catawba-Wateree 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
- CWWMG Inflow Dataset

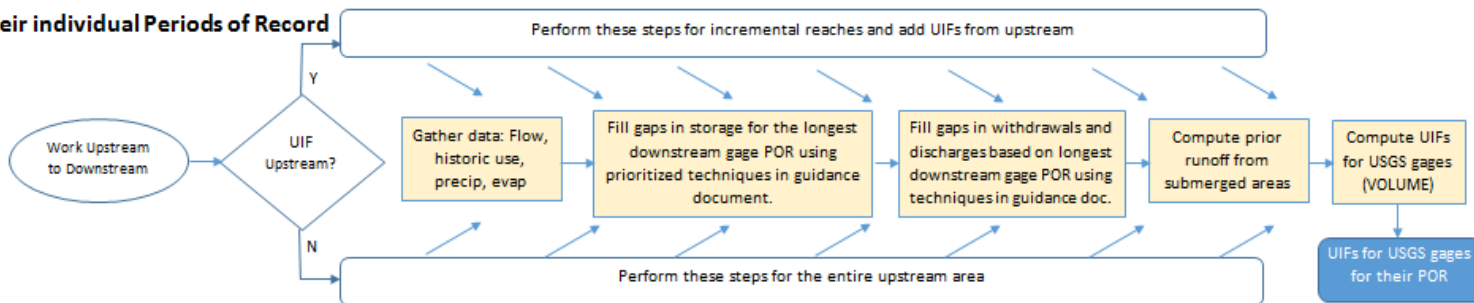
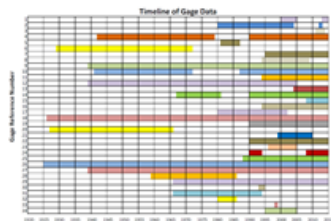
Estimated

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

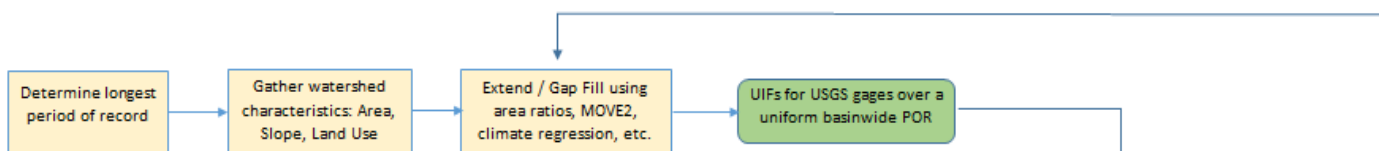
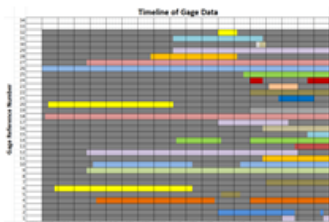
Basinwide UIF Calculation Process

Stepwise Procedure for UIF Calculation – Saluda Basin

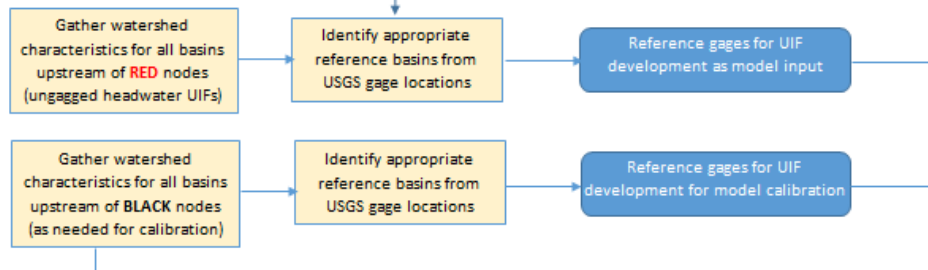
Step 1: UIFs for USGS Gages for their individual Periods of Record



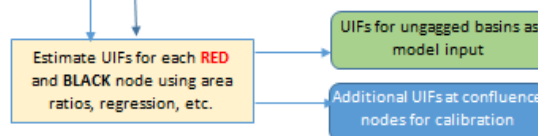
Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record



Step 3: Correlation between Ungaged Basins and Gaged Basins

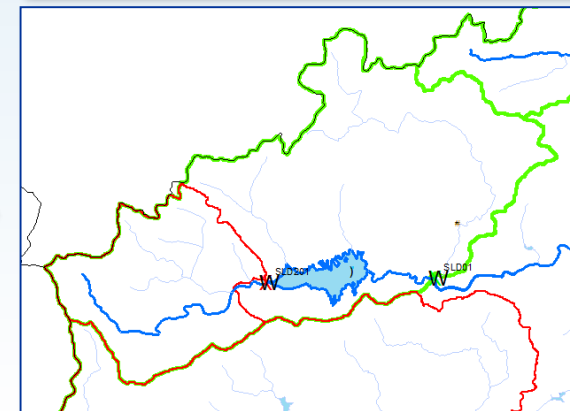
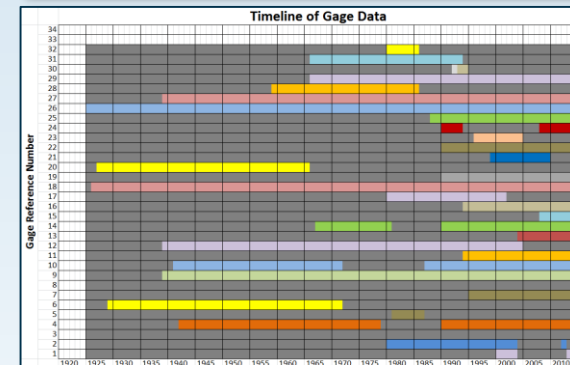
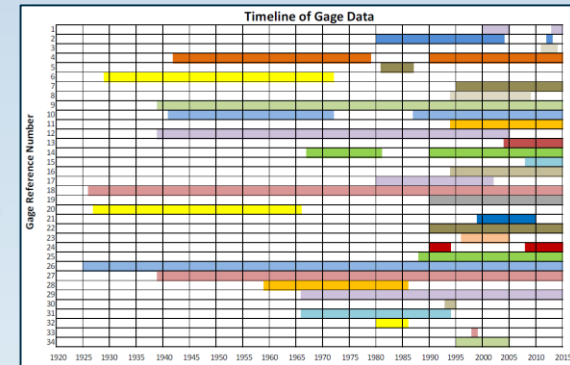


Step 4: UIFs for Ungaged Basins

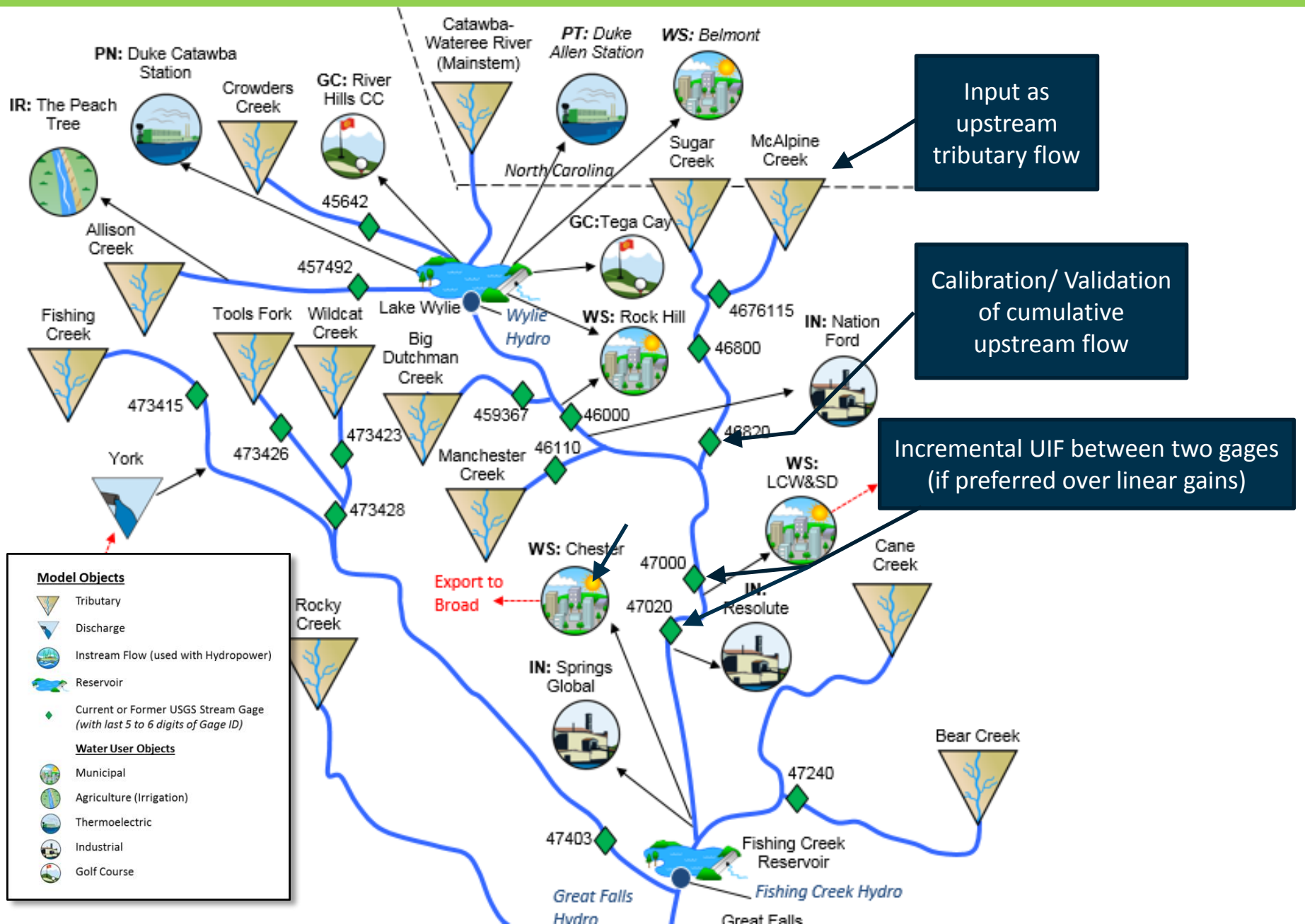


Four Steps in UIF Calculation Process

- **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



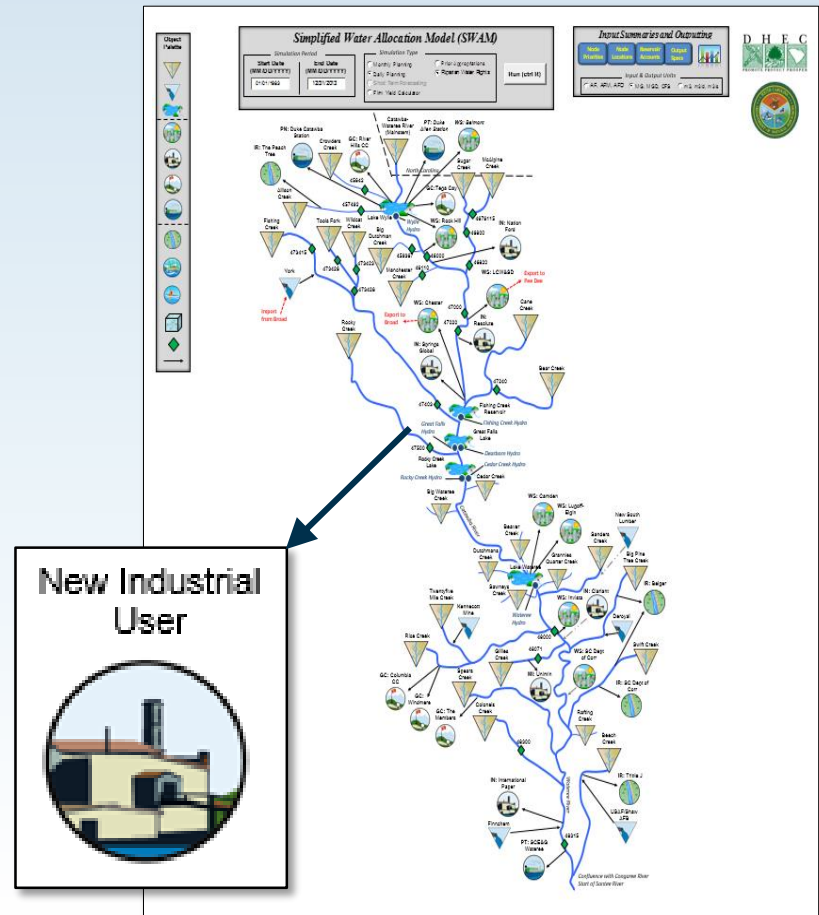
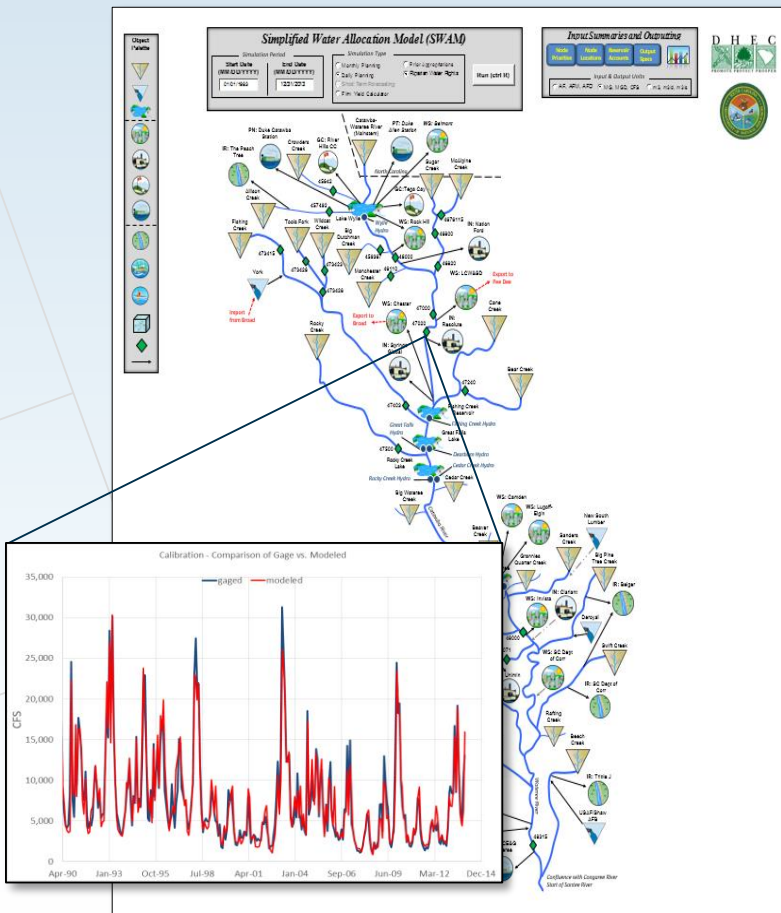
How UIFs are Used in SWAM



Two Versions of Every Model

Calibration with UIFs and Historic Use Records

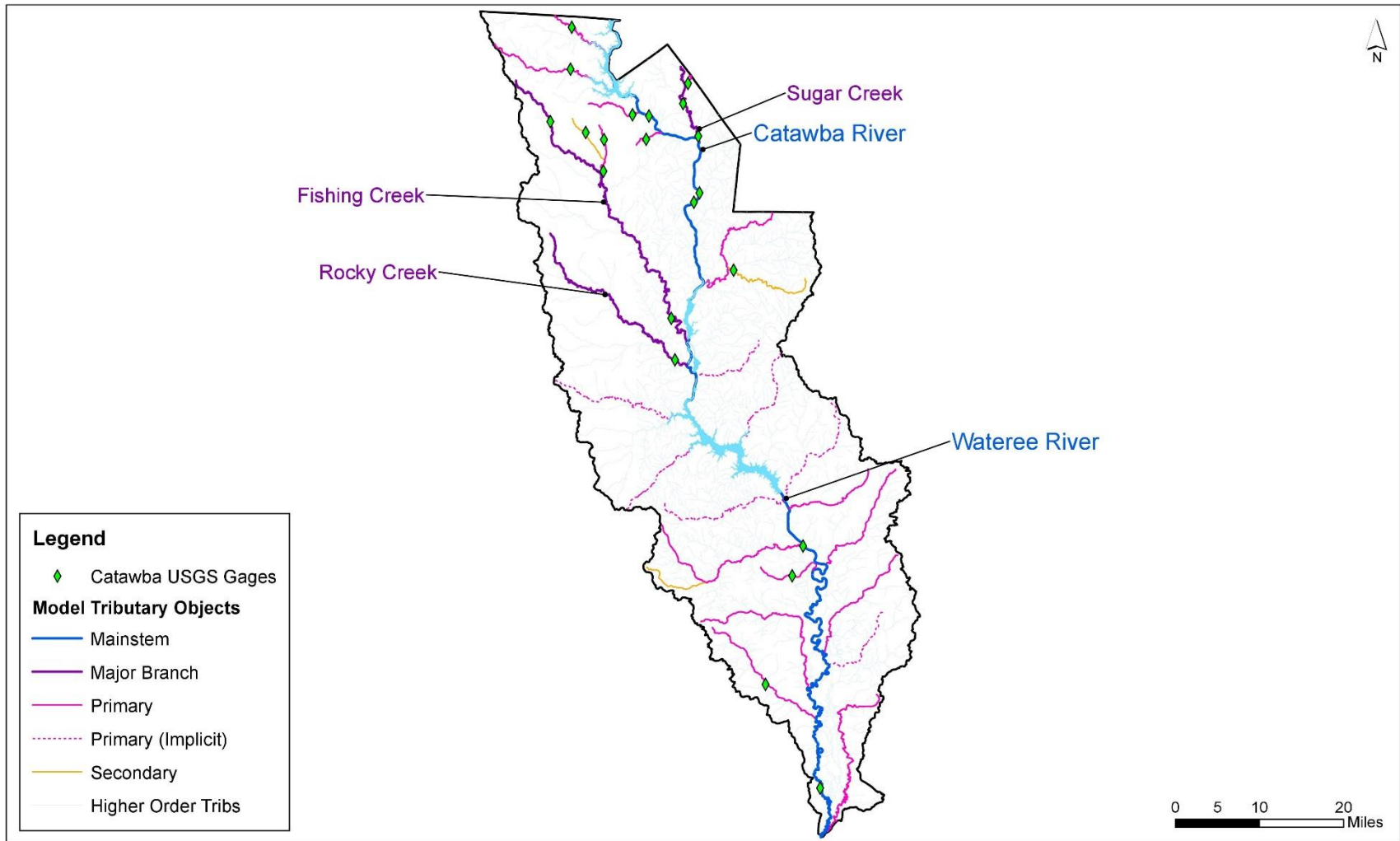
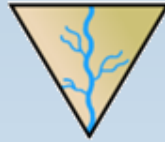
Planning with UIFs, Current Uses, and User-Defined Future Uses



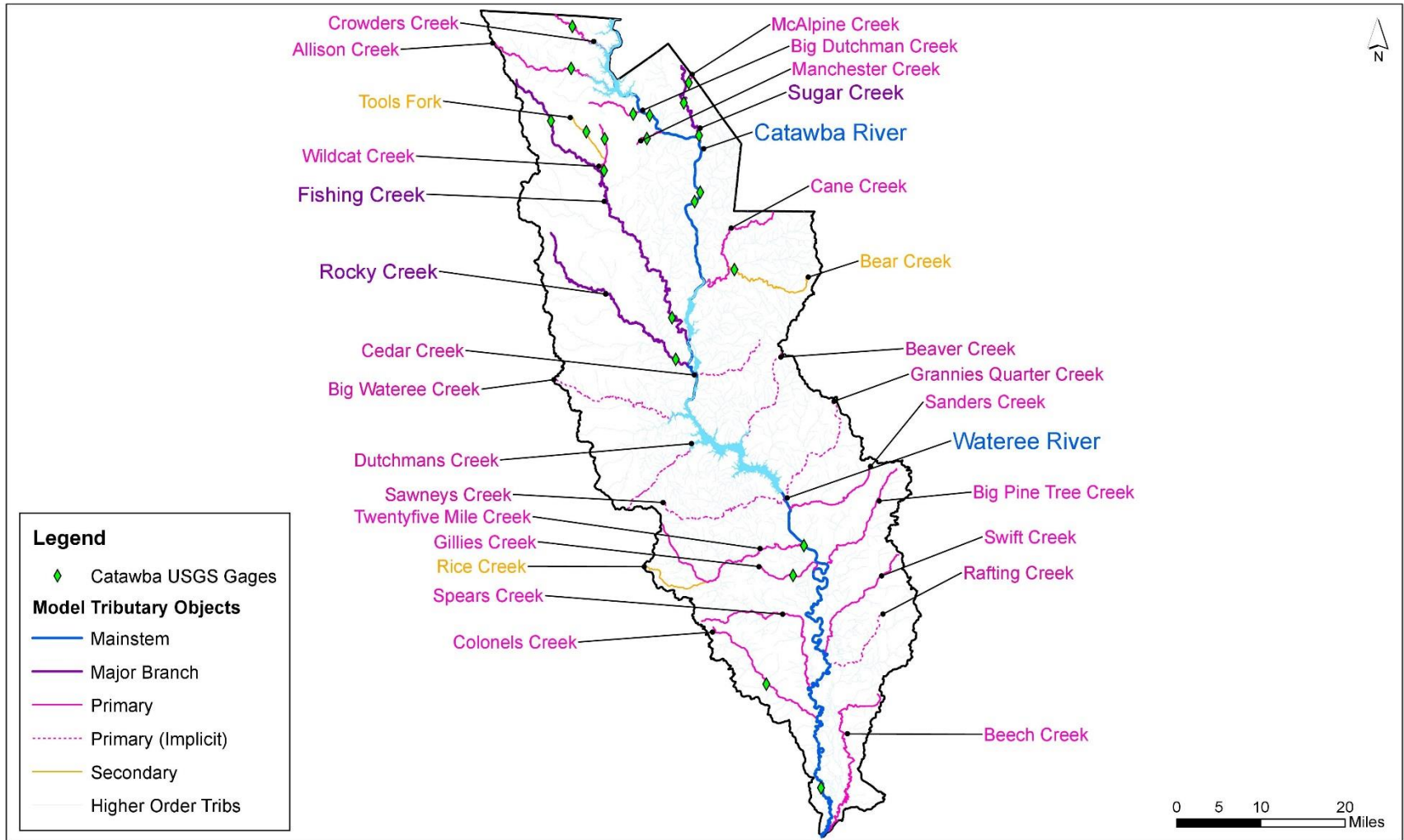
Catawba-Wateree River Basin

OVERVIEW OF MODEL FRAMEWORK

Catawba-Wateree Basin Main and Major Branches

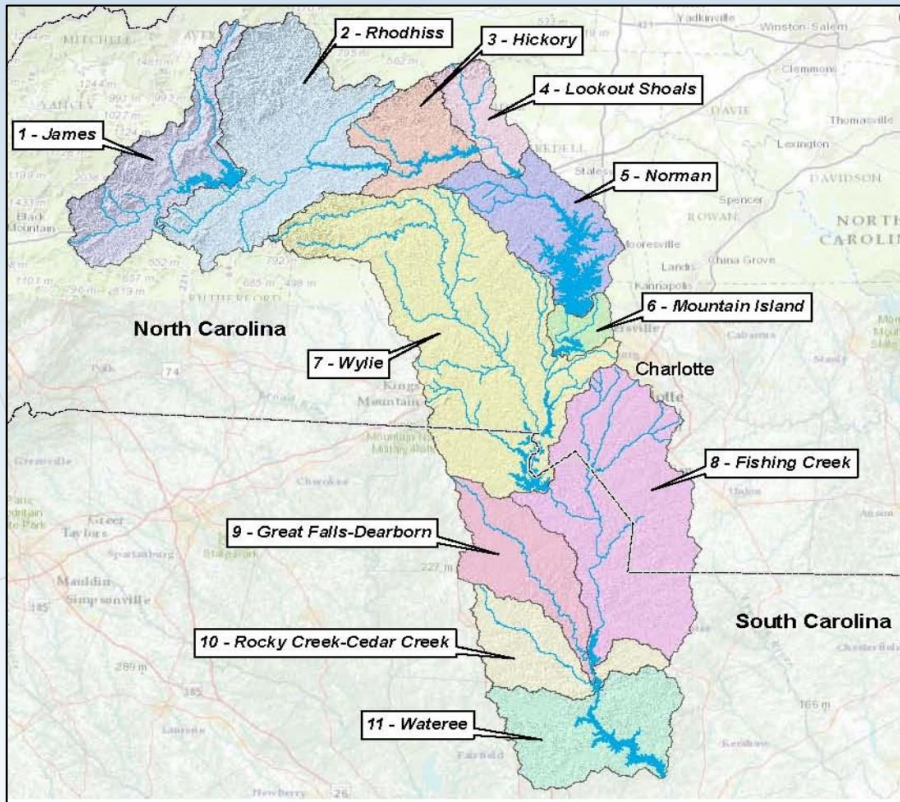


Primary and Secondary Tributaries



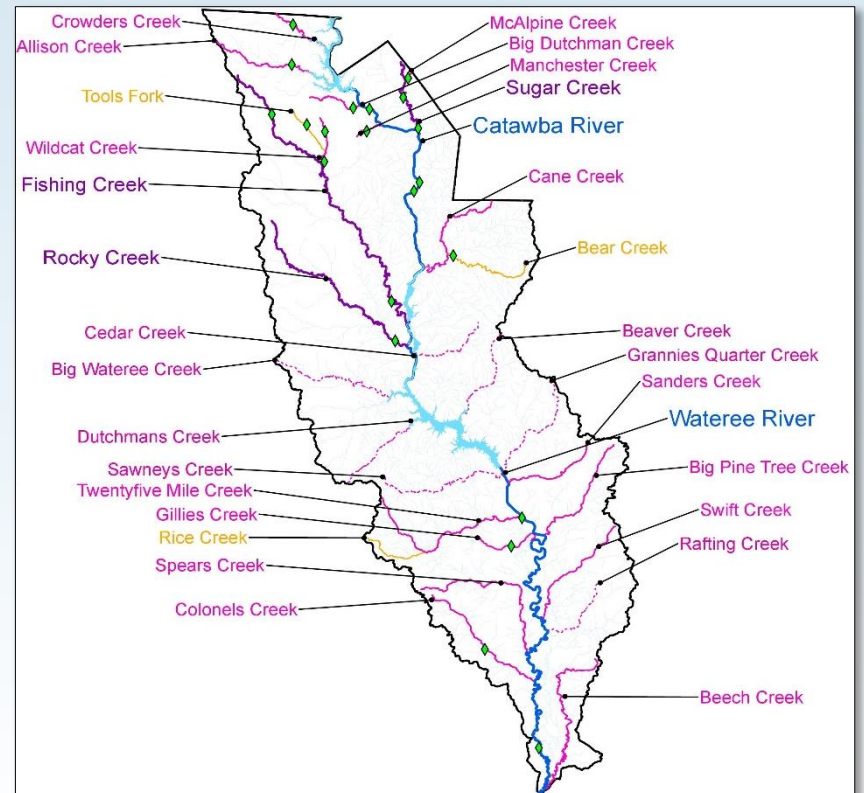
Catawba-Wataree Basin

CHEOPS Model Coverage

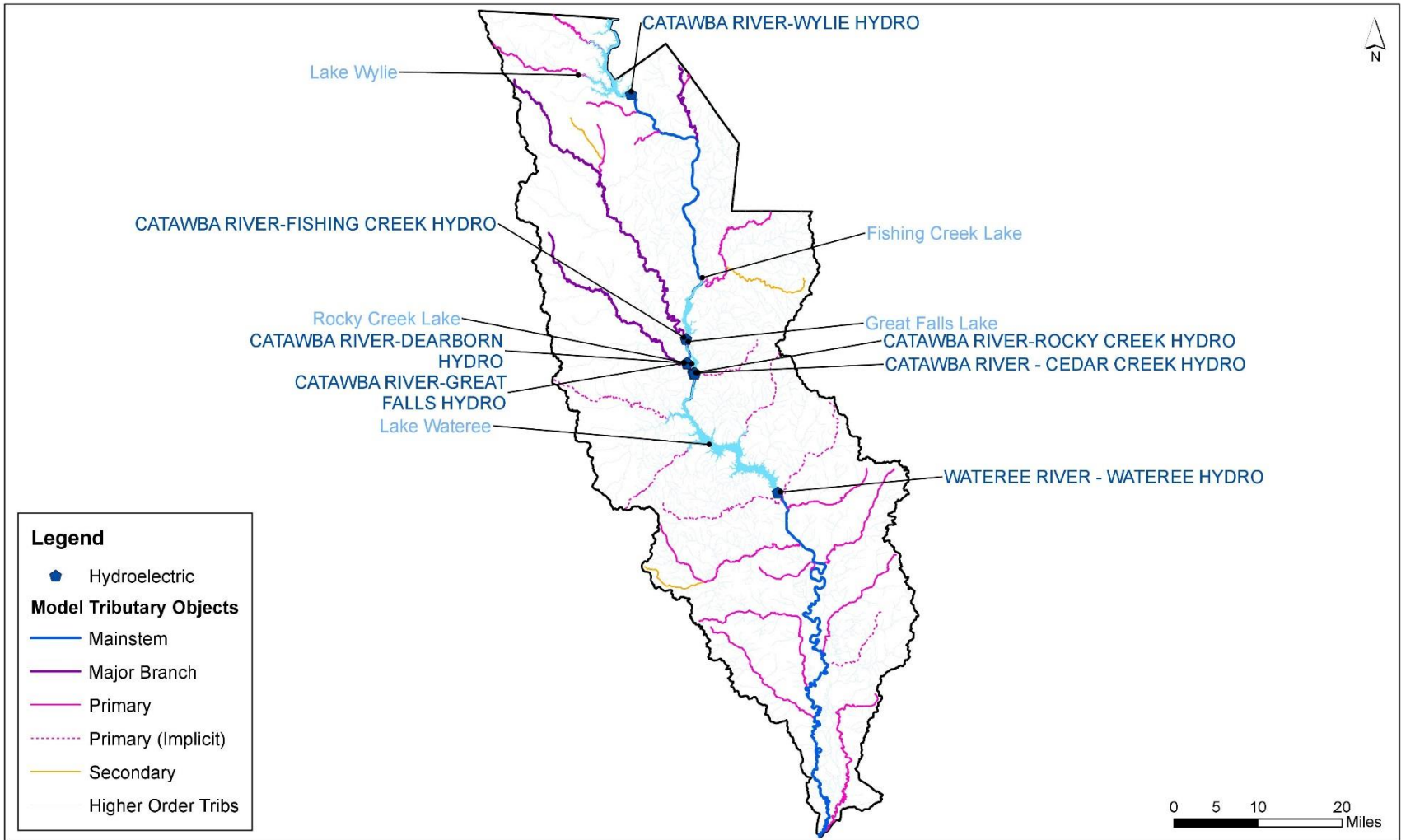
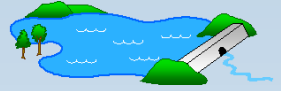


Source: CWWMG Master Plan CHEOPS Model, HDR, Inc.

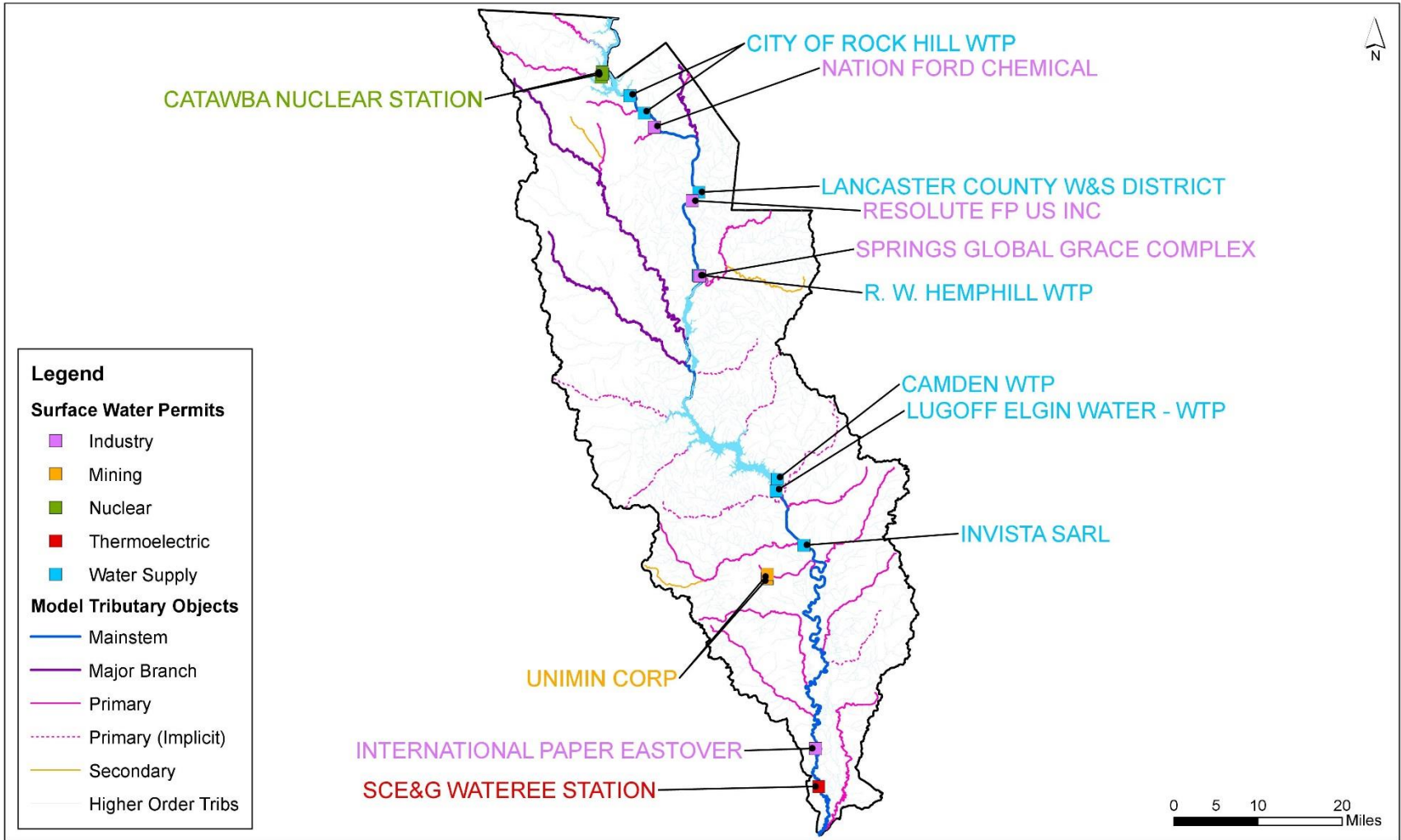
SWAM Model Intended Coverage



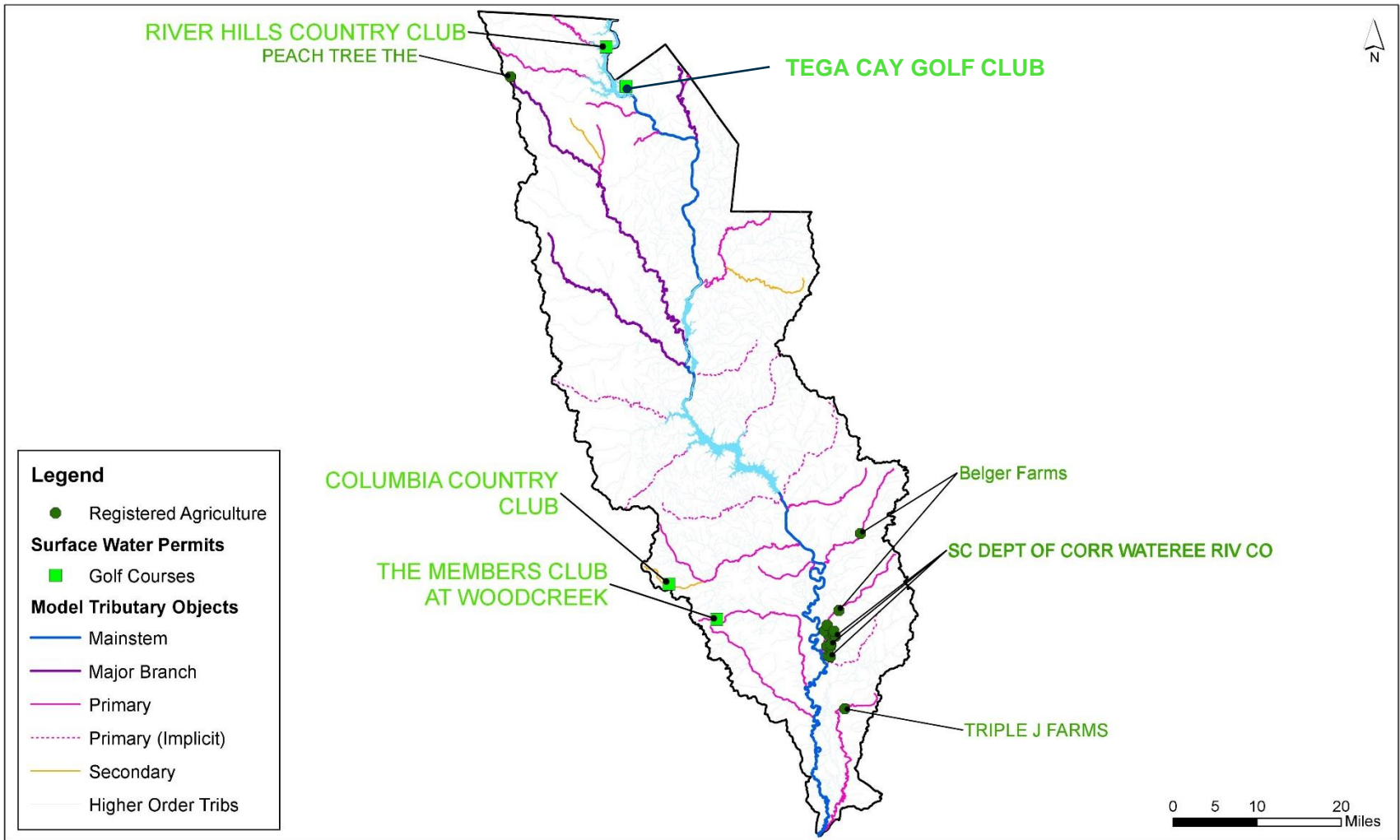
Reservoirs and Hydroelectric



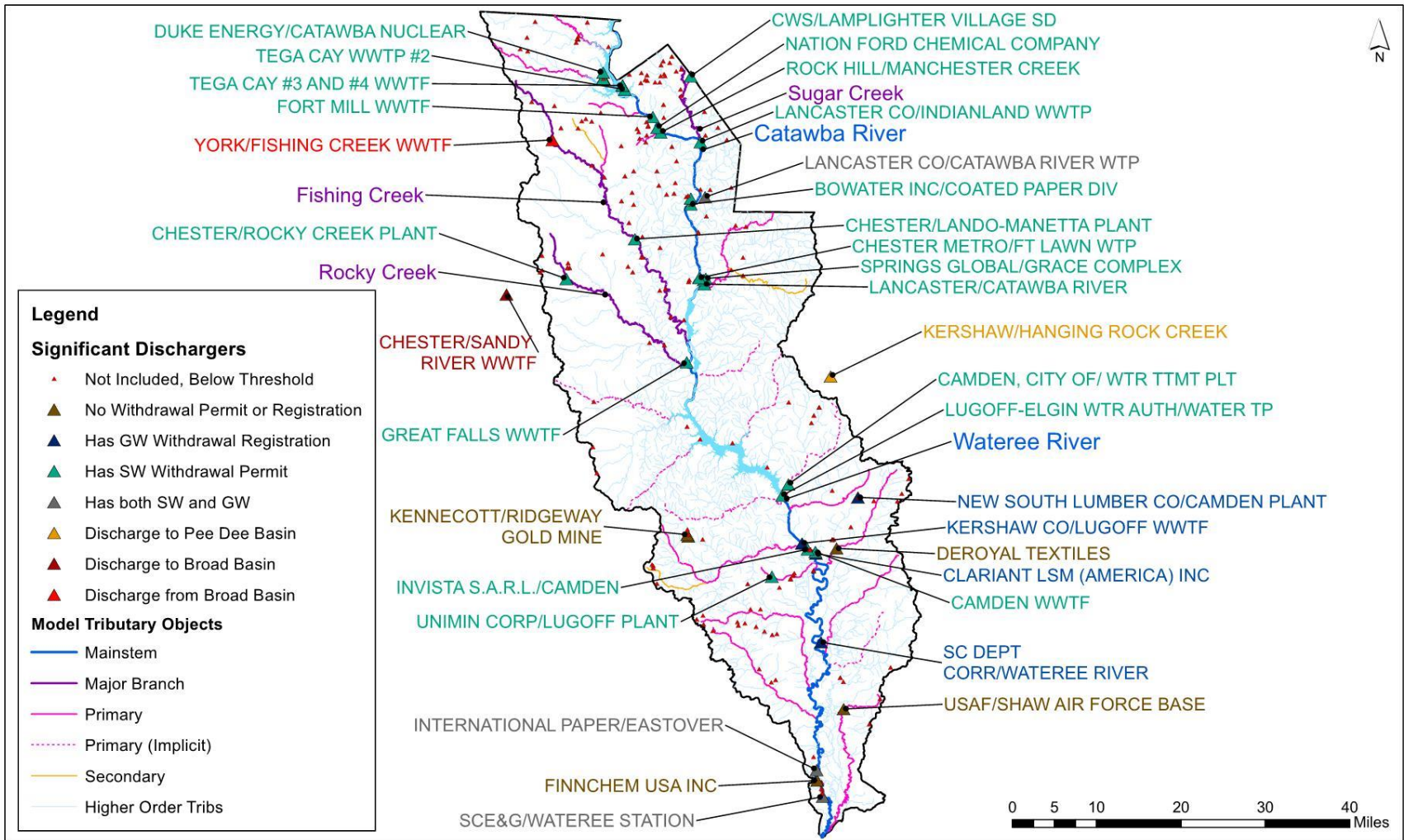
M&I and Energy Surface Water Withdrawals



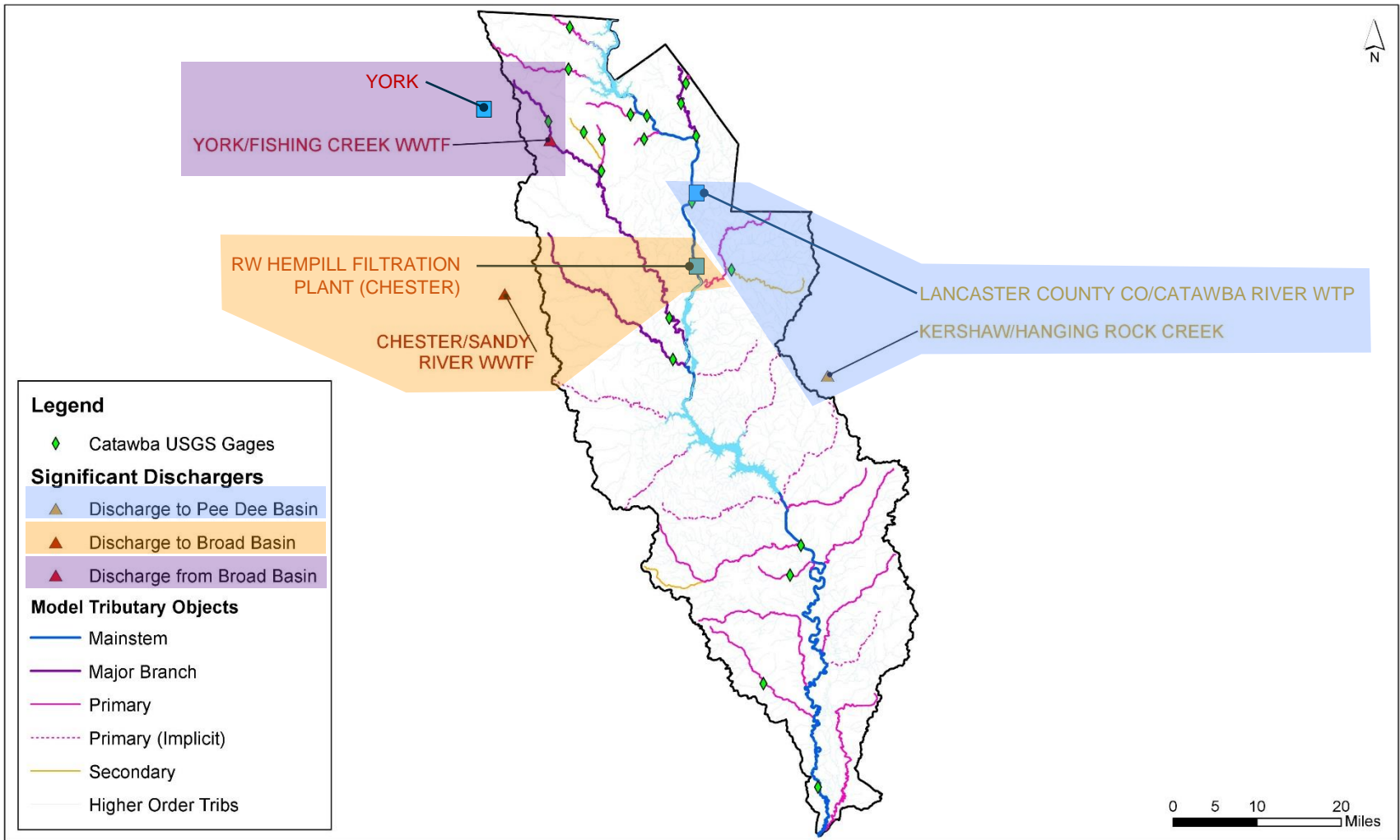
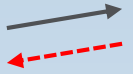
Surface Water Withdrawals for Irrigation



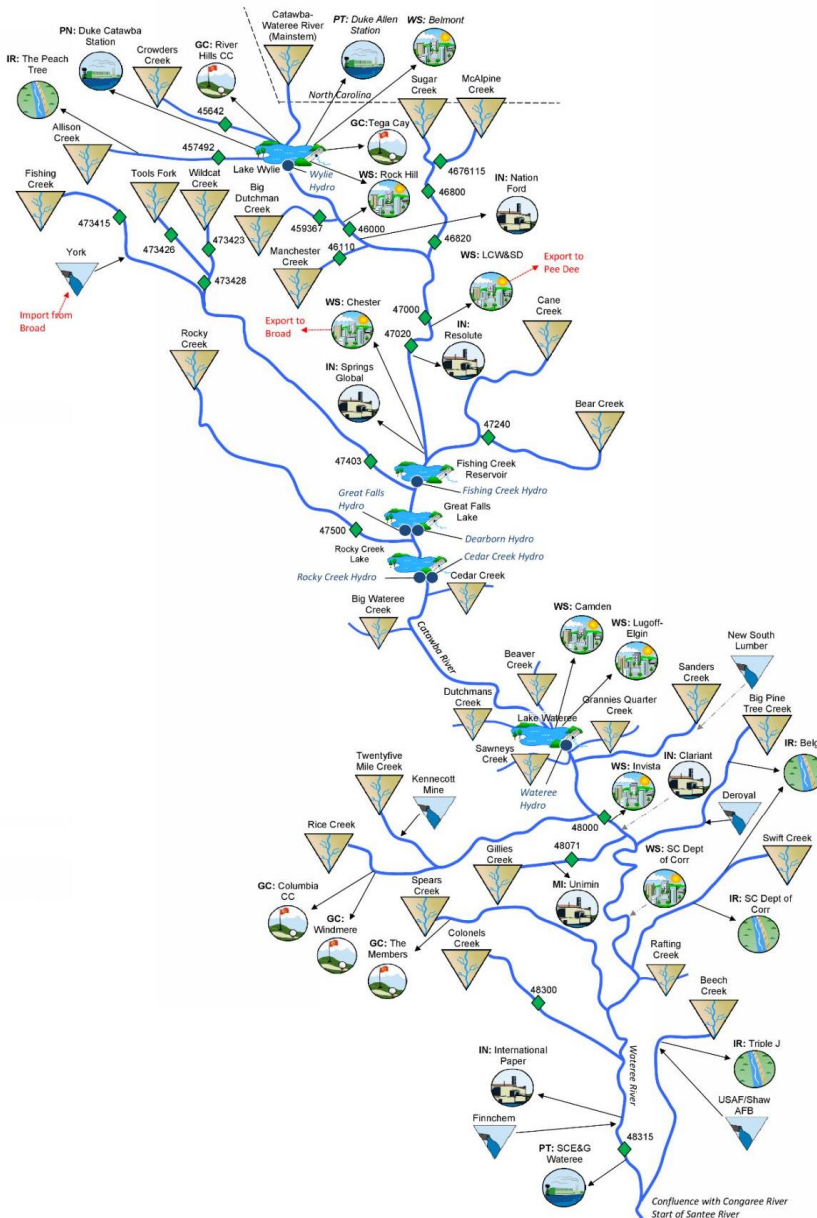
Discharges to Surface Water



Interbasin Transfers



Catawba-Wataree 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



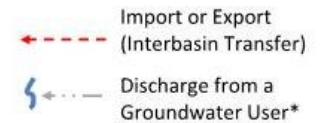
Industrial or Mining



Golf Course (Irrigation)



Hydropower



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

Catawba-Wateree River Basin

MODEL SETUP

Tributary Input Form

U26

Simplified Water Allocation Model (SWAM) | *Input Summaries and Outputting* | 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**

Reservoir Input Form

U26 : X ✓ fx

Simplified Water Allocation Model (SWAM)

Input Summaries and Outputting



Reservoir

Main

Reservoir Name: **Delete Node** **Storage Capacity (AF)** **Initial Storage (AF)** Offline Online

Evaporation Inches/day % Volume Input Timeseries

Reservoir Releases **Receiving Stream:** Simple Advanced

Release Location (mi)

Monthly Rates

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

Area-Capacity Table Simple Detailed

Month	Volume (AF)	Area (ac)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

User Defined Releases

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

Comments:

Save
Close



Water User Input Form – Main

U26

Water User [X]

Main | Water Usage | Source Water | Return Flows

Water User Name: [] **Delete**

D H E C

Object Palette

Supplemental S

Cons

Reca

Ag T

Comments:

Water User [X]

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)

Water User [X]

Main | Water Usage | Source Water | Return Flows

Source Stream: []

Source Water Type

Direct River

Reservoir

Groundwater

Downstream Location (mi) []

Priority Date [1/1/2008]

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) [1]

Carry Over Rule

Identifying Notes:

60381

Nursery

IN: Carlisle Finishing

IN: Chemtrade

WS: York

Sanc

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:

Main
Water Usage
Source Water
Return Flows

Blaney Criddle ET

Original

Modified

Irrigated Acres

0

Ditch Loss (%)

10

Irrigation Efficiency (%)

90

Elevation (ft absl)

0

Latitude (degr)

40

Crops

Edit Coeffs	% of Total Acreage	Start Month
▼	0	5
▼	0	5
▼	0	5
▼	0	5
▼	0	5
▼	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 [X]

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**



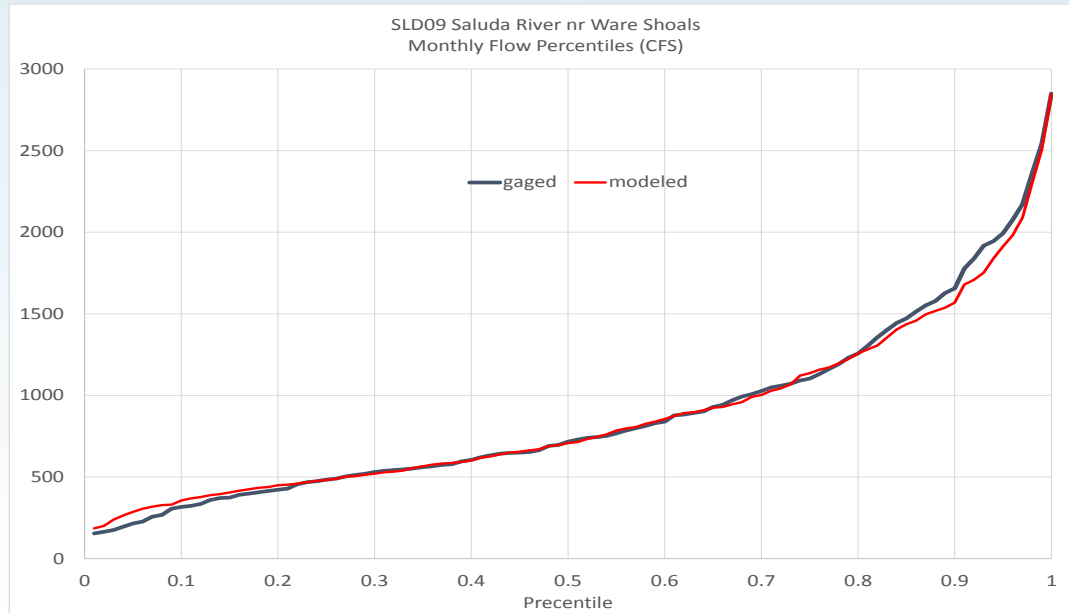
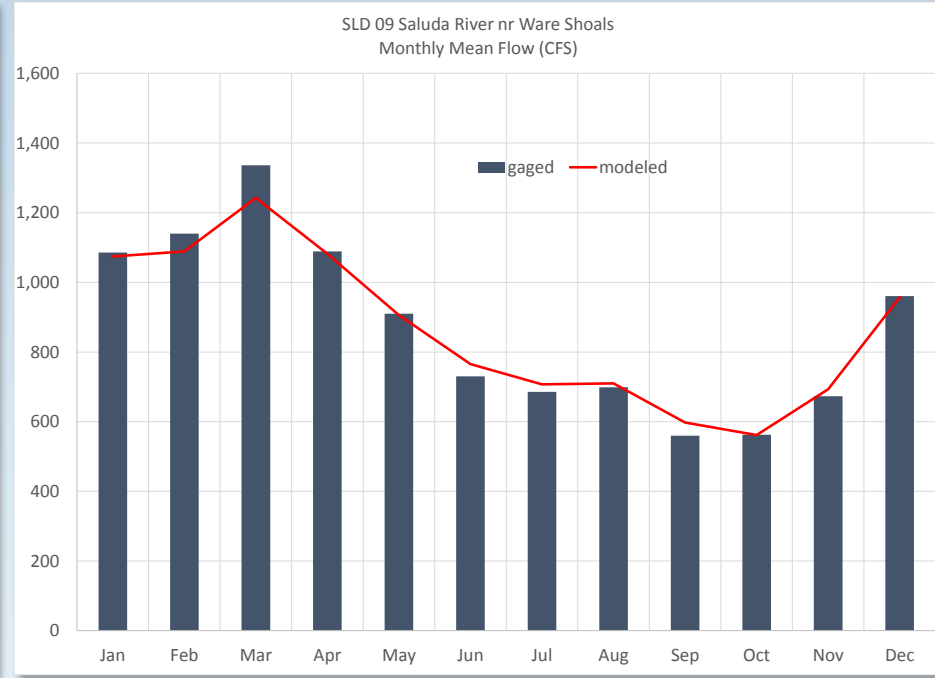
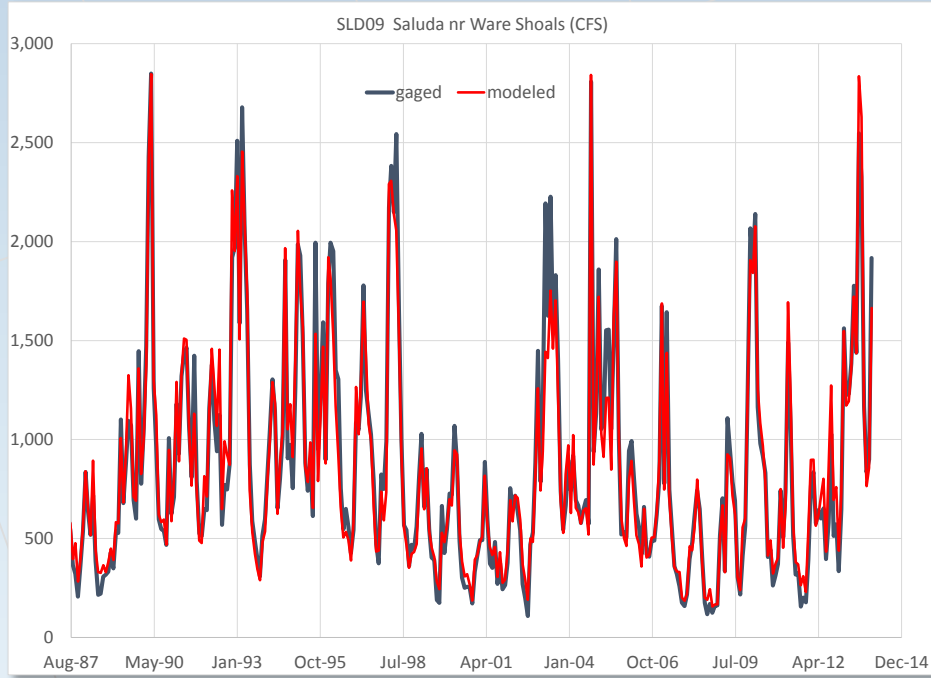
Catawba-Wateree River Basin

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
 - CWWMG Inflow Dataset

Calibration Result Graphs



Preliminary
examples
from the
Saluda Basin

Catawba-Wateree River Basin

THANK YOU