South Carolina Surface Water Quantity Modeling Project

Pee Dee River Basin Meeting No. 1 – Model Framework

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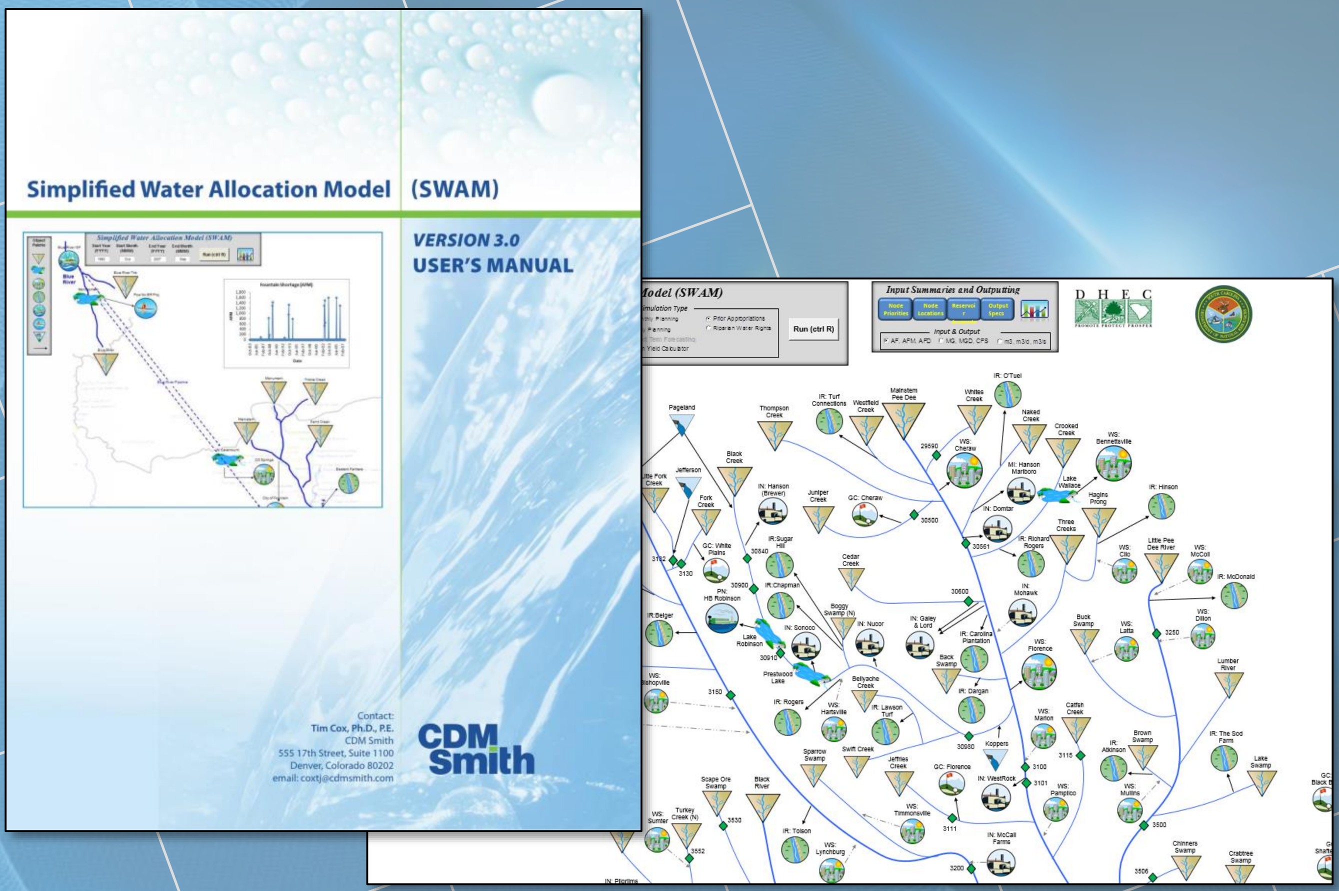
November 3, 2015



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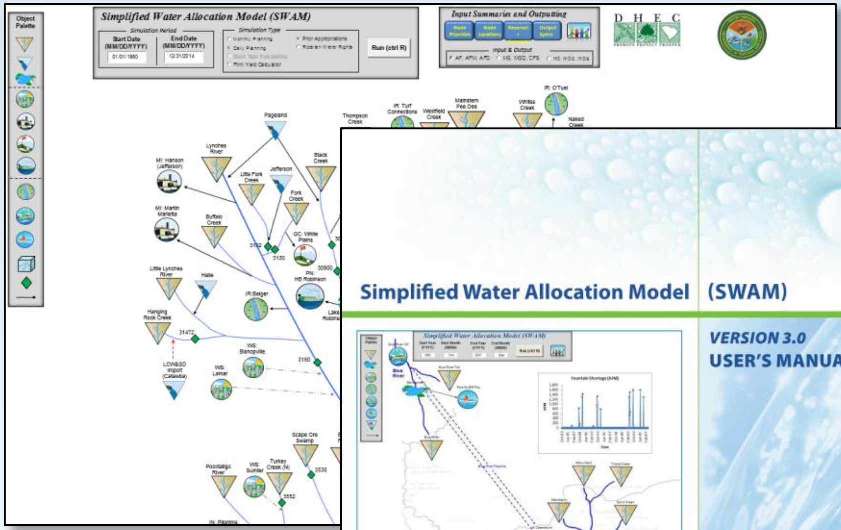
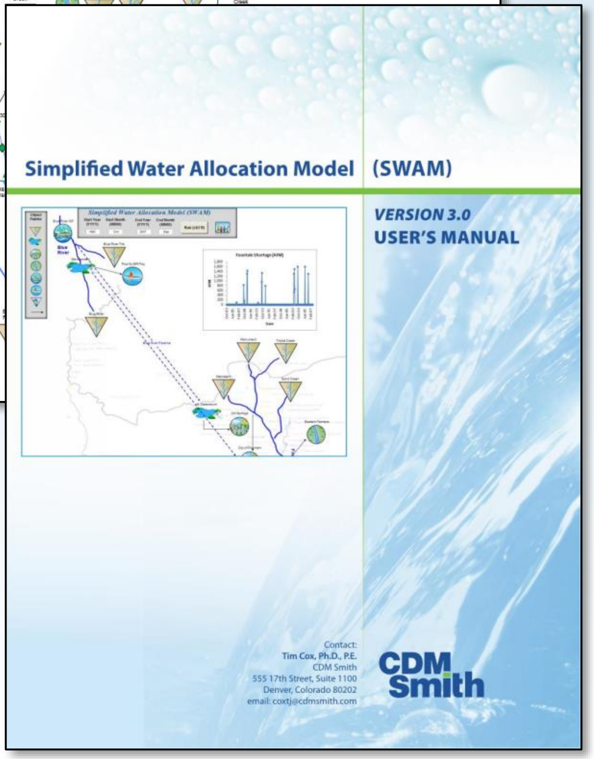
Project Purpose

- 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

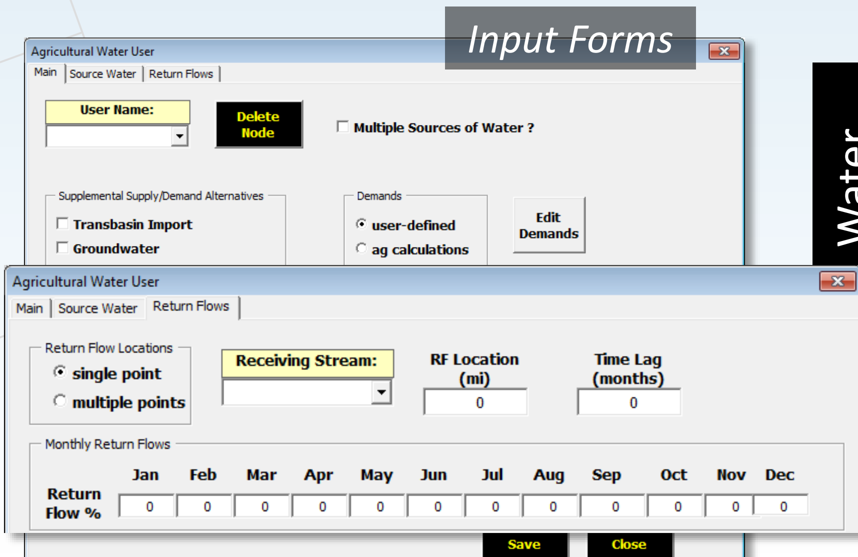
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

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



Objects

Tributaries

Discharges

Reservoirs

Water User Objects:

Municipal

Industrial

Golf Courses

Power Plants

Agriculture

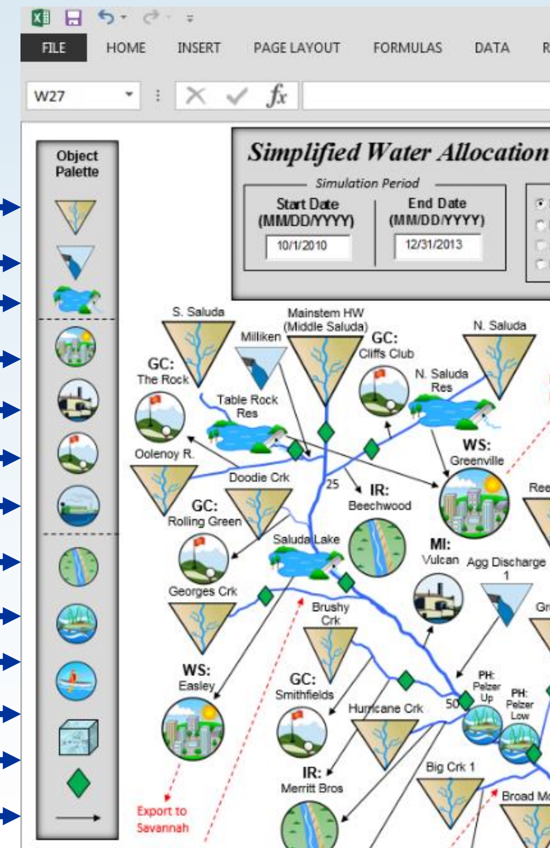
Instream Flow

Recreational Pool

Aquifer

USGS Gage

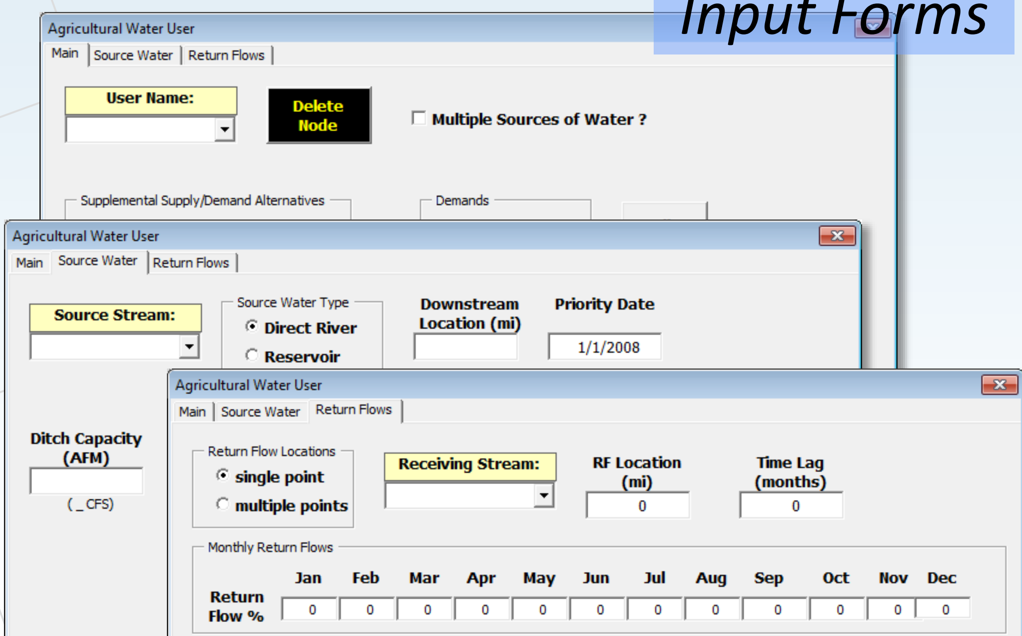
Interbasin Transfer



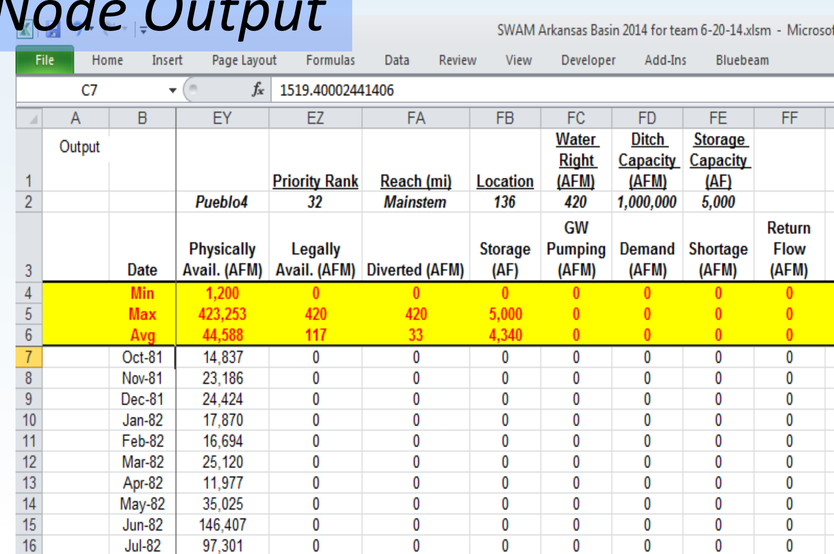
Simplified Water Allocation Model (SWAM)

- **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



Node Output



	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
1	Output			Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)	
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

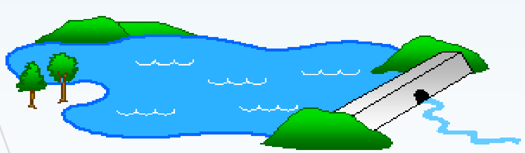
Simplified Water Allocation Model (SWAM)

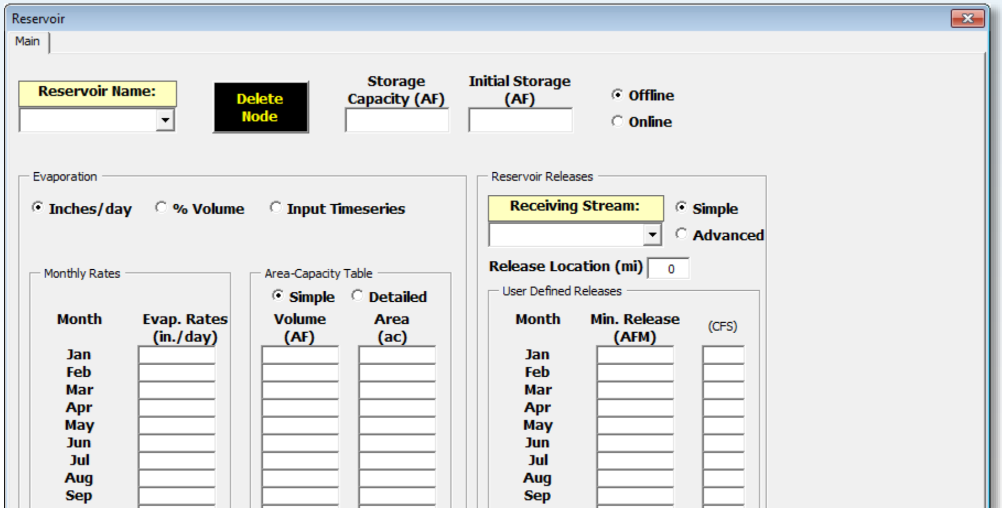
- Supports multiple layers of complexity for development of a range of systems, for example…

A Reservoir Object can include:

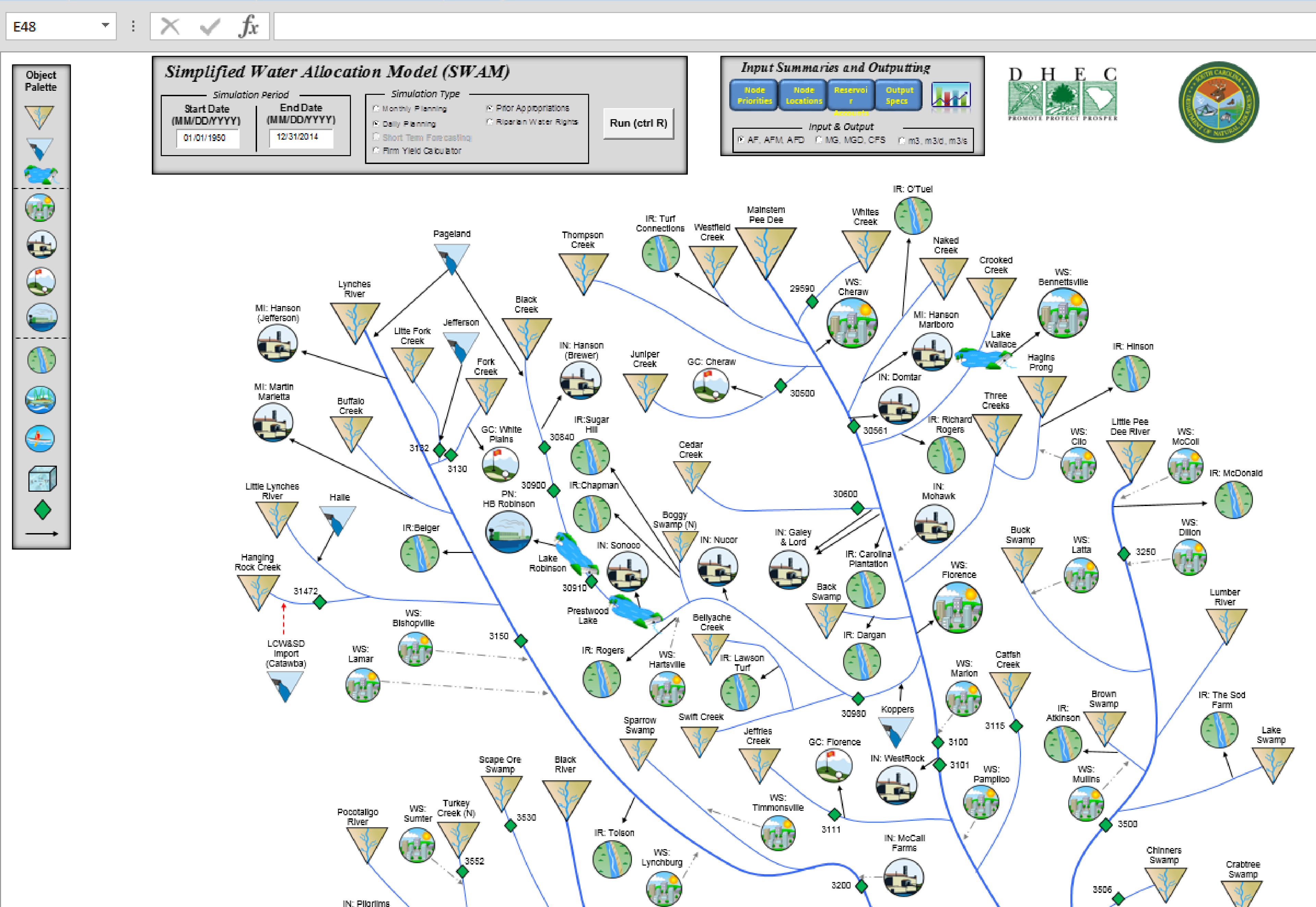
1. Basic hydrology dependent calculations
2. Operational rules of varying complexity such as prescribed releases, conditional releases, or hydrology dependent releases.

Reservoir





SWAM Model Main Screen



Pee Dee 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

Pee Dee 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

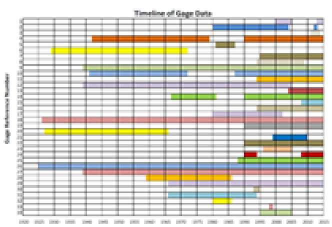
Estimated

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

Basinwide UIF Calculation Process

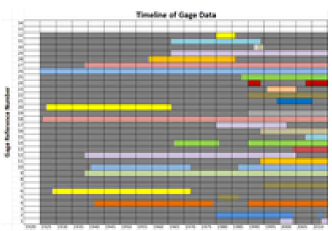
Stepwise Procedure for UIF Calculation – Saluda Basin

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



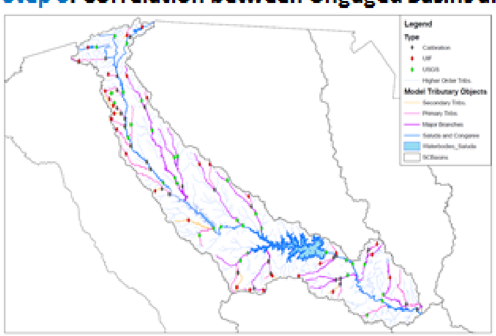
- Work Upstream to Downstream
- UIF Upstream?
  - Y: Perform these steps for incremental reaches and add UIFs from upstream
  - N: Perform these steps for the entire upstream area
- Gather data: Flow, historic use, precip, evap
- Fill gaps in storage for the longest downstream gage POR using prioritized techniques in guidance document.
- Fill gaps in withdrawals and discharges based on longest downstream gage POR using techniques in guidance doc.
- Compute prior runoff from submerged areas
- Compute UIFs for USGS gages (VOLUME)
- UIFs for USGS gages for their POR

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



- Determine longest period of record
- Gather watershed characteristics: Area, Slope, Land Use
- Extend / Gap Fill using area ratios, MOVE2, climate regression, etc.
- UIFs for USGS gages over a uniform basinwide POR

Step 3: Correlation between Ungaged Basins and Gaged Basins



- Gather watershed characteristics for all basins upstream of RED nodes (ungagged headwater UIFs)
- Identify appropriate reference basins from USGS gage locations
- Reference gages for UIF development as model input

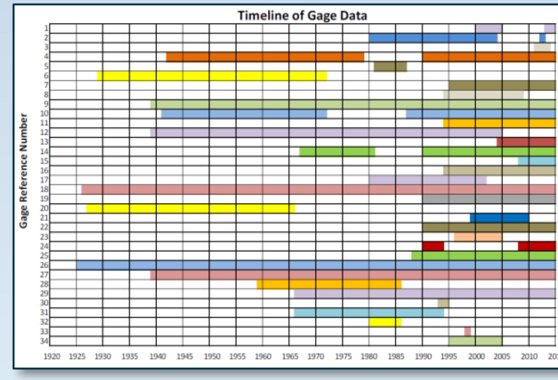
- Gather watershed characteristics for all basins upstream of BLACK nodes (as needed for calibration)
- Identify appropriate reference basins from USGS gage locations
- Reference gages for UIF development for model calibration

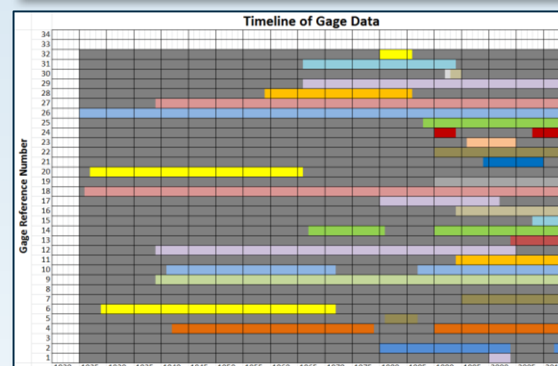
Step 4: UIFs for Ungaged Basins

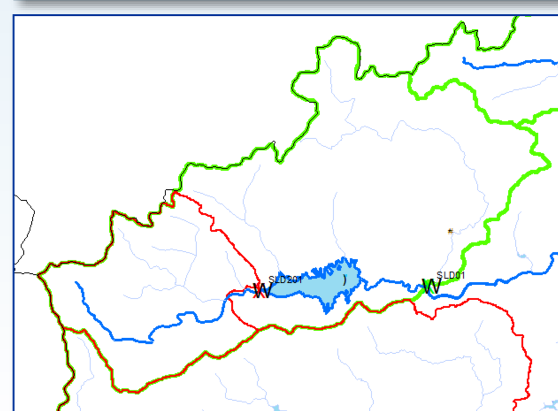
- Estimate UIFs for each RED and BLACK node using area ratios, regression, etc.
- UIFs for ungagged basins as model input
- Additional UIFs at confluence nodes for calibration

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





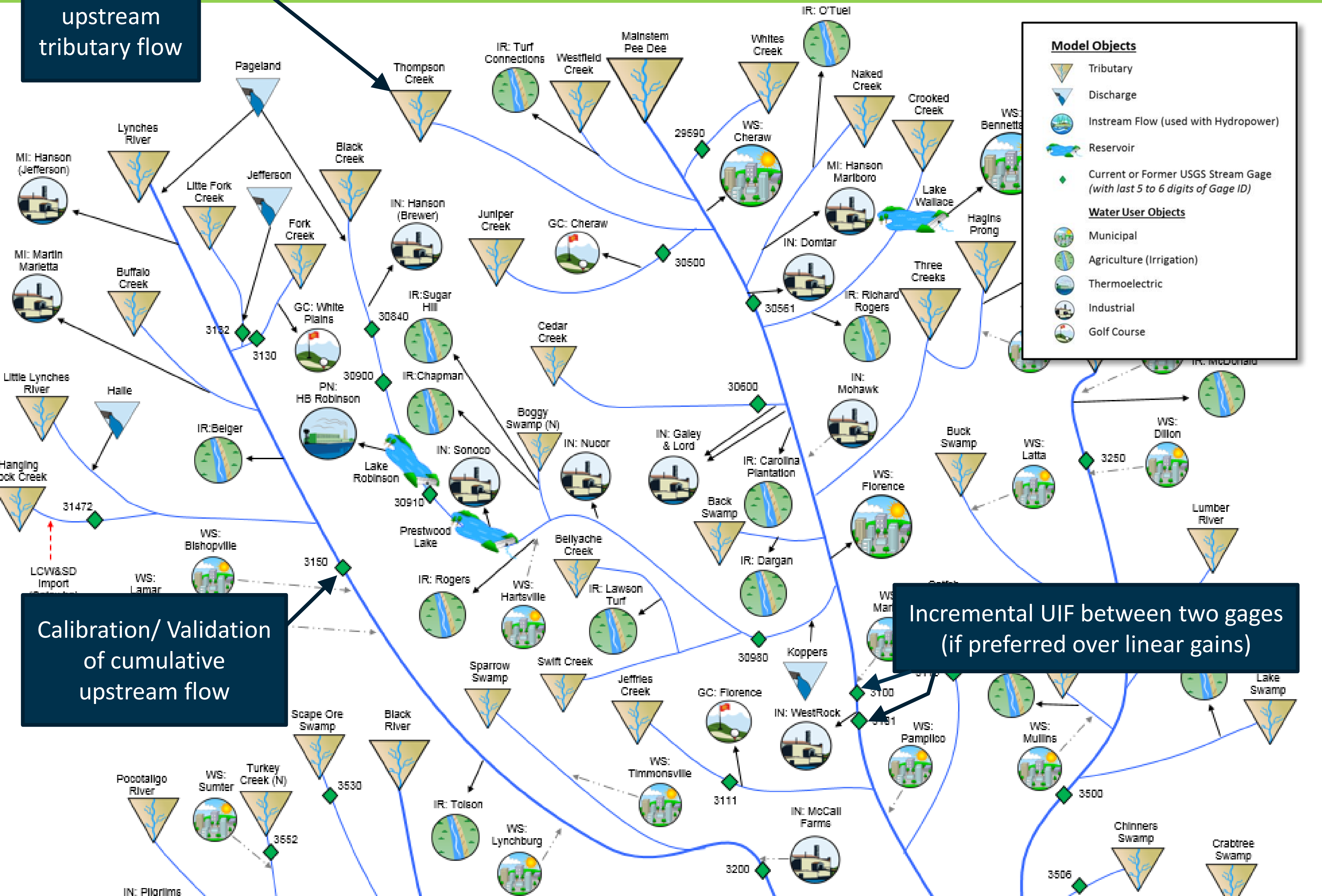


How UIFs are Used in SWAM

Input as upstream tributary flow

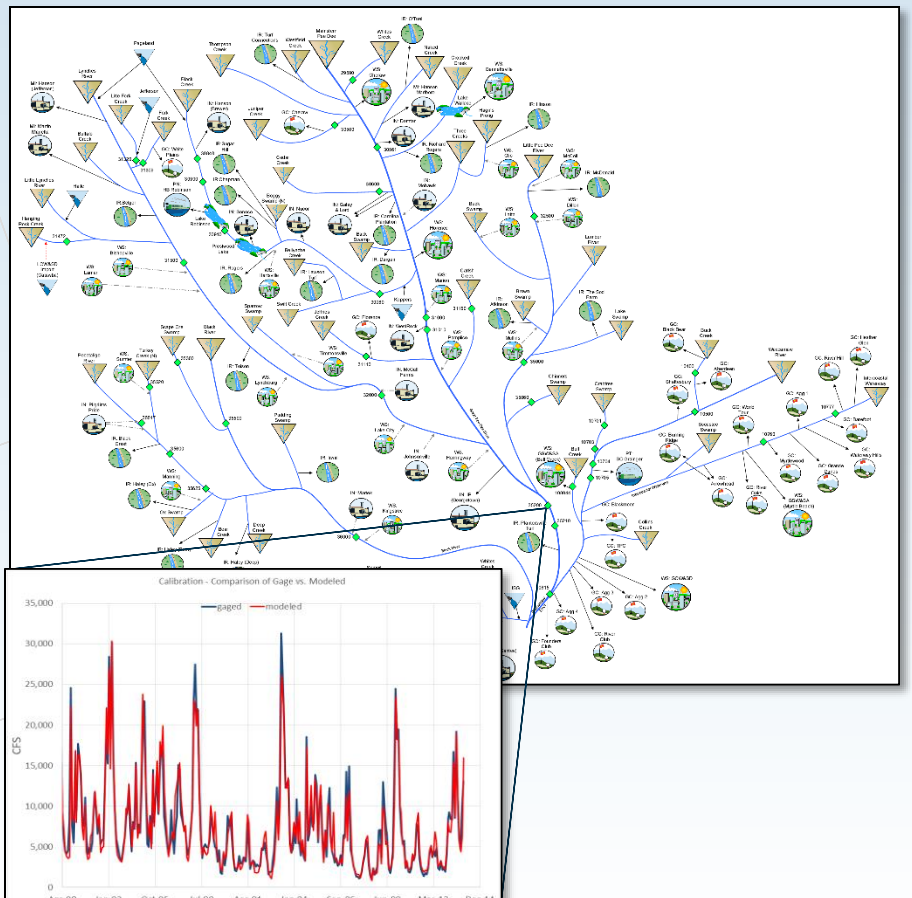
Calibration/ Validation of cumulative upstream flow

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

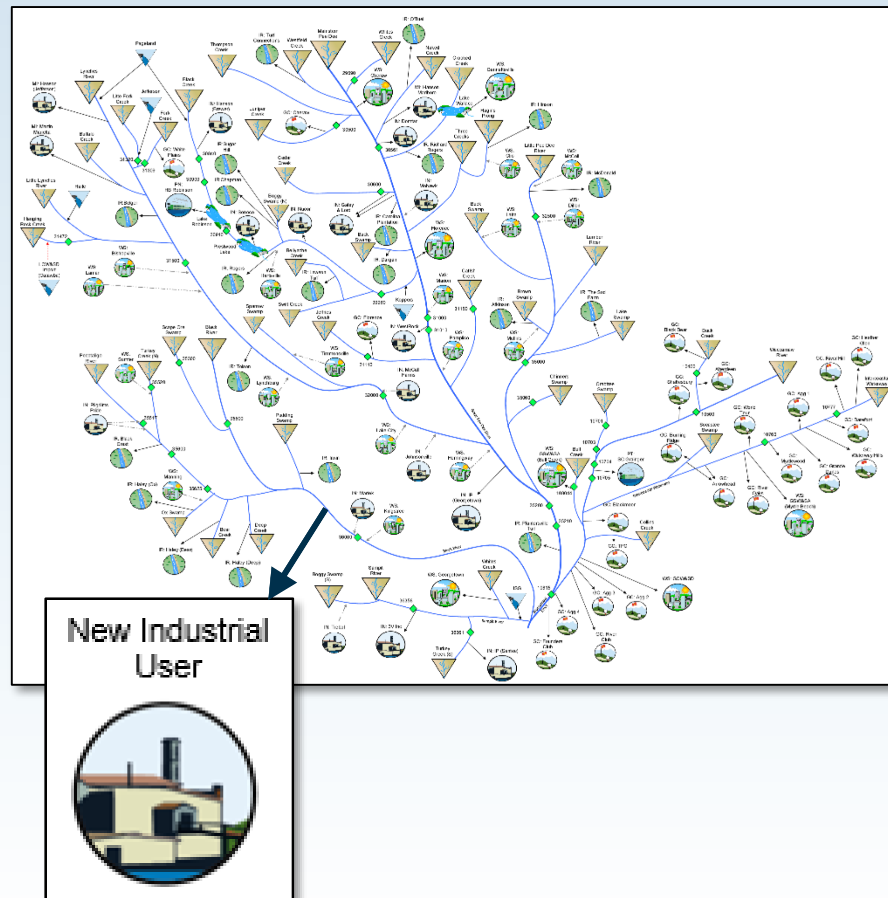


Two Versions of Every Model

Calibration with UIFs and Historic Use Records



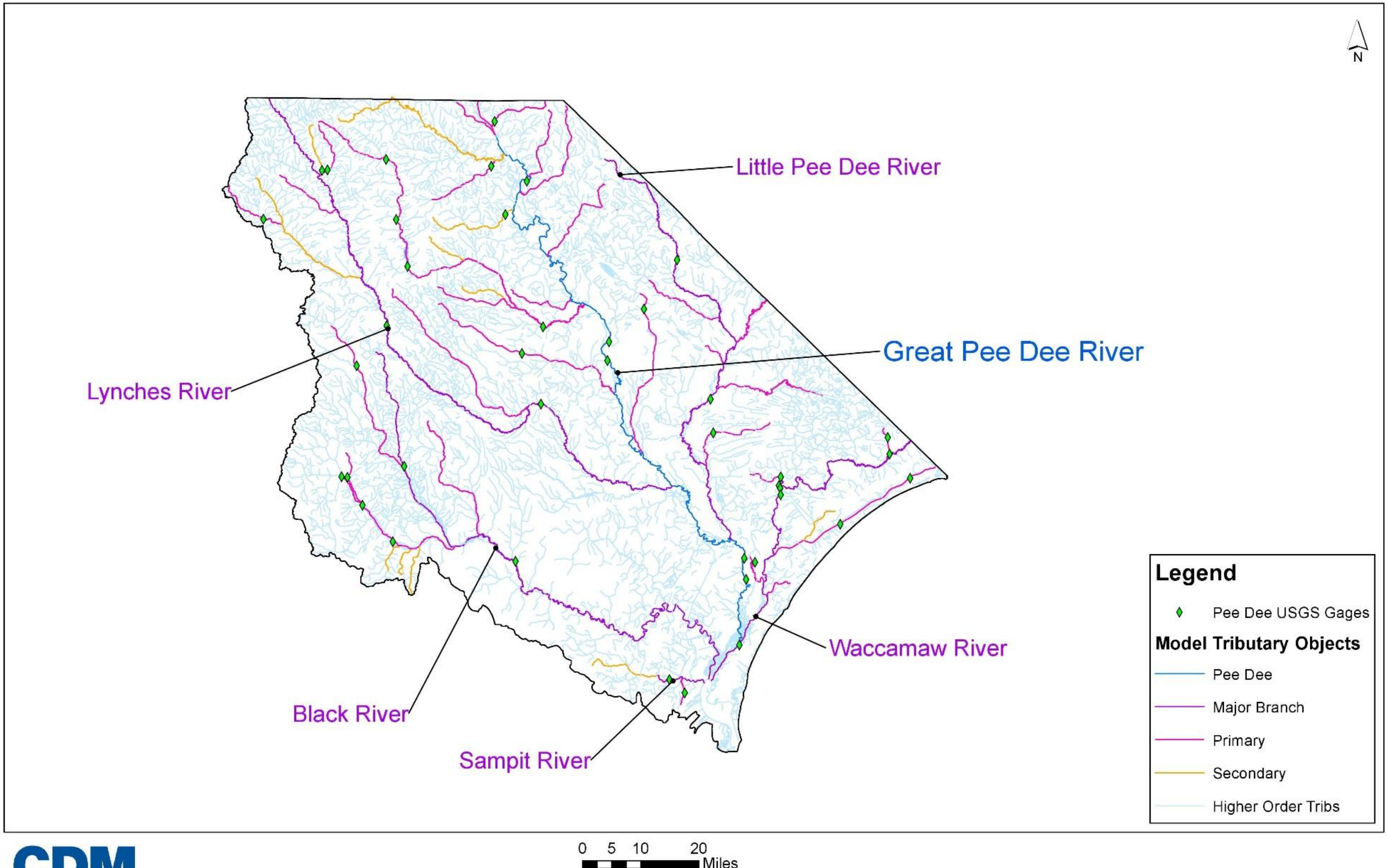
Planning with UIFs, Current Uses, and User-Defined Future Uses



Pee Dee River Basin

OVERVIEW OF MODEL FRAMEWORK

Pee Dee Basin – Main and Major Branches



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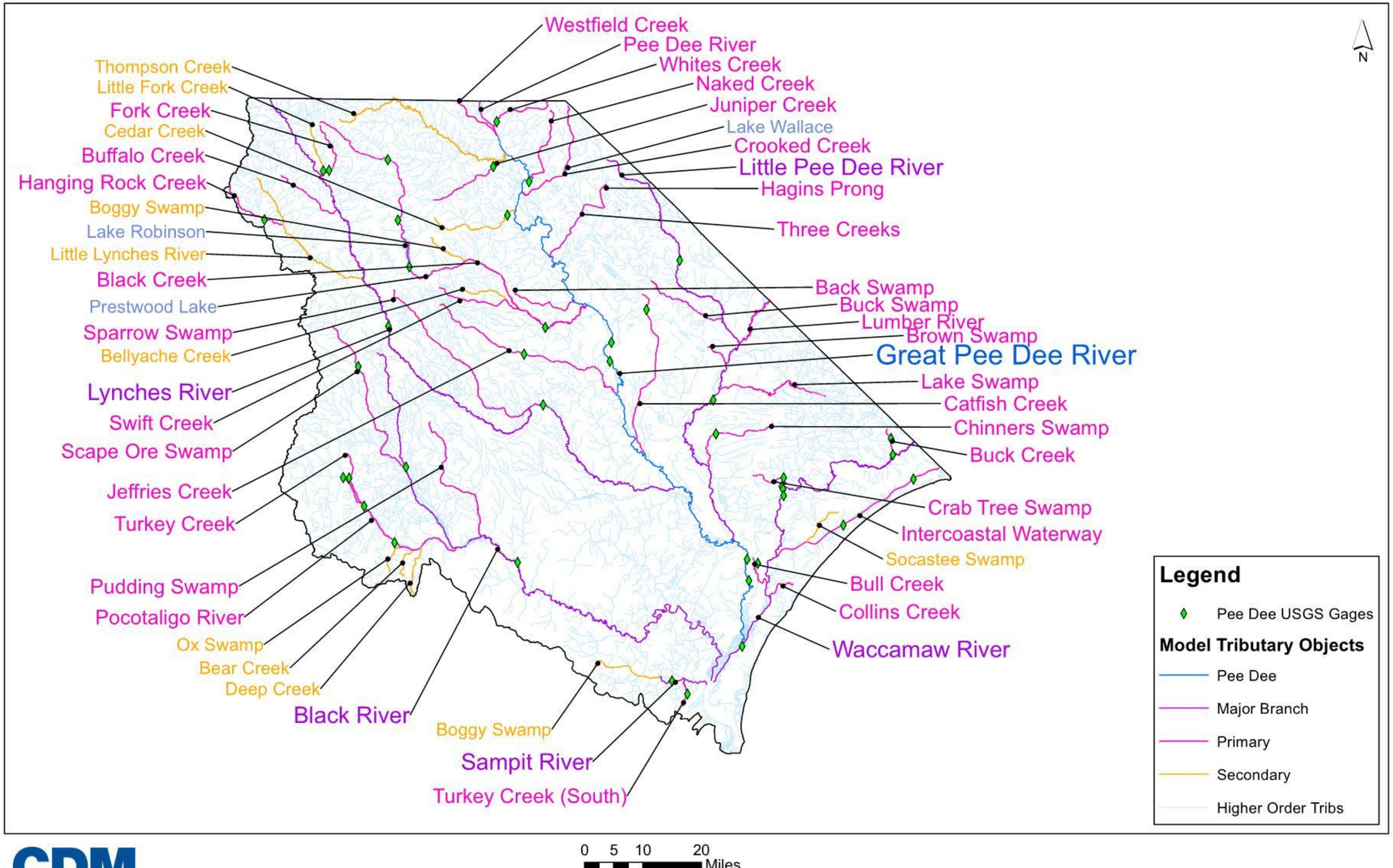
Primary and Secondary Tributaries



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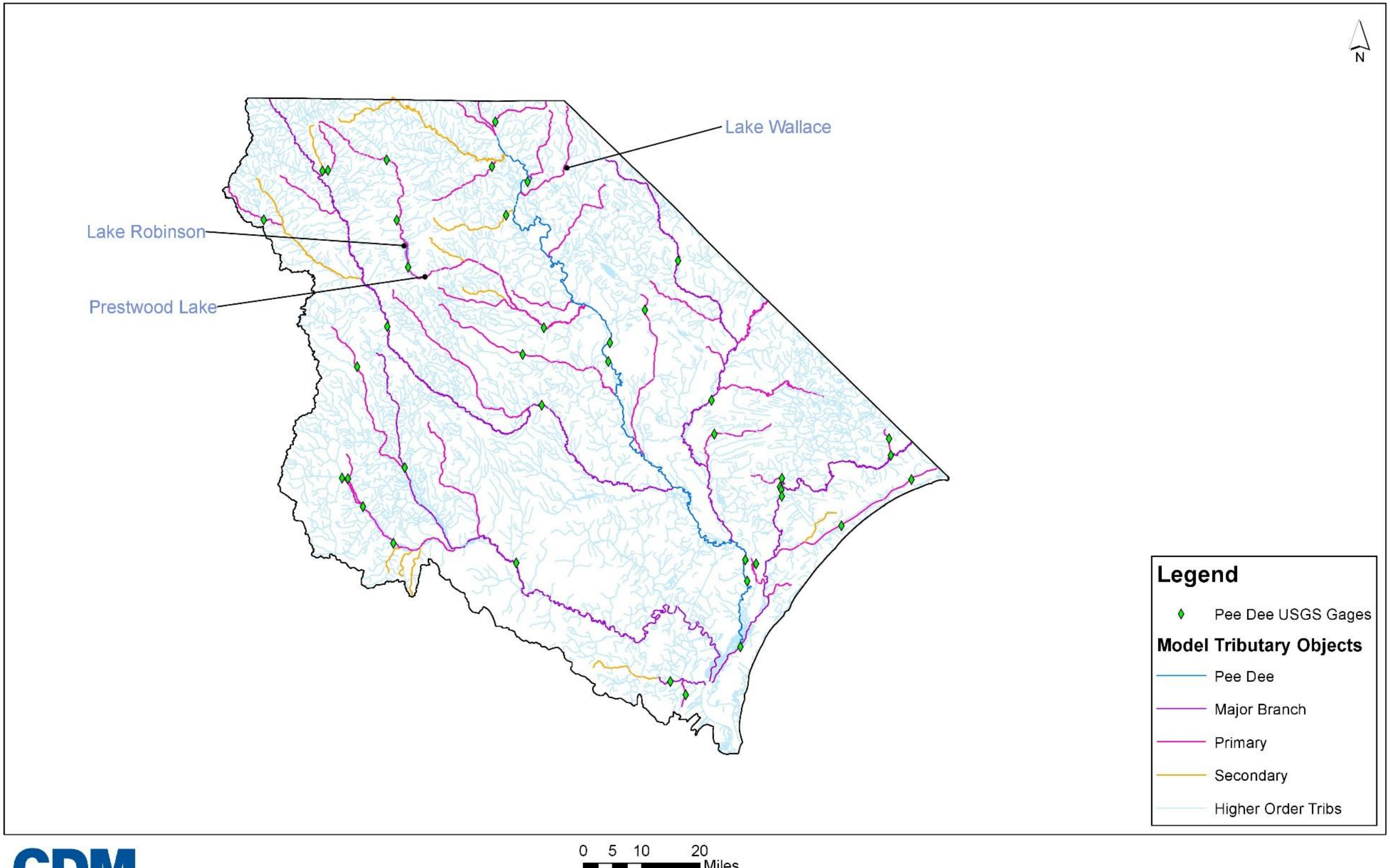
Reservoirs



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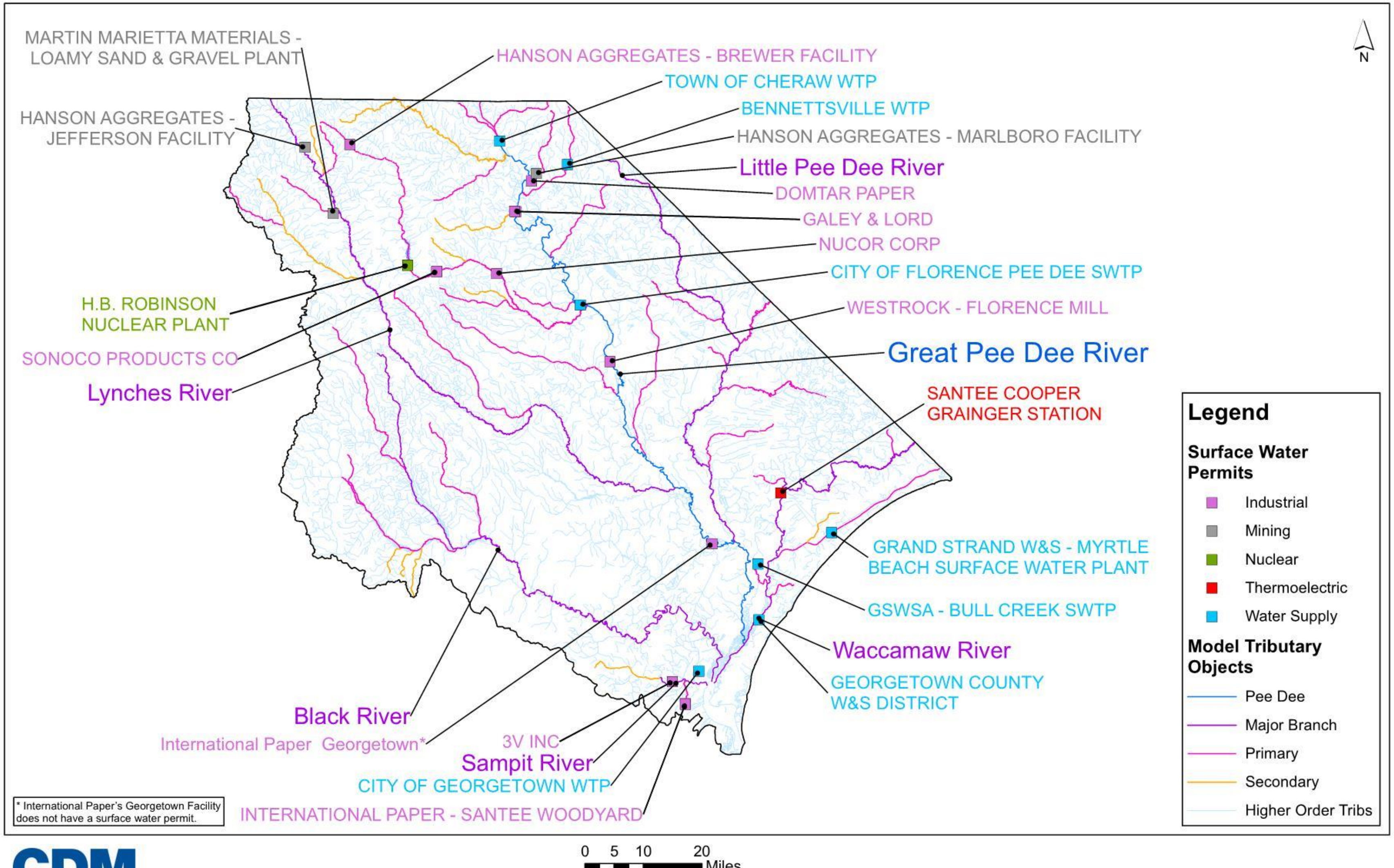
M&I and Energy Surface Water Withdrawals



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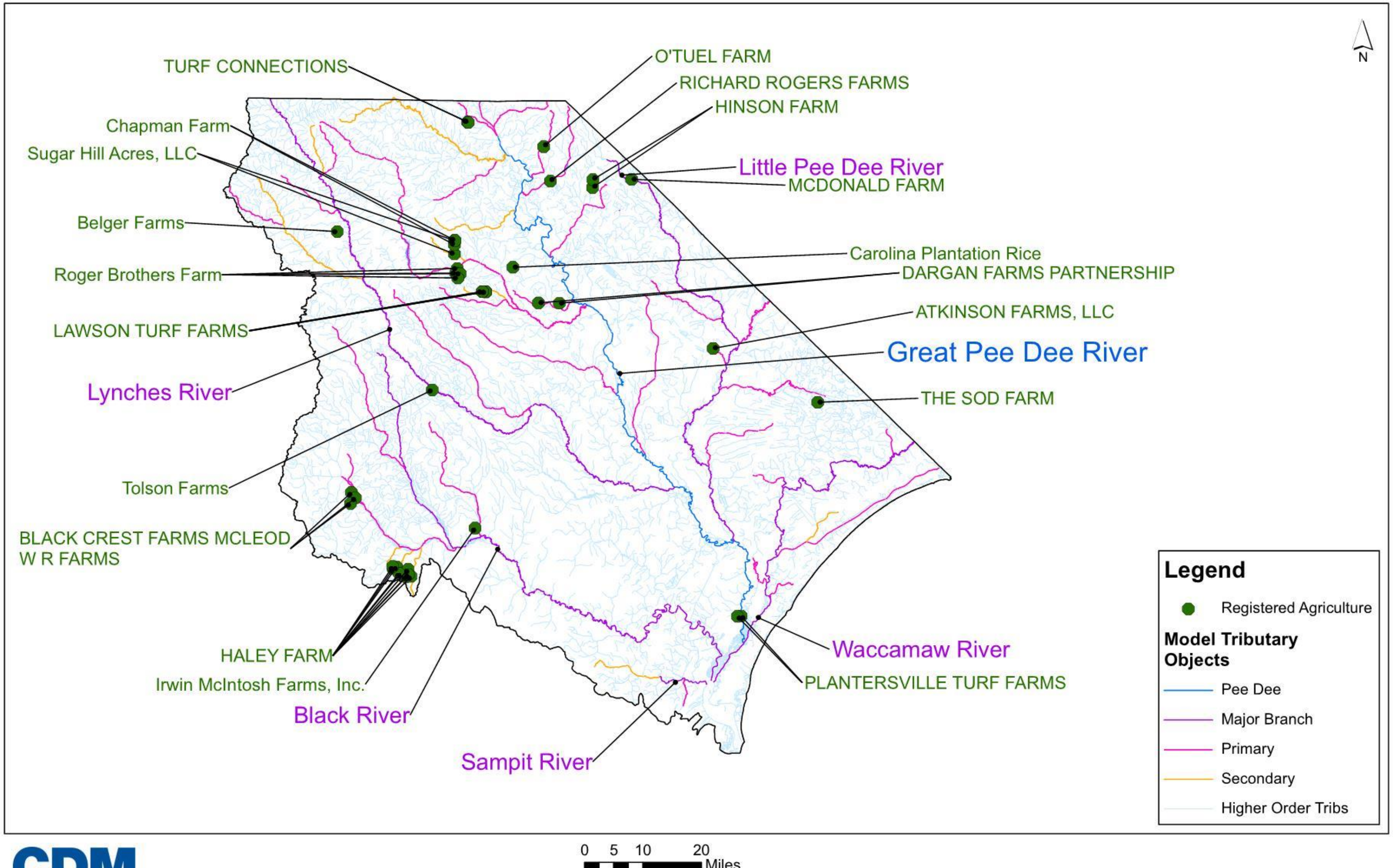
Agriculture Surface Water Withdrawals



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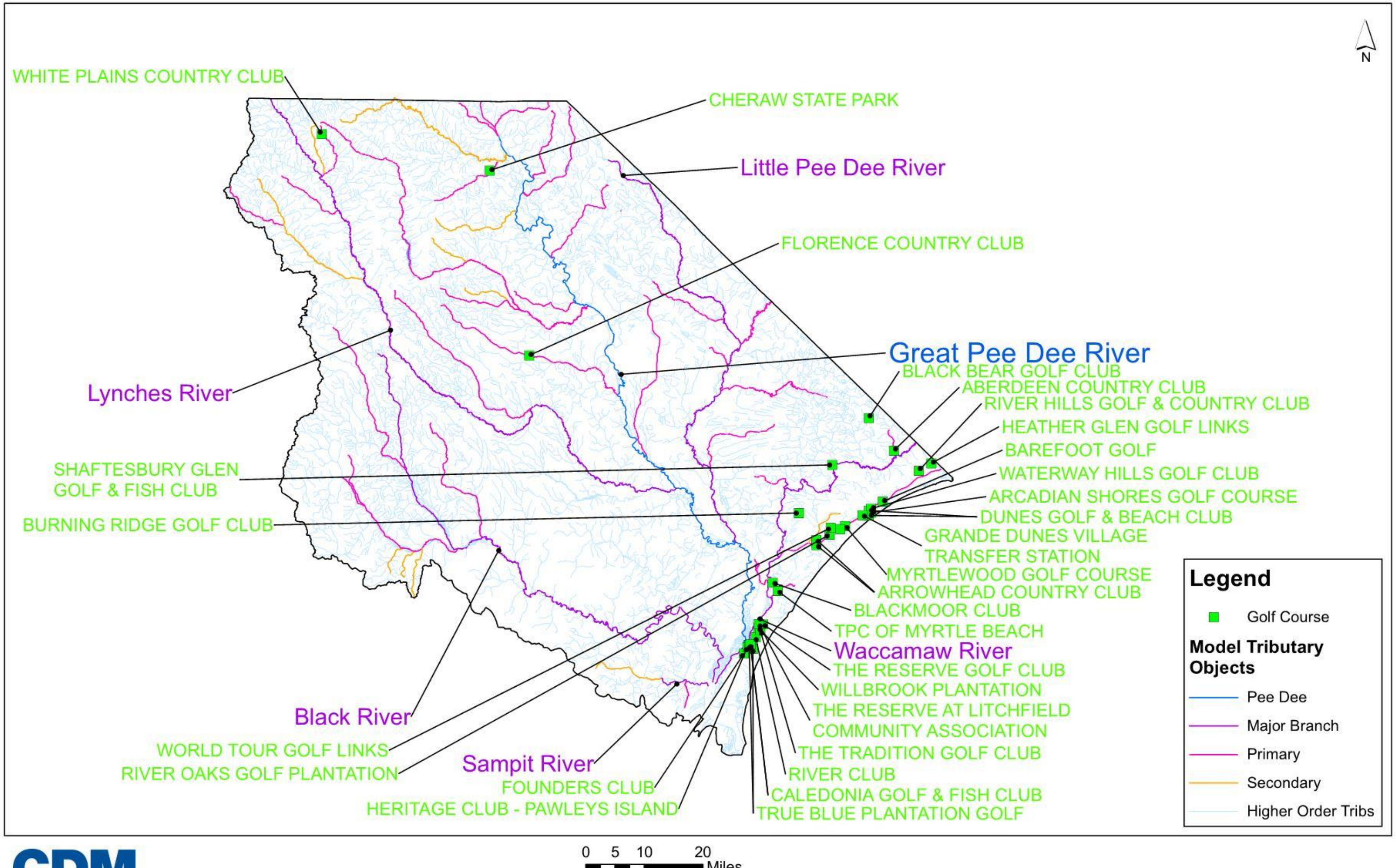
Golf Course Surface Water Withdrawals



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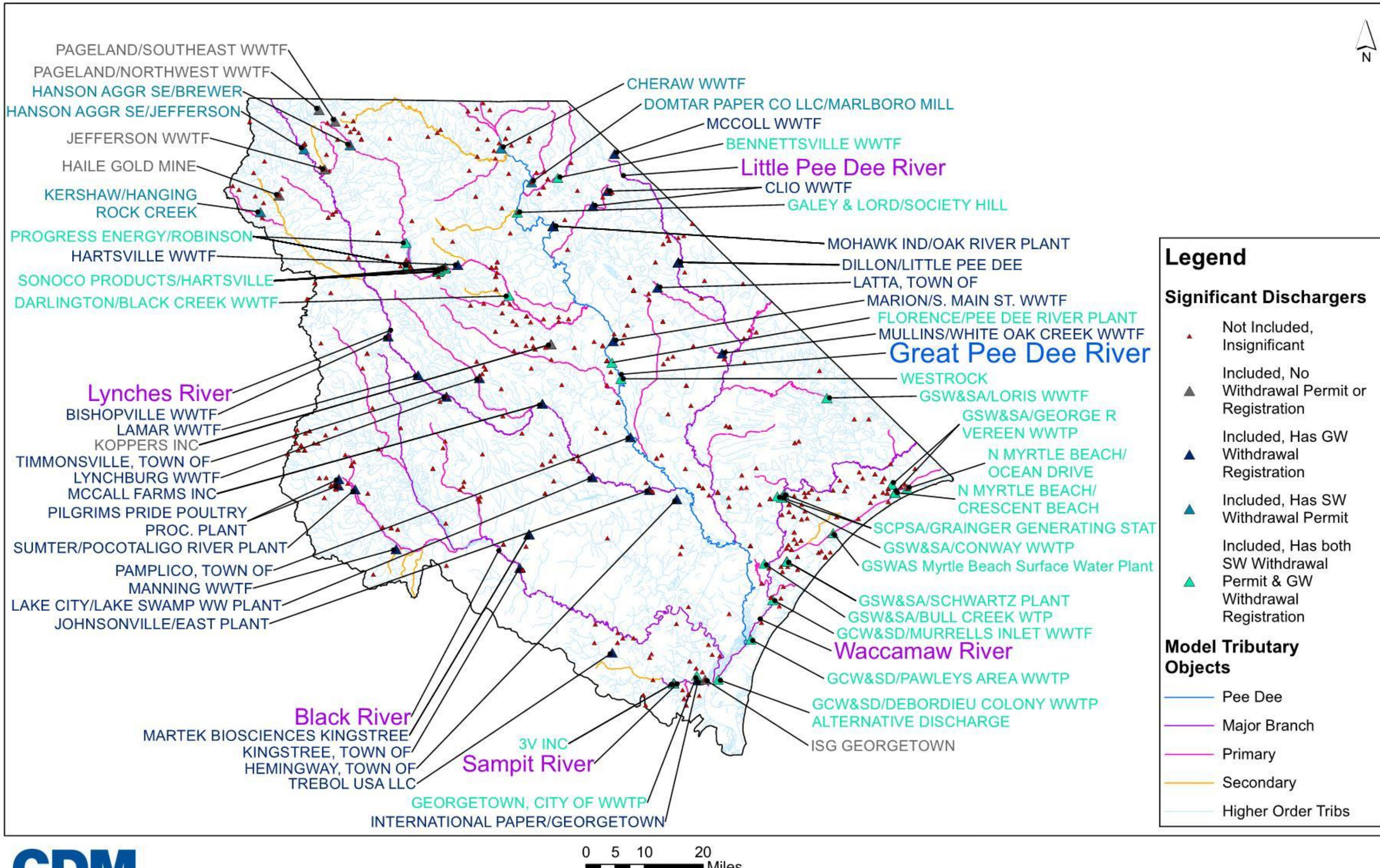
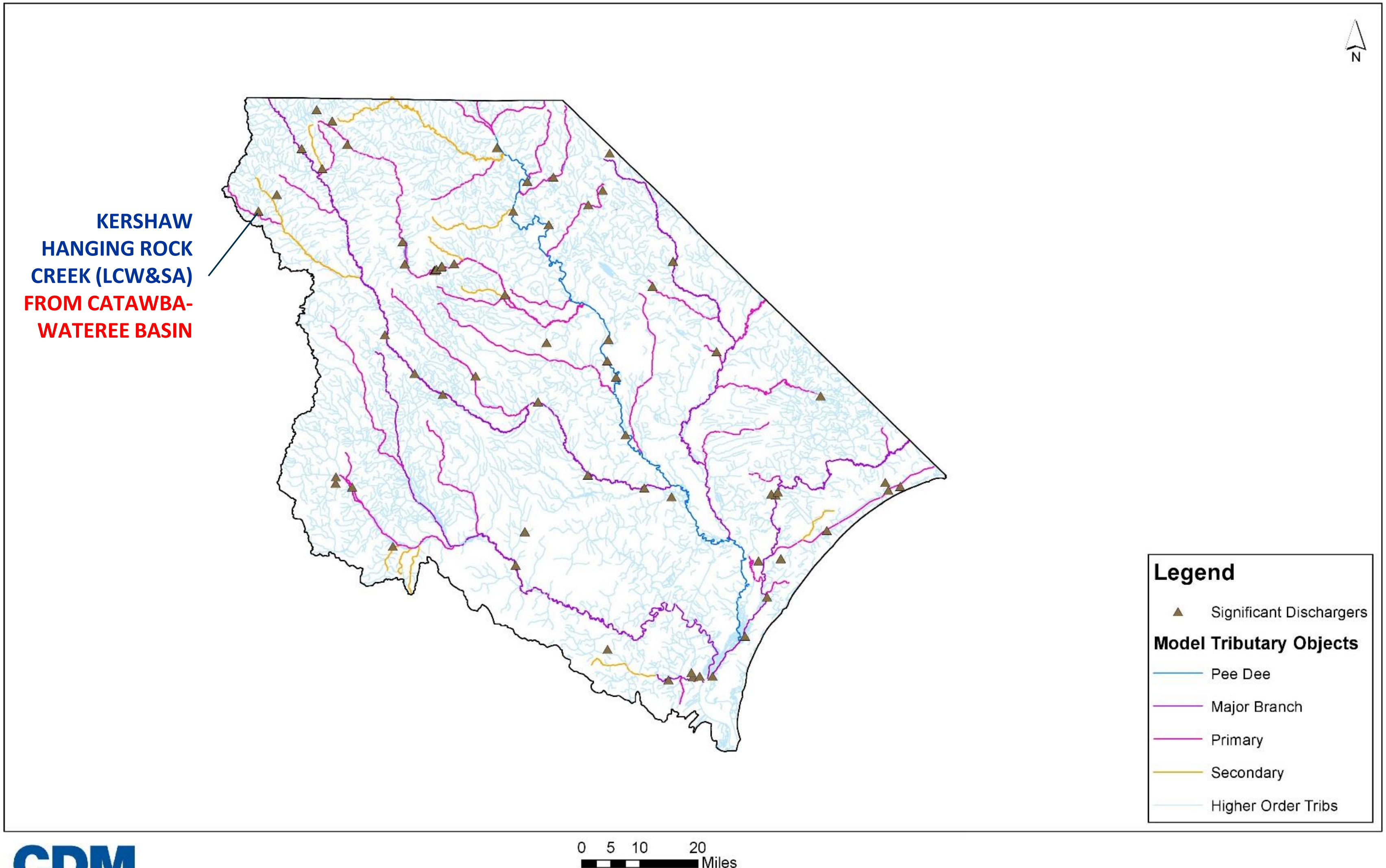
Discharges to Surface Water



Interbasin Transfers

KERSHAW
HANGING ROCK
CREEK (LCW&SA)
FROM CATAWBA-
WATEREE BASIN



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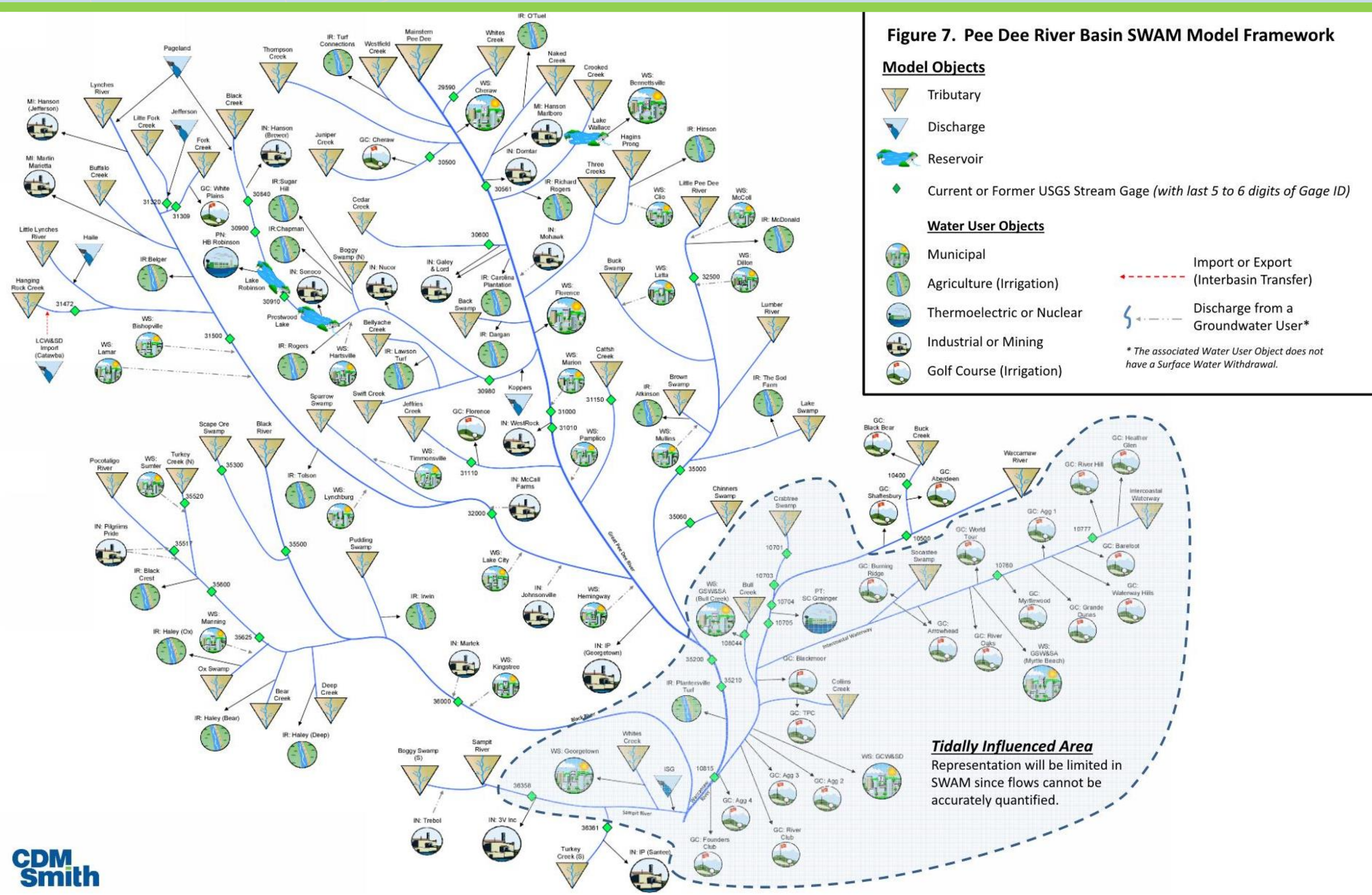
Pee Dee Basin – SWAM Framework



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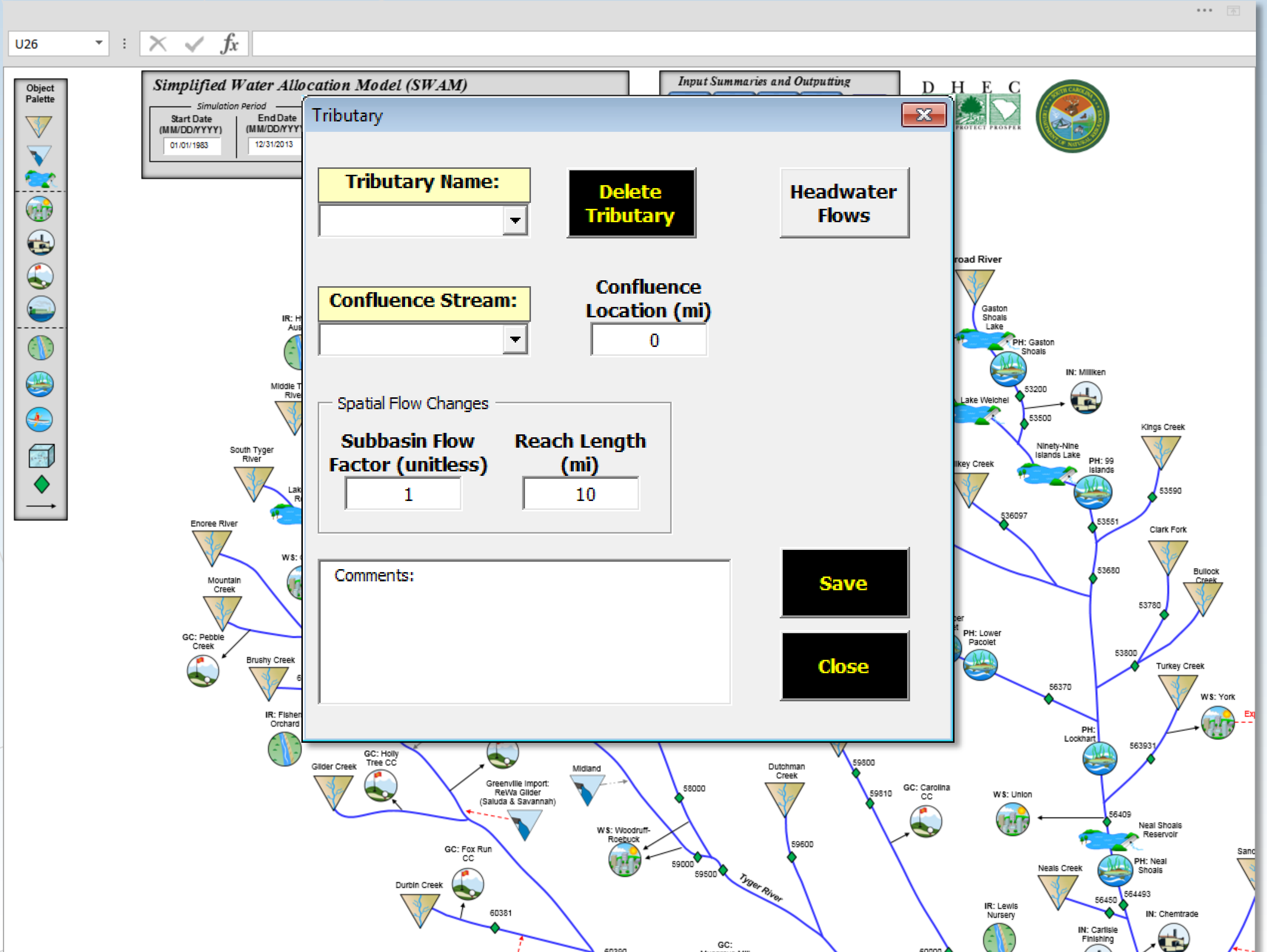
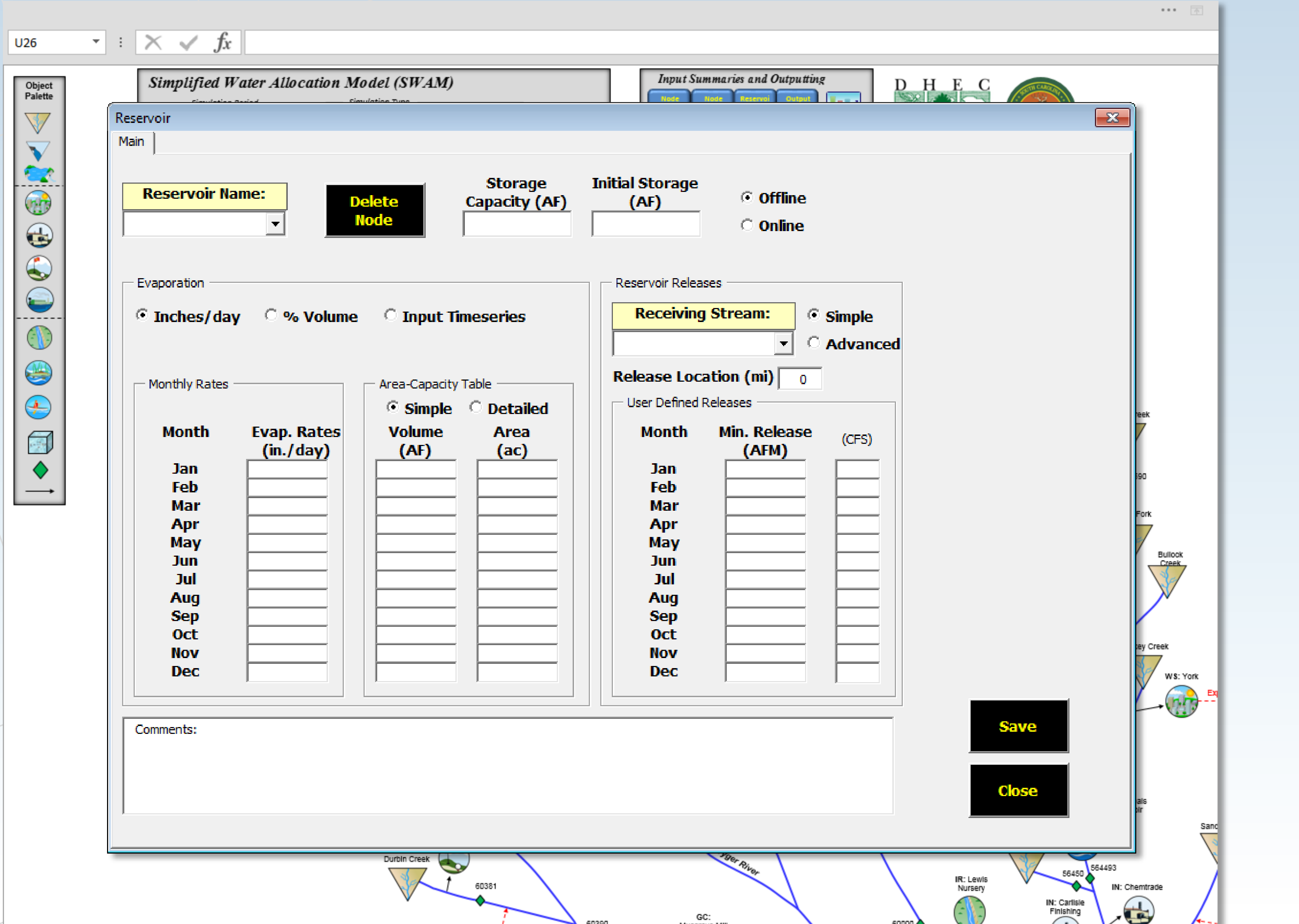
Pee Dee River Basin

MODEL SETUP

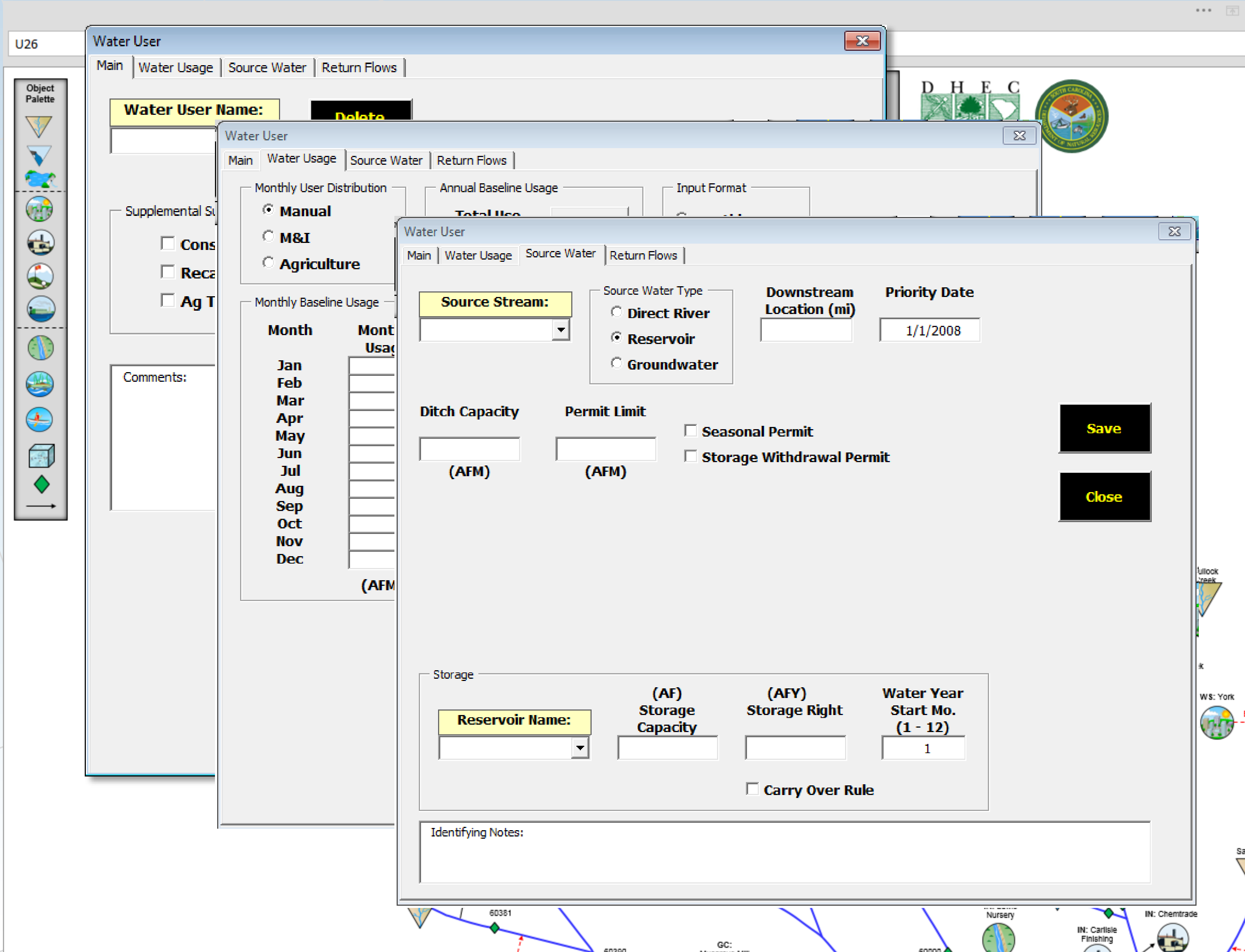
Tributary Input Form



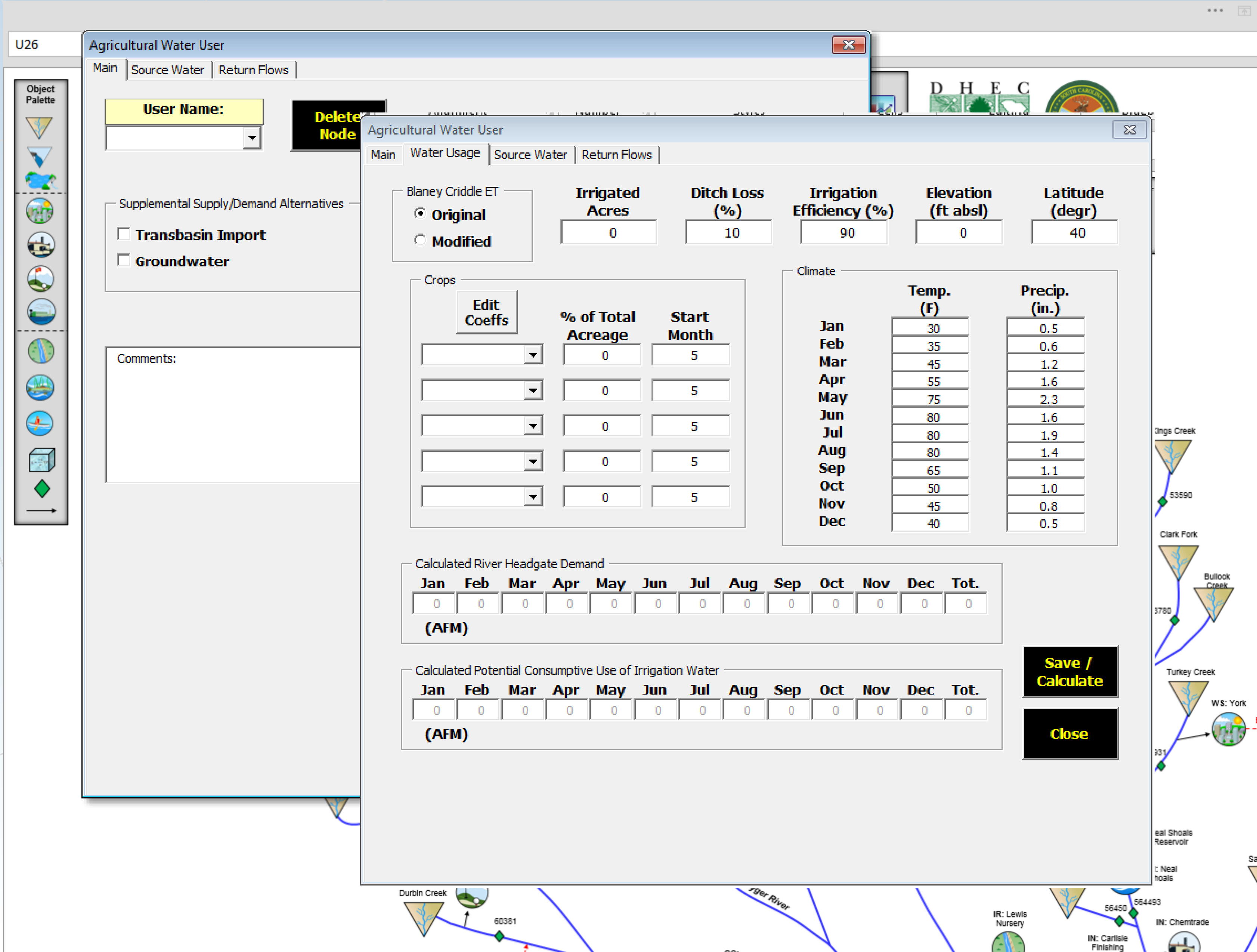
Reservoir Input Form



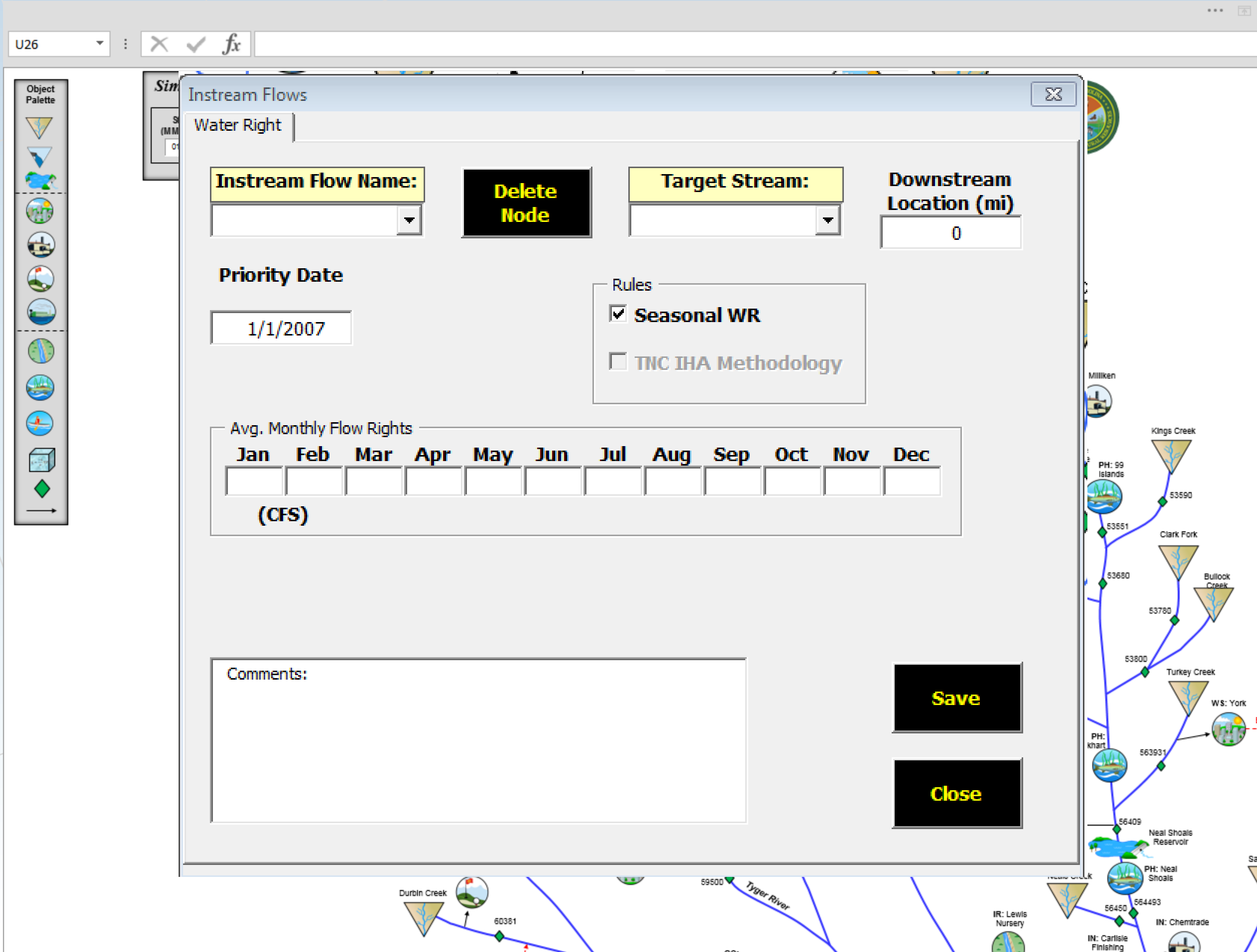
Water User Input Form – Main



Agricultural Water User Input Forms



Instream Flow Input Form



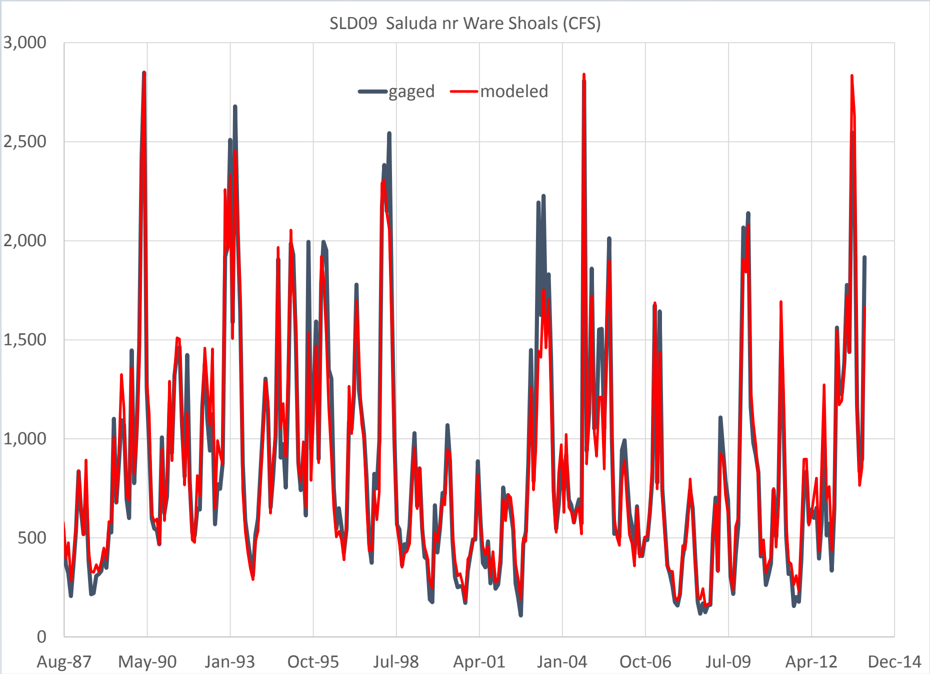
Pee Dee River Basin

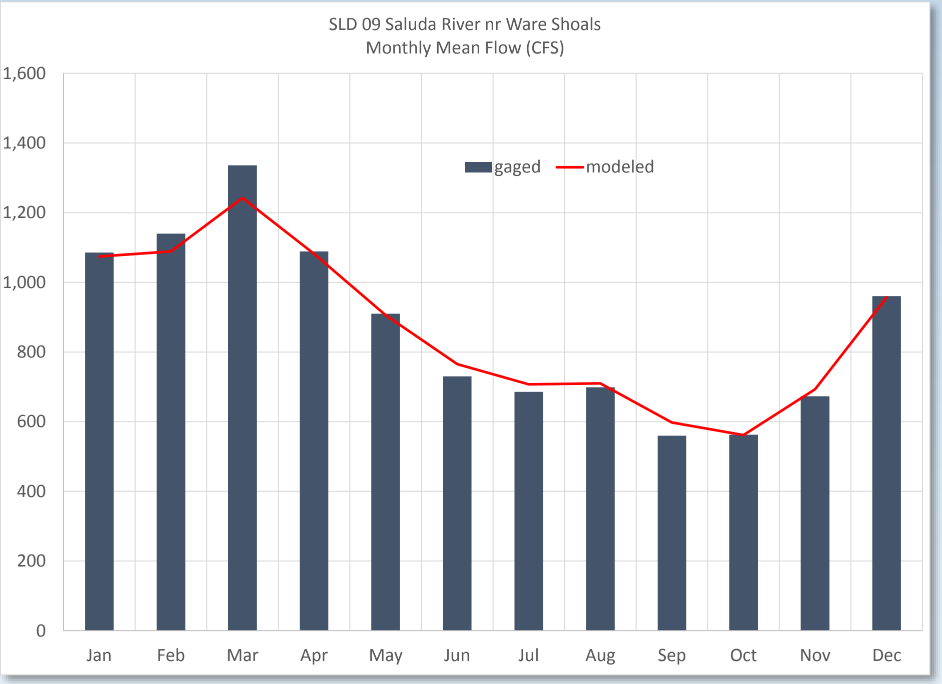
MODEL VALIDATION

SWAM Calibration/Validation

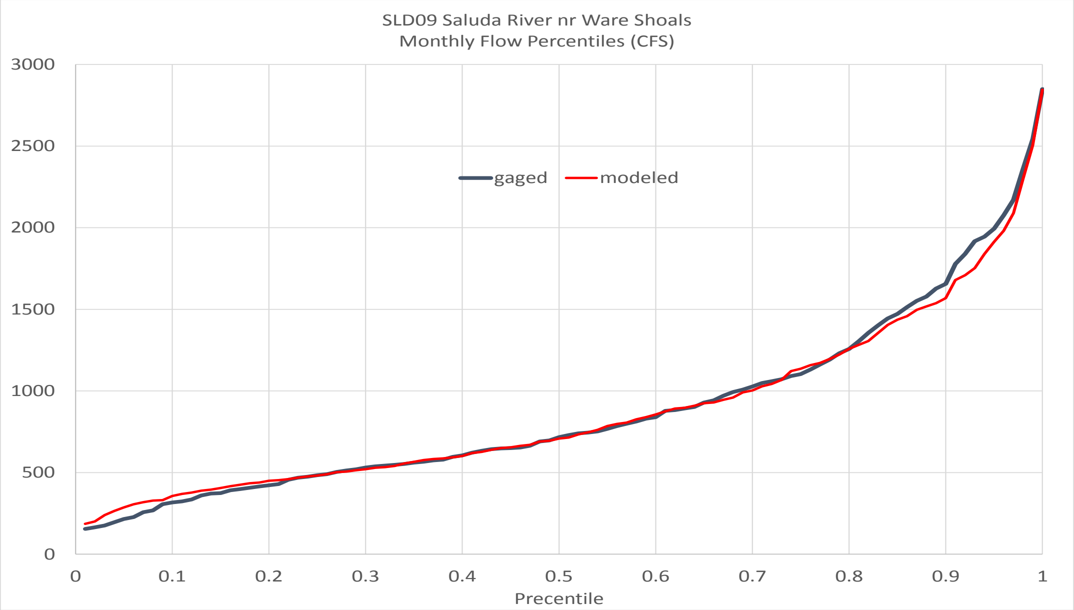
- Calibration targets = downstream flow gage records
- Calibration parameters =
  - reach gains/losses,
  - ungaged flow records,
  - reservoir operations
  - ag return flow percentages, locations, lags
- Performance metrics =
  - Annual avg flows (overall water balance)
  - Monthly avg flows (seasonality)
  - Flow percentile distributions (variability, extreme events)
  - Flow timeseries (specific timings, operations)
  - Reservoir storage timeseries

Calibration Result Graphs





Preliminary examples from the Saluda Basin



Pee Dee River Basin

THANK YOU