



Introduction to the Santee River Basin Surface Water Quantity Model

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Agenda Item 9

What is a Model?

A *numerical model* is a representation of a real-world system that can be solved with computation methods

Numerical models allow us to explore and consider **possible futures**

Models should be as **simple** as possible and as **complex** as needed.

“All models are wrong, some are useful”

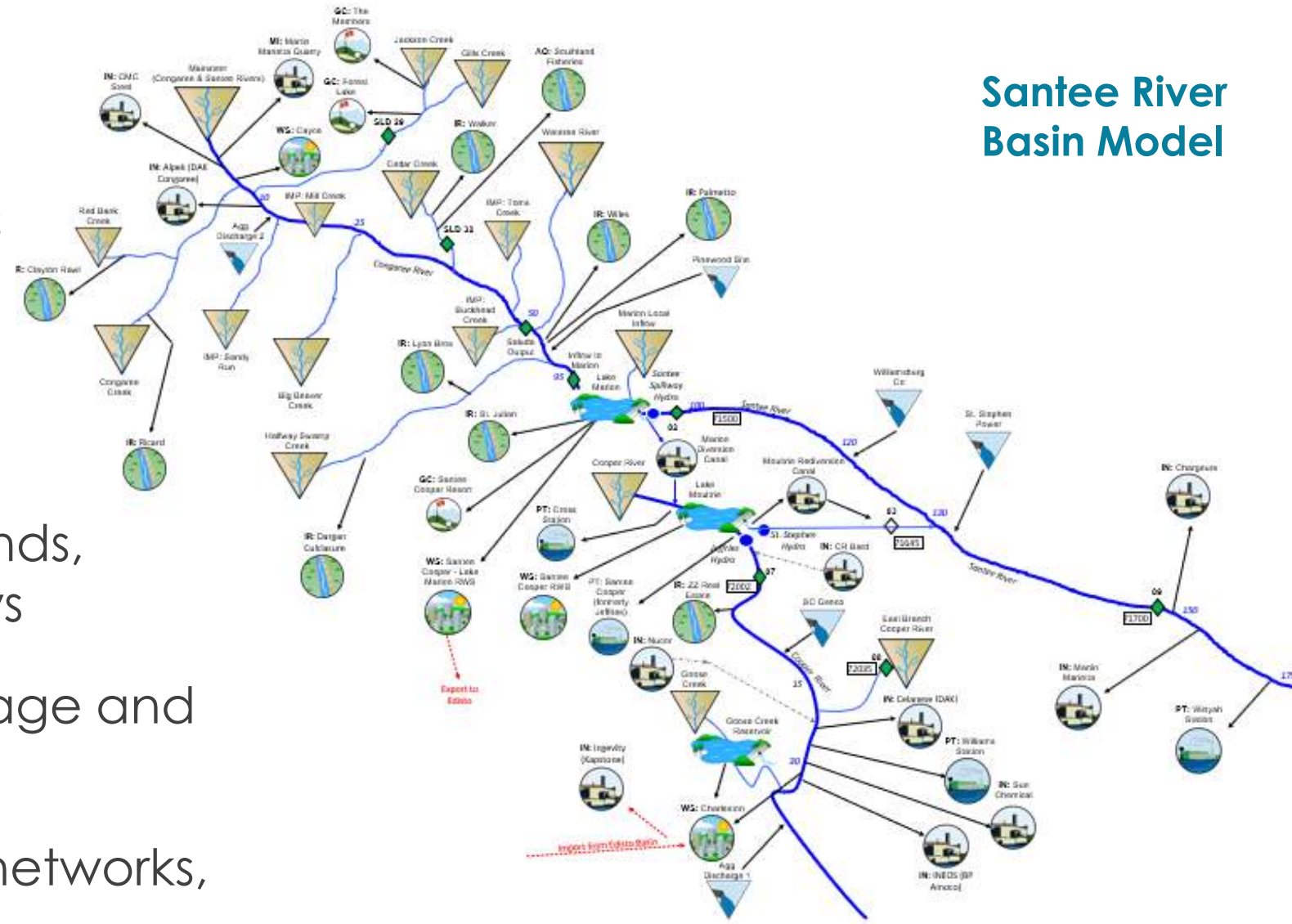
**George Box, 1976
British Statistician**

Box’s point was that we should focus more on whether something can be applied in a useful manner rather than debating endlessly if an answer is correct in all cases

Surface Water Model Overview

Water Allocation Modeling *is*:

- Water balance calculations of physical flow
- Water rights calculations of legally available flow
- Accounting of water demands, withdrawals, and return flows
- Accounting of reservoir storage and loss to evaporation
- A representation of stream networks, multiple “nodes”
- Data intensive



Santee River Basin Model

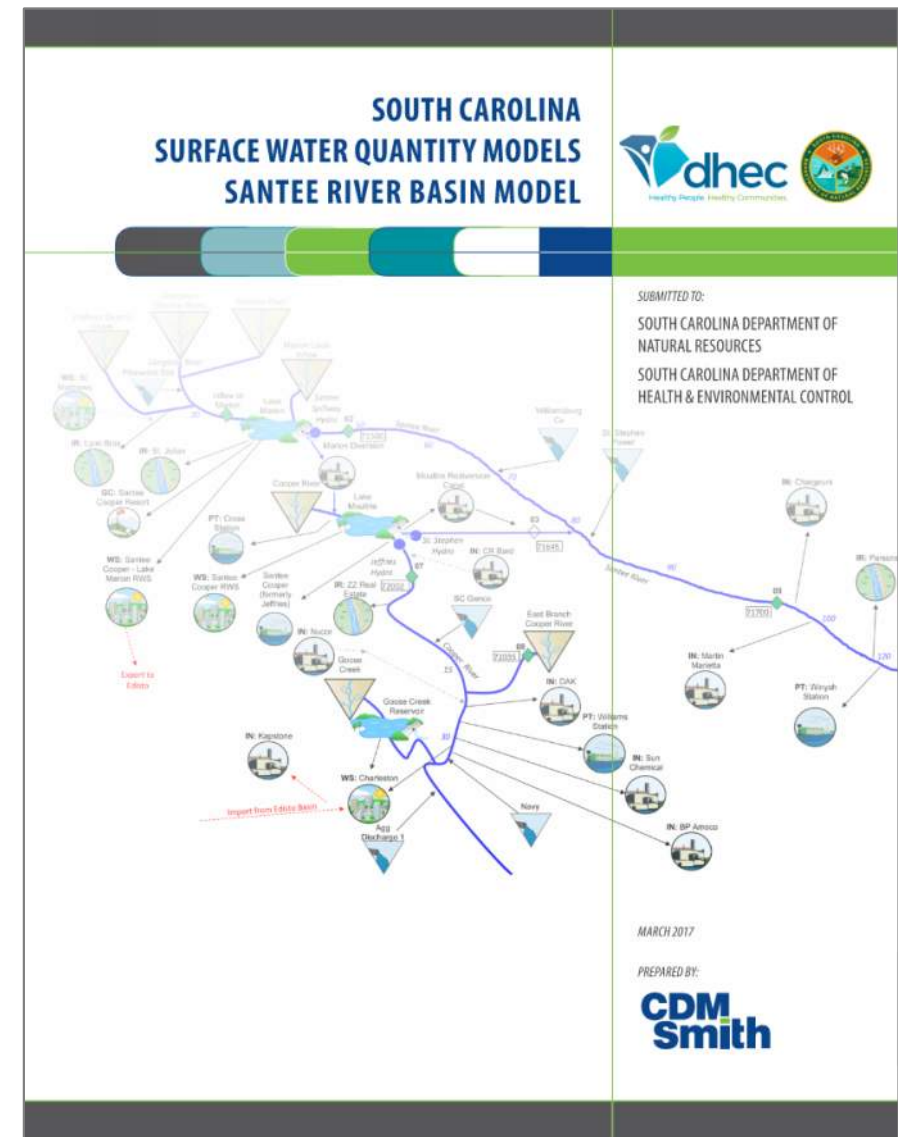
Surface Water Model Overview

Water Allocation Modeling *is not*:

- Rainfall-runoff calculations
- Hydrologic routing calculations
- Groundwater hydrology modeling
- Water quality modeling

Simplified Water Allocation Model (SWAM)

- Developed as a desktop tool to facilitate regional and statewide water planning and allocation
- SWAM calculates physically and legally available water, diversions, storage, consumption and return flows at user-defined nodes
- From 2014 to 2017, all eight South Carolina surface water quantity models were built in the SWAM platform
- Updates to the Santee model are being completed now





In Support of River Basin Planning, the Model Will be Used to:

- Assess current supply availability and shortages across a range of hydrologic conditions
- Assess a range of future potential scenarios with respect to changes in water demand
- Assess potential impacts of a “full allocation” scenario
- Compare managed flows to natural flows
- Evaluate drought management plans
- Test, evaluate and help prioritize water management strategies

Model Inputs and Supporting Information

Model Inputs

- USGS daily flow records
- Historical operational data
 - Withdrawals (municipal, industrial, thermoelectric, agricultural, golf courses, hatcheries)
 - Wastewater discharges and return flows
 - Transfers in and out of the basin
- Reservoir characteristics and operating rules

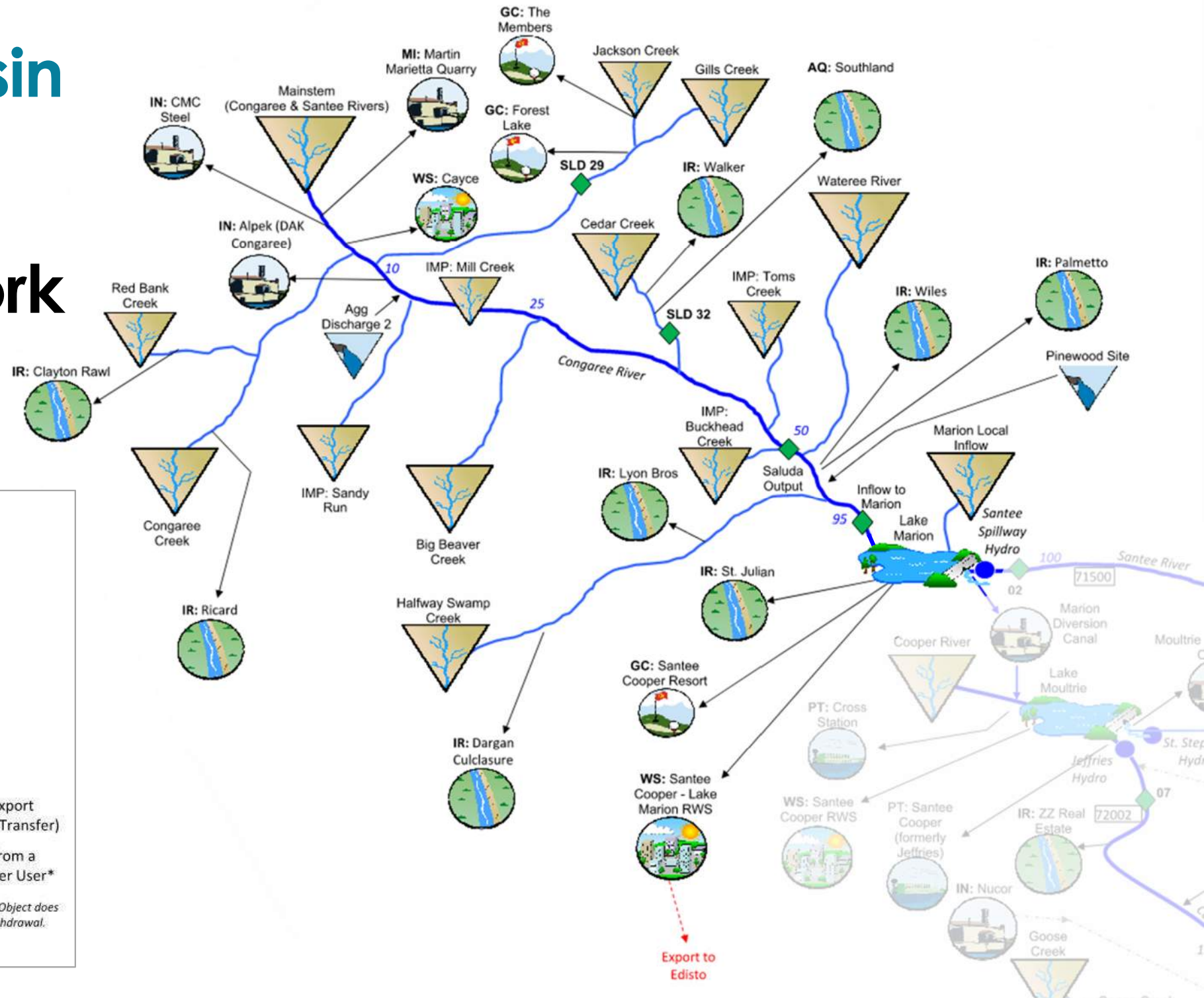
Supporting Information

- Subbasin characteristics
 - Drainage area, land use, and slope



USGS Streamflow Gaging Station

Santee River Basin (Upper Portion) Surface Water Model 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)



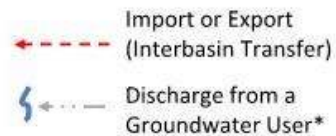
Thermolectric or Nuclear



Industrial or Mining



Golf Course (Irrigation)



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

Santee River Basin (Lower Portion) Surface Water Model Framework

Model Objects

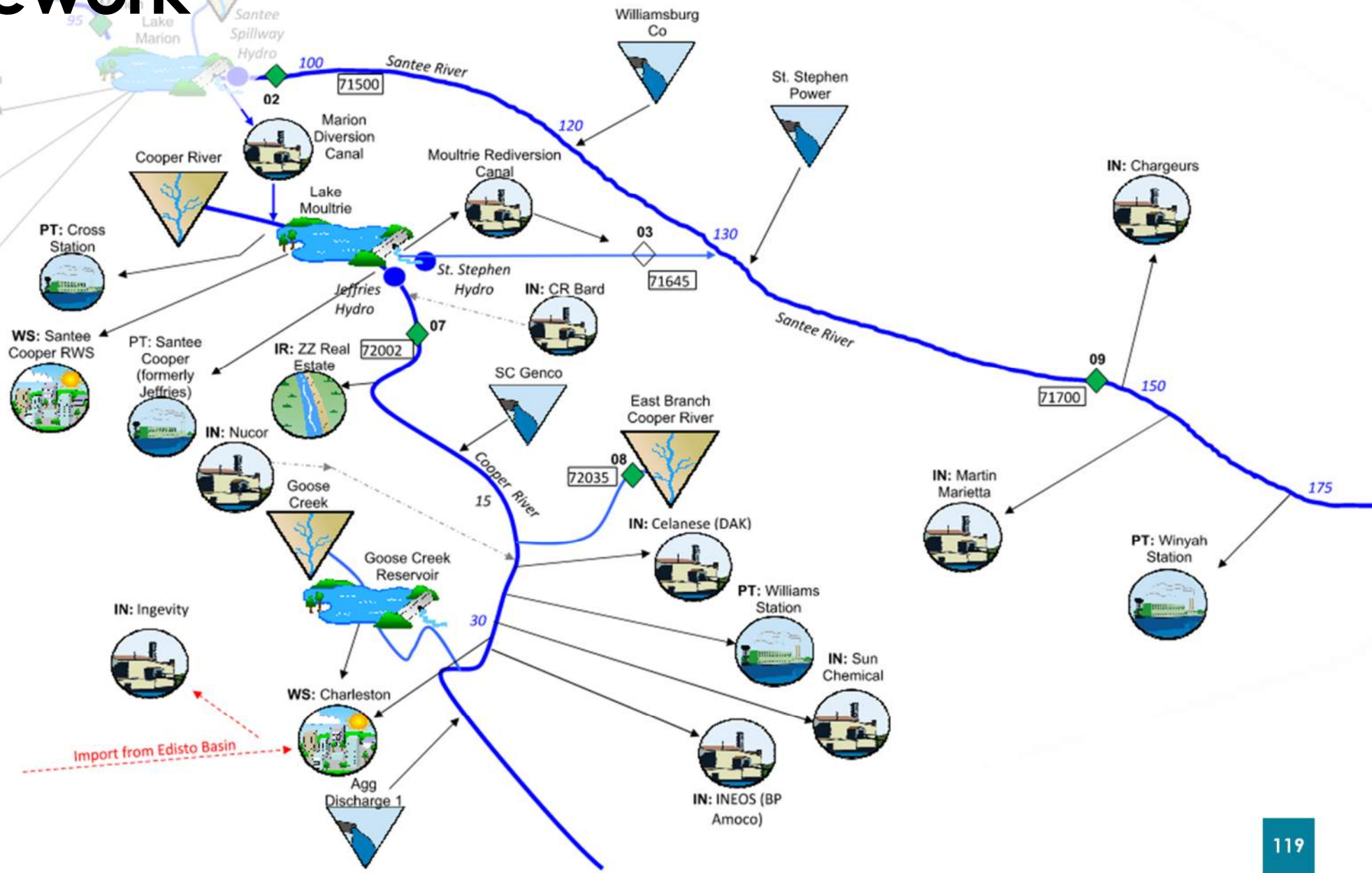
- Tributary
- Discharge
- Reservoir
- Current or Former USGS Stream Gage (with last 5 to 6 digits of Gage ID)

Water User Objects

- Municipal
- Agriculture (Irrigation)
- Thermoelectric or Nuclear
- Industrial or Mining
- Golf Course (Irrigation)

Import or Export (Interbasin Transfer)
 Discharge from a Groundwater User*

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



SWAM Calculations: Supply

- Physically available flow is a function of:
 - upstream tributary inflows,
 - reach gains and losses,
 - upstream diversions, withdrawals, returns, and storage

Cedar Creek Headwater Flows

Year (YYYY)	Month (MMM)	Monthly Flow (CFS)
1980	Jan	36.0
1980	Feb	40.8
1980	Mar	86.4
1980	Apr	71.1
1980	May	27.3
1980	Jun	18.8
1980	Jul	17.1
1980	Aug	11.6
1980	Sep	11.5
1980	Oct	23.8
1980	Nov	18.3
1980	Dec	18.3
1981	Jan	15.4
1981	Feb	24.0
1981	Mar	17.9
1981	Apr	11.3
1981	May	7.9
1981	Jun	16.7
1981	Jul	9.5

Tributary ✕

Tributary Name:
Cedar Creek **Delete Tributary** **Headwater Flows**

Confluence Stream:
Mainstem **Confluence Location**
43 (mi)

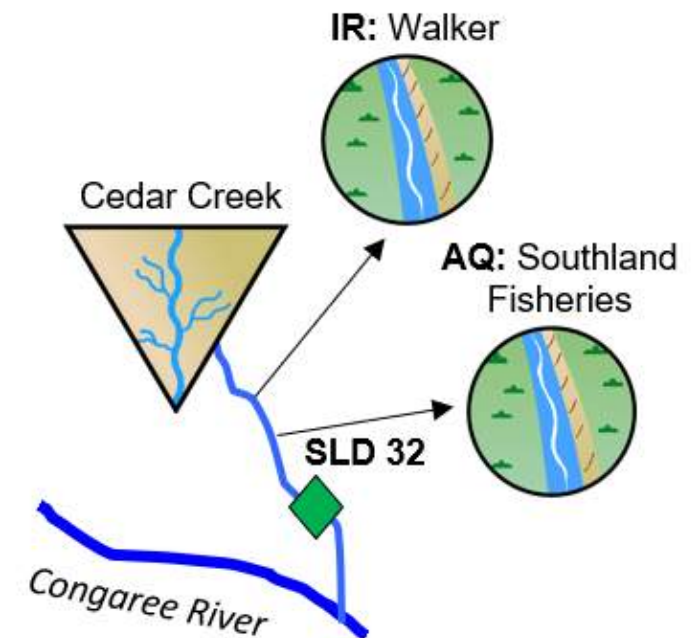
Spatial Flow Changes
Subbasin Flow Factors (unitless)

end mile:	9	14.4							
factor:	2.6	4.4							

Temporally Variable Factors

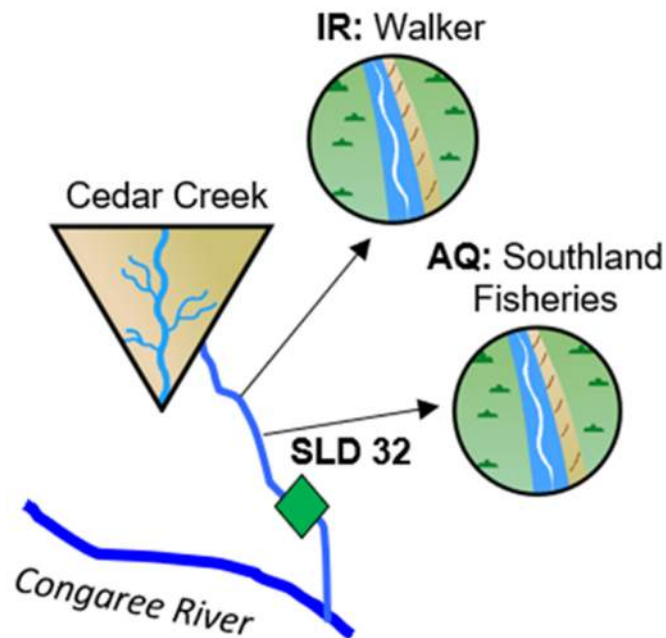
Comments: SLD225. Flow factors adjusted slightly as part of the calibration process.

Save **Close**



SWAM Calculations: Supply

- **Legally available** flow is a function of:
 - Permit limits / water rights
 - Minimum Instream flow requirements



IR: Walker Farm

Agricultural Water User

Main Source Water Return Flows

Source Stream: Cedar Creek

Source Water Type:
 Direct River
 Reservoir
 Groundwater

Diversion Location: 1 (mi)

Priority Date: 1/9/1900

Diversion Capacity: 10000 (CFS)

Permit Limit: 3 (MGM)

Seasonal Permit
 Minimum Flow Requirements

Save

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Identifying Notes: registration limit of 3 MGM

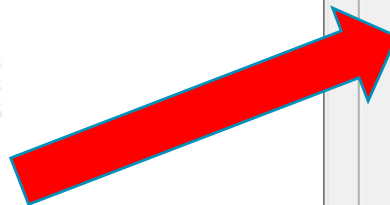
SWAM Calculations: Demand

■ WS: User Object:

- Node based withdrawals and returns
- Municipal water demands (prescribed monthly mean)

WS: Santee Cooper RWS

WS: Santee Cooper RWS



Water User

Main | **Water Usage** | Source Water | Return Flows

Monthly User Distribution

Manual
 M&I
 Agriculture

Annual Baseline Usage

Total Use (MGY)

Input Format

monthly means
 timeseries

Monthly Baseline Usage

Month	Monthly Usage	% Indoor Use	% CU Indoor	% CU Outdoor
Jan	19.74	100	44.7	100
Feb	18.97	100	40.8	100
Mar	19.54	100	45.3	100
Apr	20.55	100	51.7	100
May	24.02	100	60.6	100
Jun	24.2	100	57.8	100
Jul	24.07	100	56.6	100
Aug	23.64	100	56.2	100
Sep	22.51	100	54.5	100
Oct	22.03	100	52.8	100
Nov	19.9	100	50.5	100
Dec	20.01	100	47.4	100

(MGD)

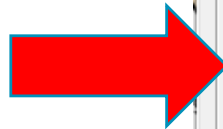
SWAM Calculations: Reservoirs

- Reservoir Object:

- Dynamic water balance, water supply pool, customized operating rules



Lake Marion



Reservoir

Main | Rule Set 1 | Rule Set 2 | Rule Set 3 | Rule Set 4 | Rule Set 5

Reservoir Name: Lake Marion **Delete Node**

Storage Capacity: 464338 (MG) Initial Storage: 464338 (MG) Dead Pool: 142703 (MG) Offline Online

Evaporation: Monthly Mean % Volume Input Timeseries **Edit Timeseries**

Area-Capacity Table: Simple Detailed

Volume (MG)	Area (Ac)
2281	10
2933	1500
7820	6000
13686	10000
32585	19000
71687	29000
136858	40000
211803	51000
276974	60000
342144	71000
391022	80000
464338	106700

Reservoir Operations: Receiving Stream: Mainstem Simple Advanced Release Location: 96.6 (mi) Release Accounts: All Users Specified User

Flood Control Outflow: % Vol Outflow (CFS)

% Vol	Outflow (CFS)
0	0
100	0

Save **Close**

Comments: Info from 2007 Santee Cooper EIS and USGS documents (<https://pubs.er.usgs.gov/publication/wri884062>); releases from Santee Dam are to mainstem, releases to Diversion Canal represented by user object

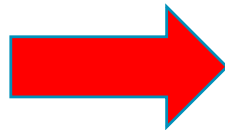
SWAM Calculations: Reservoirs

- Reservoir Object:

- Example operating rule: Lake Marion normal operating target volumes (Rule Set 3)



Lake Marion



Reservoir

Main | Rule Set 1 | Rule Set 2 | Rule Set 3 | Rule Set 4 | Rule Set 5

Minimum Releases
 Storage Curve
 Instream Flow

Priority #3
 Include Rule

Maximum Release
1000000 (CFS)

Normal operating targets.

Rule Details

Moving Averages | Composite Metrics | Ramping Periods | Moving Triggers Start of Timestep Storage Conditions

Start Date	End Date	Target	Condition Type	Conditional Object 1:	Criteria1:	Cond. 1:	Conditional Object 2:	Criteria2:	Cond. 2:
01/16	02/08	398877	None						
02/09	03/10	418254	None						
03/11	05/31	432917	None						
06/01	07/31	432917	None						
08/01	10/11	418254	None						
10/12	12/15	381246	None						
12/16	01/15	347032	None						

(CFS or MG) (CFS or MG) (CFS or MG)

Save Close

Model Time Steps

- Model simulations may use a **daily** or **monthly** timestep
- A **monthly timestep** will be used to look for shortages, test and compare management strategies, and compare flows at strategic nodes.
- A **daily timestep** will be used for comparison to minimum instream flows and for determining changes in risk in ecological-flow relationships.

Model Calibration

- Calibration performed for multiple sites across a wide range of hydrologic conditions
 - **Calibration Targets:** USGS streamflow gage records
 - **Key calibration parameters:** reach gain/loss and sub-basin flow factors A1
 - **Performance metrics:**
 - Annual avg flows (overall water balance) A0
 - Monthly avg flows (seasonality)
 - Flow percentile distributions (variability, extreme events)
 - Flow timeseries (specific timings, operations)
 - Cumulative flows over entire calibration period
- FOCUS {
- Reservoir storage timeseries
 - Achieving representative demands for the canal Water User objects

A0

I think these are probably the same for Santee? The language is slightly different in Savannah report vs. Santee report.

Savannah:

A number of performance metrics were used to assess the model's ability to reproduce past basin hydrology and operations. These include: monthly and daily water user supply delivery and/or shortfalls, monthly and daily timeseries plots of both river flow and reservoir levels, annual and monthly mean flow values, monthly and daily percentile plots of river flow values, annual 7-day low flows with a 10-year recurrence interval (7Q10), and mean flow values averaged over the entire period of record.

Santee:

A number of performance metrics were used to assess the model's ability to reproduce past basin hydrology and operations. These include: monthly and daily water user supply delivery and/or shortfalls; monthly and daily timeseries plots of both river flow and reservoir levels; annual and monthly mean flow values; monthly and daily percentile plots of river flow values; and mean flow values averaged over the entire period of record. . As emphasized in the calibration sequence outlined in Section 7.2.1, the focus of calibration was on reproducing historic patterns of reservoir storage/elevation and achieving representative demands for the canal Water User objects such that historic variability is preserved while still maintaining predictive potential. The other calibration metrics can offer important context, but as this is no longer a strictly hydrologic calibration, cannot be construed with as much weight as in previous basins.

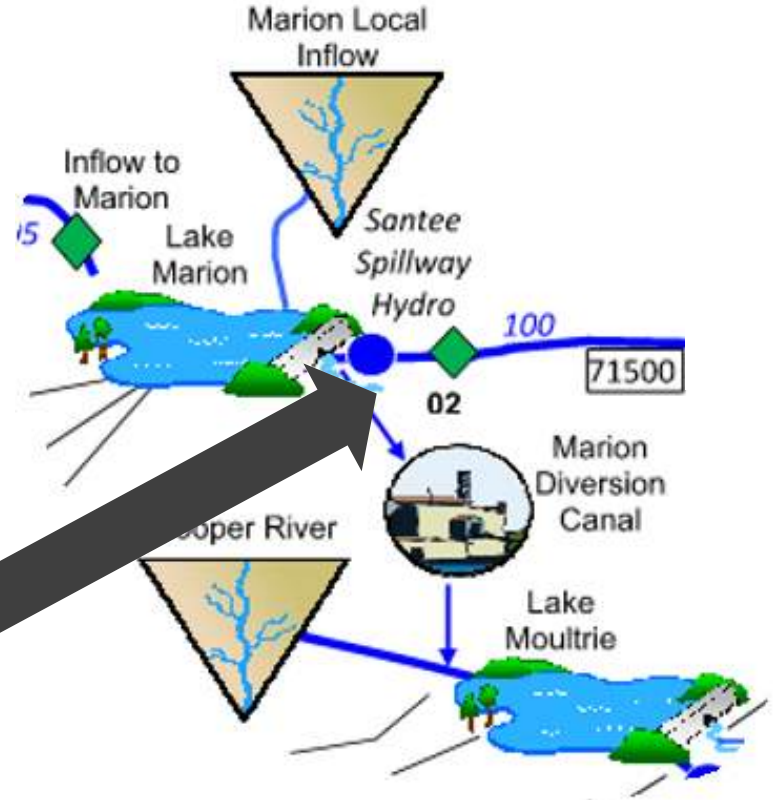
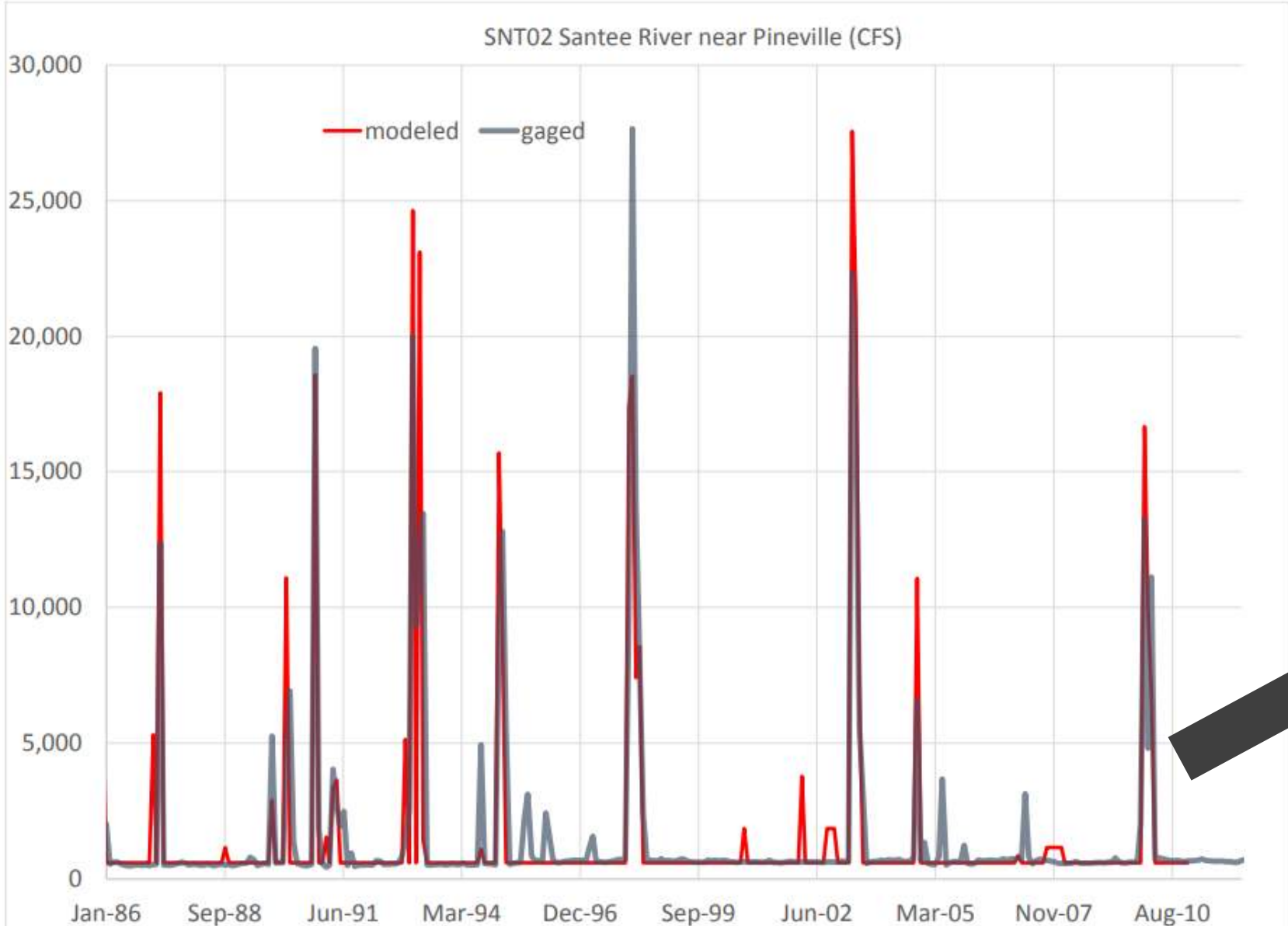
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A1

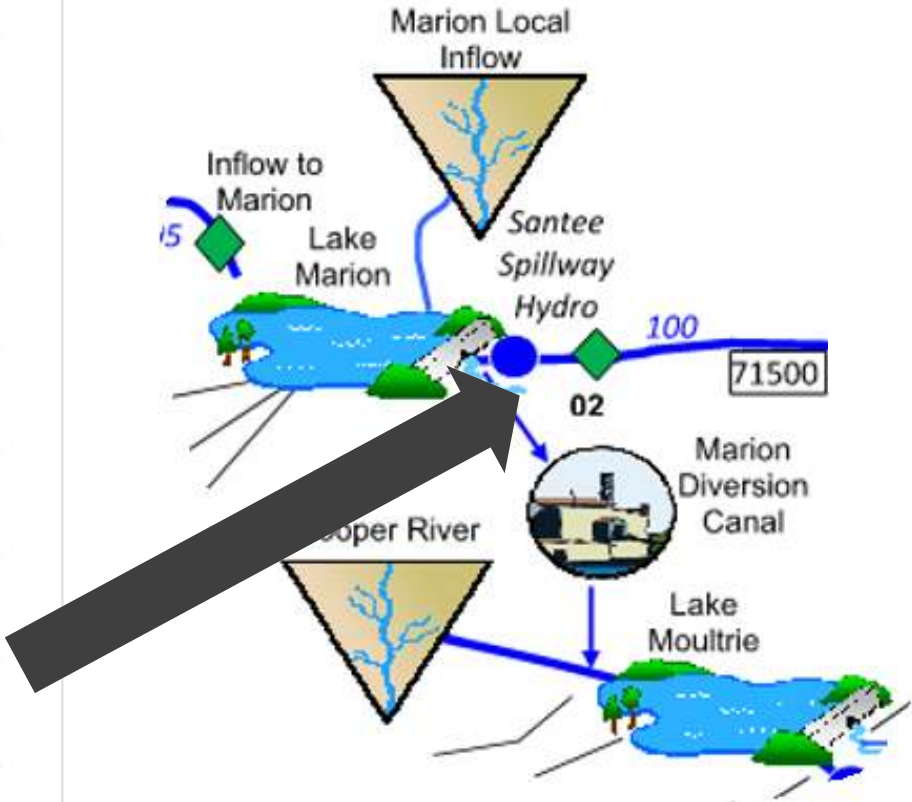
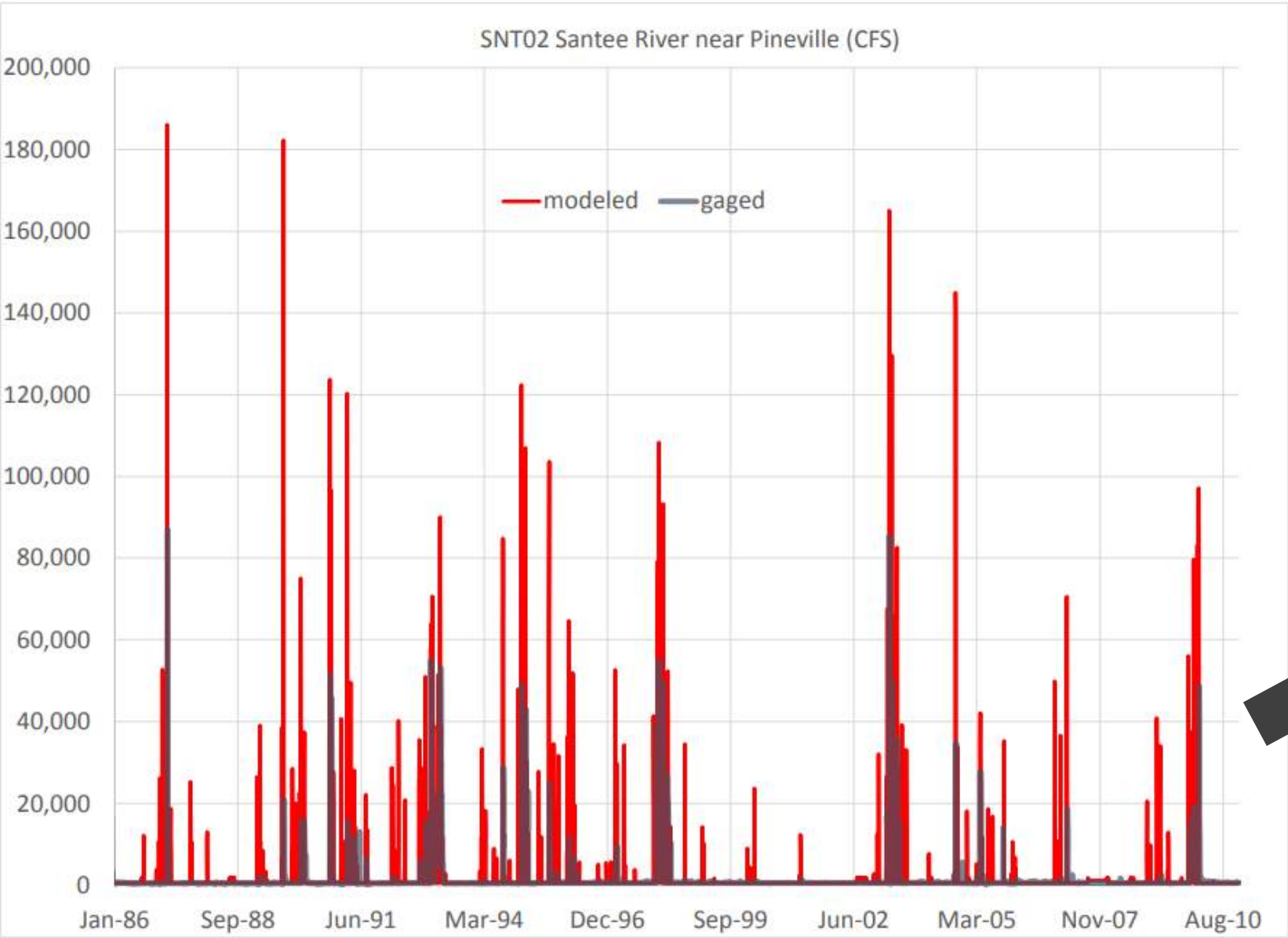
Changed from reach gain/loss factors

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Comparison of Monthly Gaged and Modeled Flows



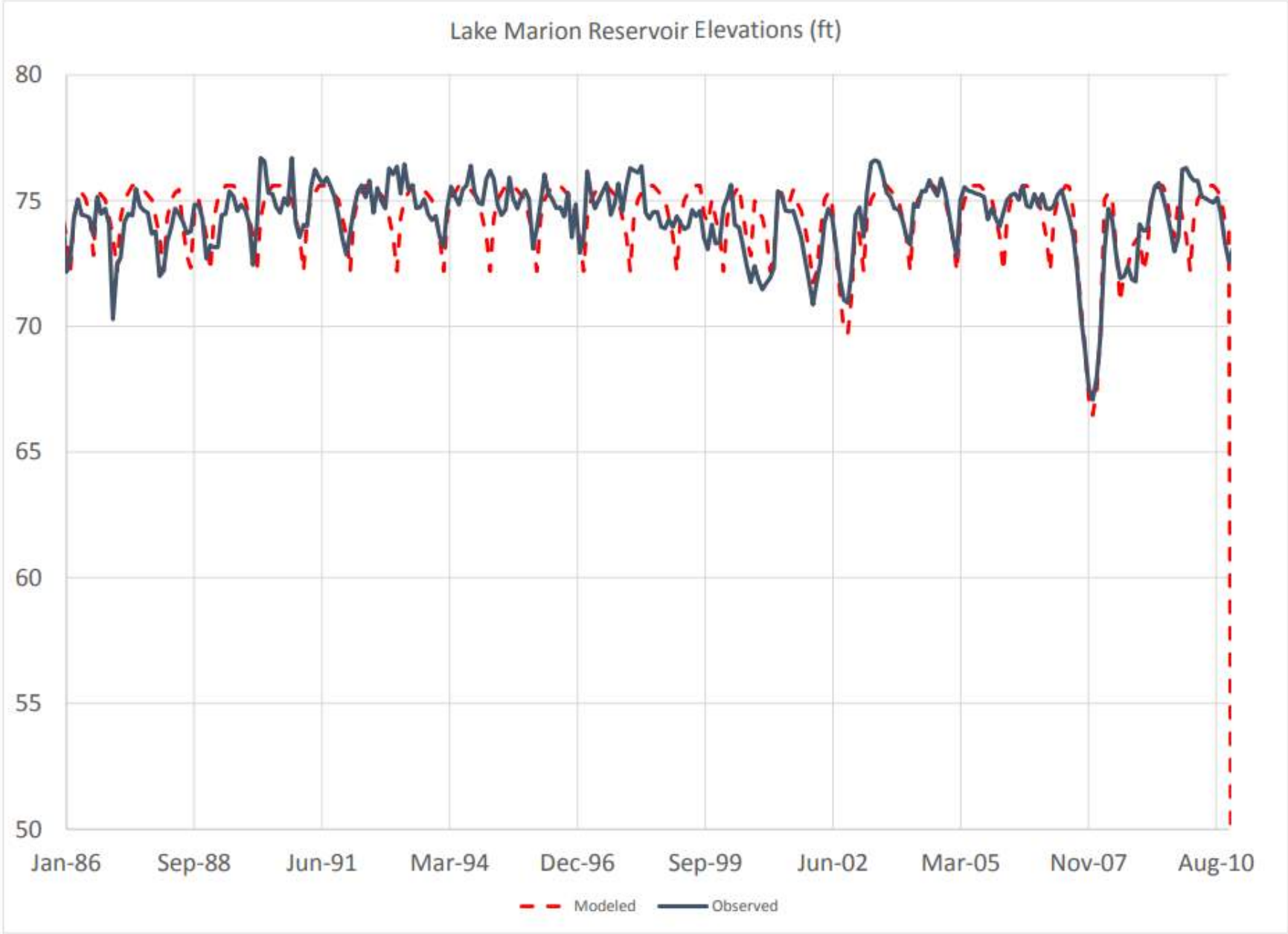
Comparison of Daily Gaged and Modeled Flows



Comparison of Measured and Modeled Lake Levels



Lake Marion





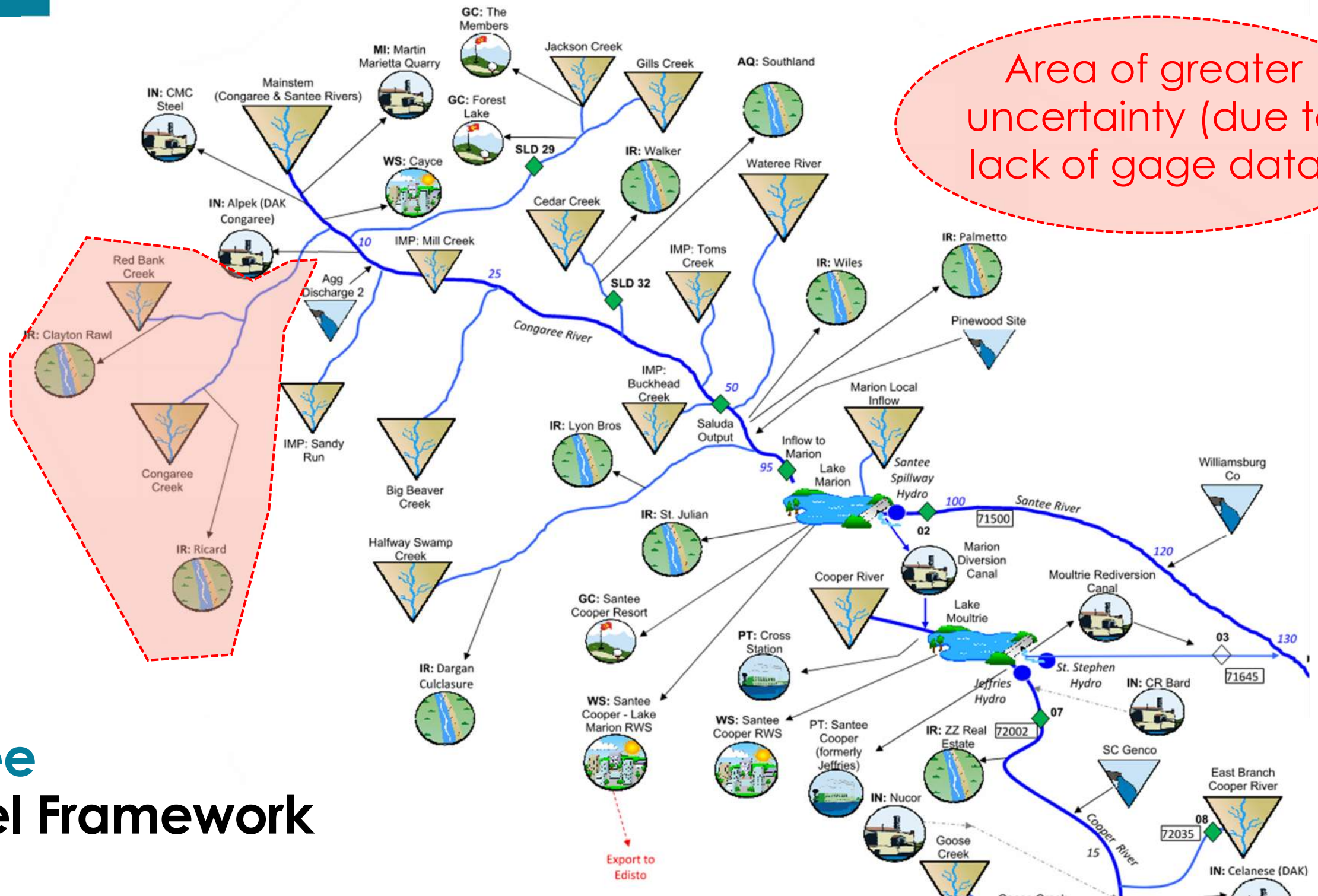
2024 Surface Water Model Updates

- Extended baseline hydrology
- Updated monthly mean water demands based on recent water use data
- Updated permit and intake location information
- Removed inactive permittees
- Added new registrations
- Software updates

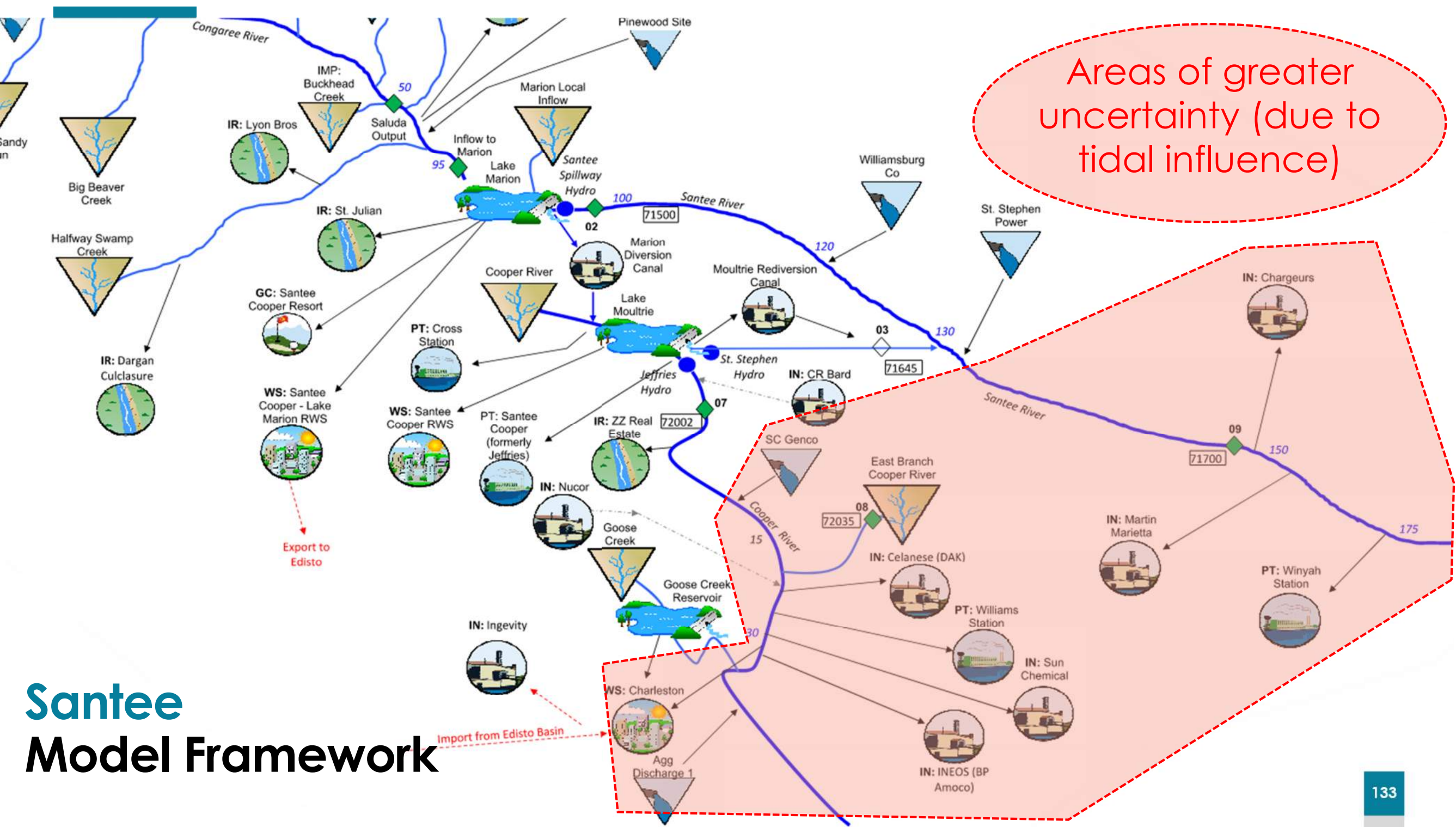
Model Limitations

- Greater uncertainty in predictions for ungaged reaches compared to gaged
- Model not designed for reach routing of flow changes at a sub-daily timestep
- Greater uncertainty in supply availability (and “shortage”) predictions associated with small stream withdrawals compared to larger river and reservoir withdrawals
 - e.g. irrigation ponds
- Baseline model assumes past hydrologic variability is representative of future hydrologic variability (stationary climate)

Santee Model Framework



Area of greater uncertainty (due to lack of gage data)



Santee Model Framework

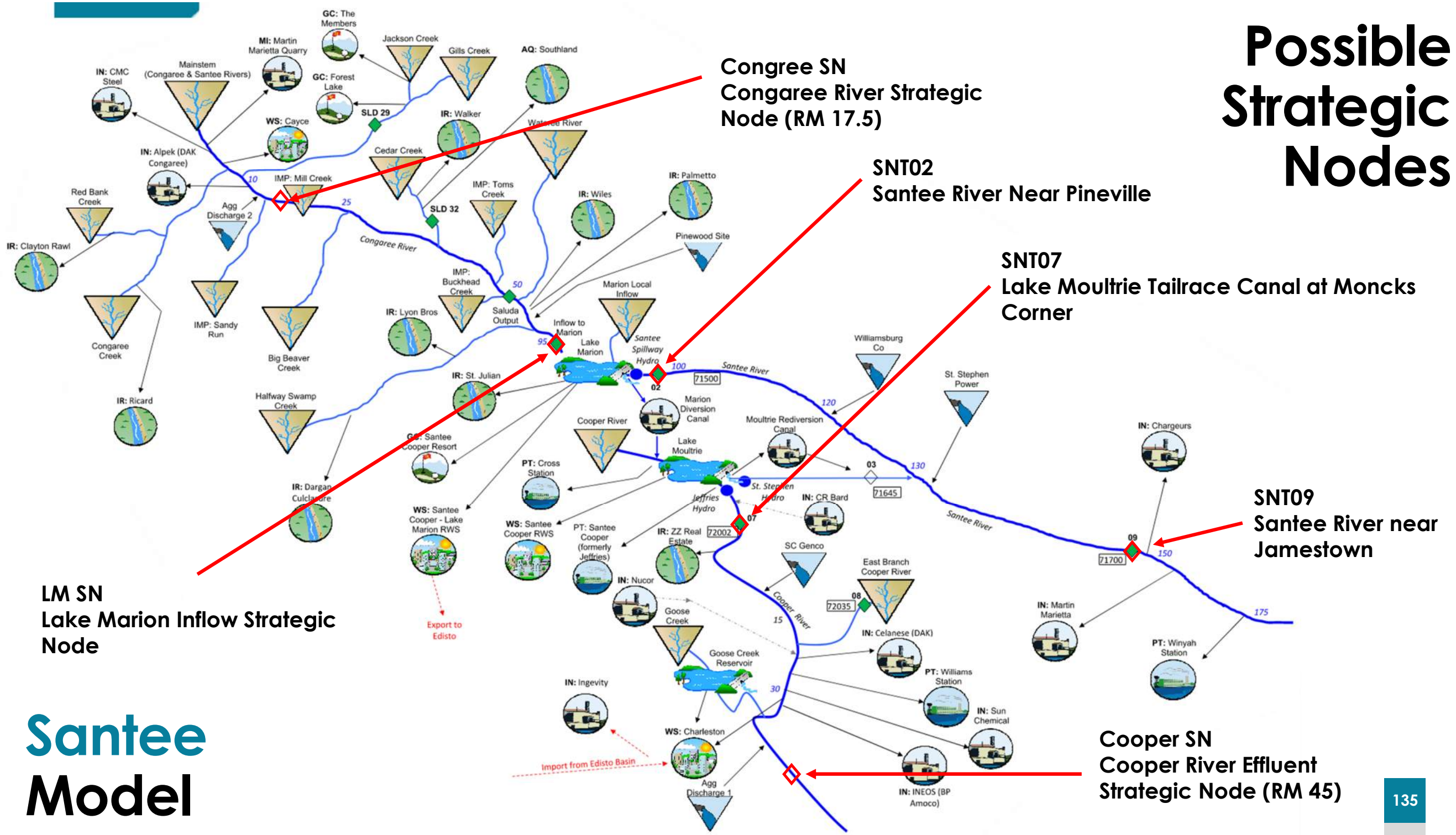
Performance Measures

Assessment of simulation results will focus on quantifying key performance measures for strategic nodes and reaches of interest across the basin.

Example / Suggestions:

- Percent change in a monthly minimum flow, 5th percentile flow, mean, and/or median flow
- Percent change in seasonal or monthly flows
- Percent change in surface water supply
- Percent change in mean annual shortage or mean percent shortage
- Change in the number and magnitude of excursions below 20, 30 and 40 percent mean annual daily flows and/or 7Q10 flow
- Change in number of water users that experience a shortage
- Change in the average frequency of shortage
- Percent of time recreational facilities were unavailable on a stream reach

Possible Strategic Nodes



LM SN
Lake Marion Inflow Strategic Node

Congree SN
Congaree River Strategic Node (RM 17.5)

SNT02
Santee River Near Pineville

SNT07
Lake Moultrie Tailrace Canal at Moncks Corner

SNT09
Santee River near Jamestown

Cooper SN
Cooper River Effluent Strategic Node (RM 45)

Santee Model