

Presentation Outline

- Project background and status
- Model calibration/verification
 - Calibration/verification philosophy and approach
 - Calibration results and discussion
- Overview and demonstration of the model

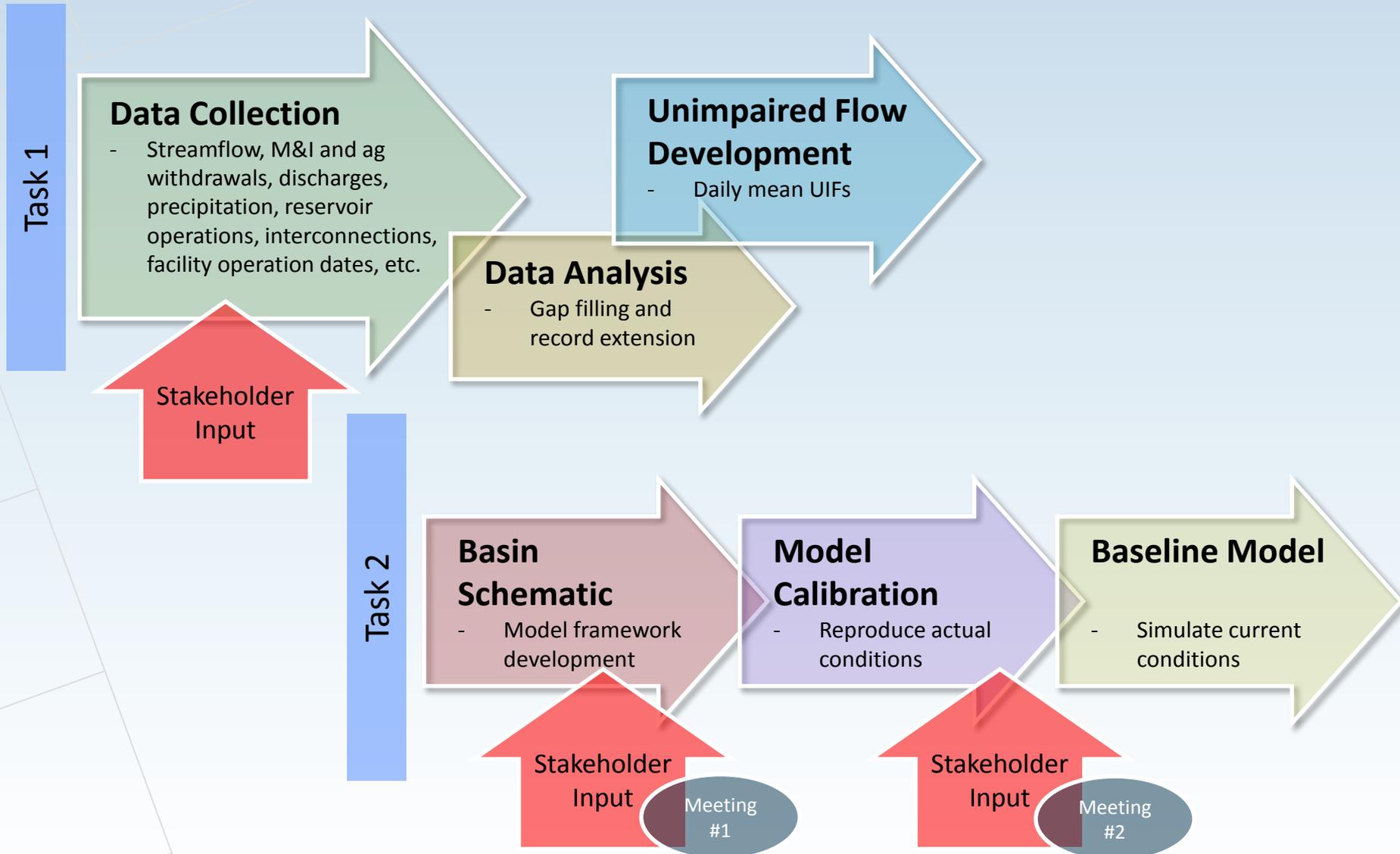
Project Purpose

- 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
 - system performance

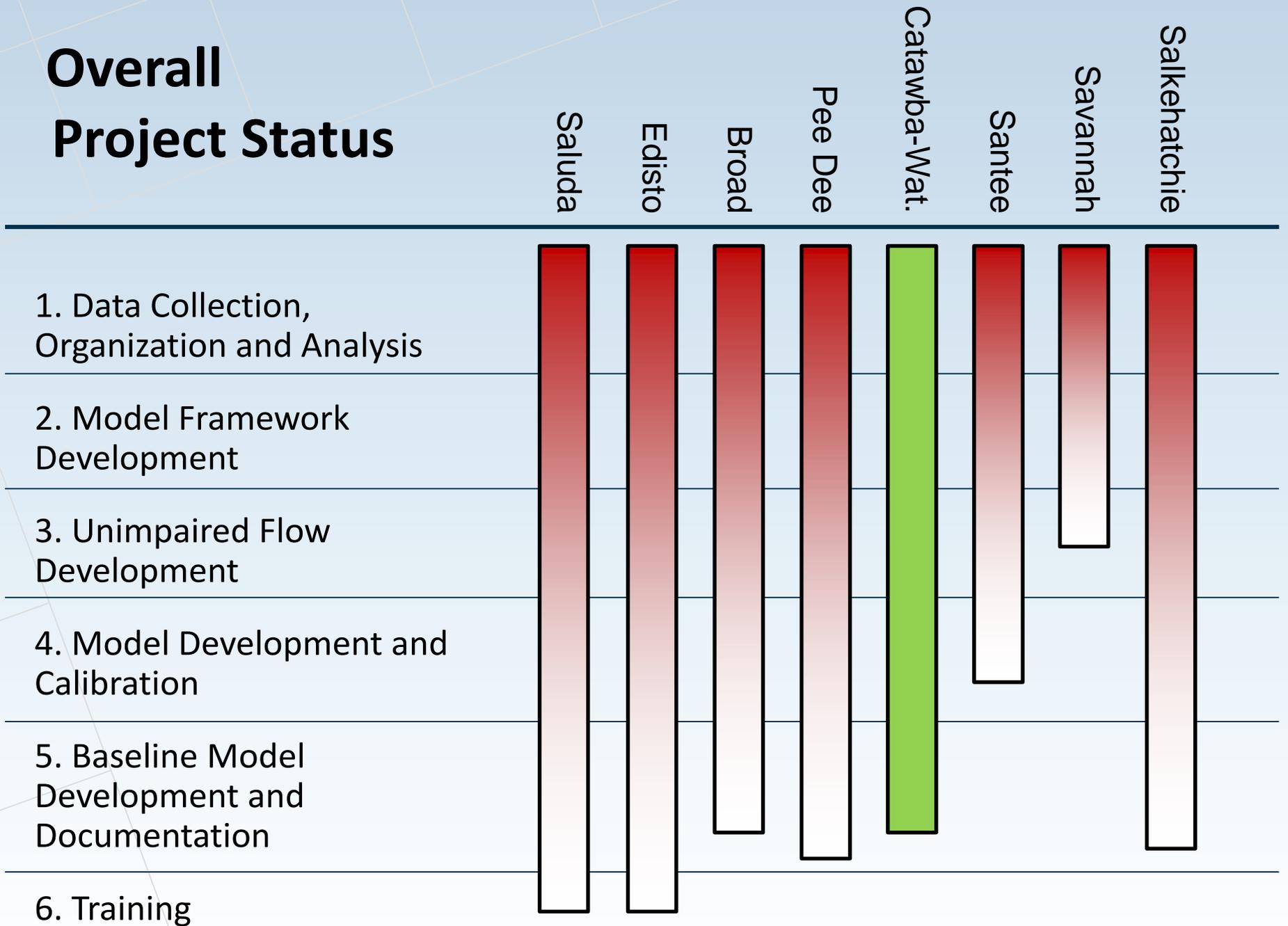
The Simplified Water Allocation Model is...

- A water accounting tool
 - *Calculates physically and legally available water*
 - *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)

Project Status – Catawba-Wateree Basin



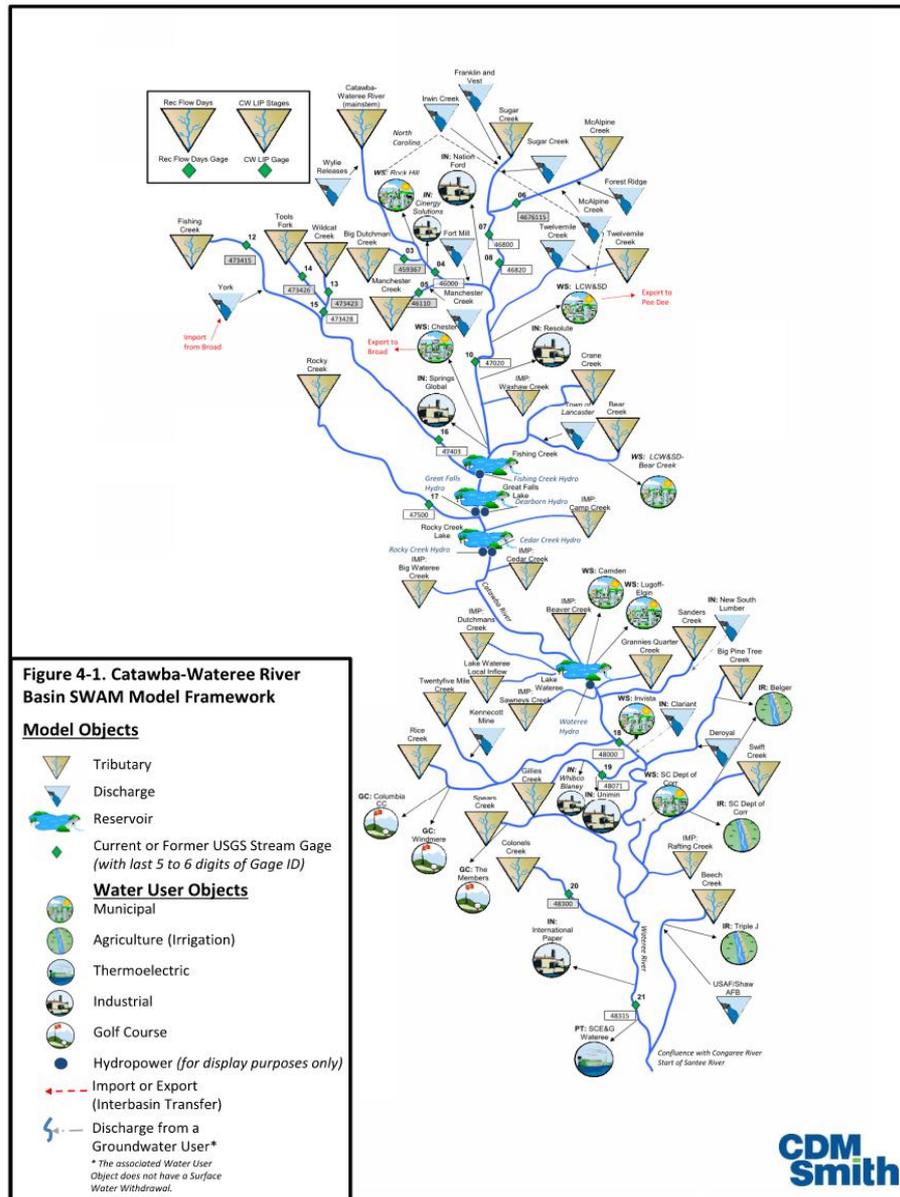
Overall Project Status



Calibration vs. Baseline Model

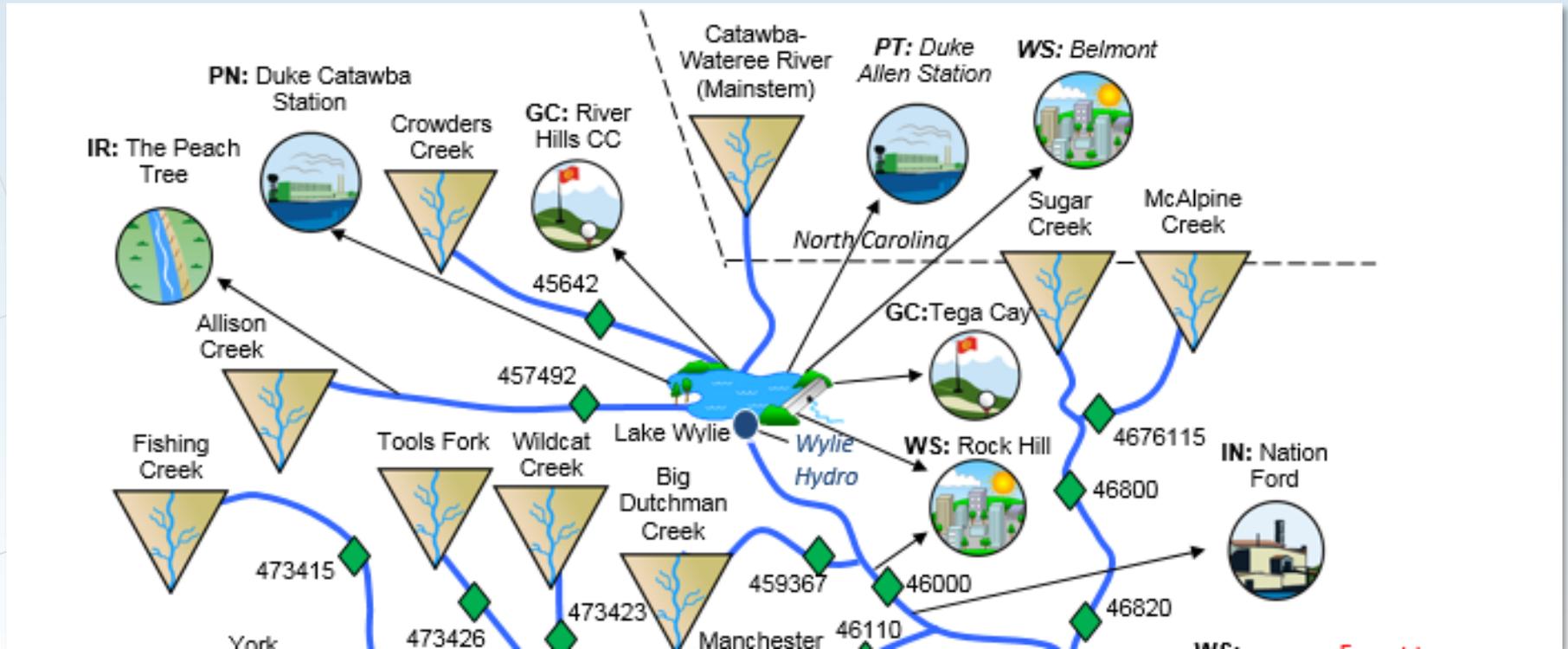
- **Calibration Model**
 - Purpose: confirm models ability to accurately simulate river basin flows and storage amounts
 - Uses recent withdrawal, discharge and flow records
- **Baseline Model**
 - Purpose: Evaluate water availability under future conditions
 - Uses entire record of flow and most current withdrawals and discharges
- Both models are used coordination with CHEOPS model to obtain flows from NC portion of the system (outflow from Lake Wylie)

Catawba-Wateree Basin – SWAM Framework



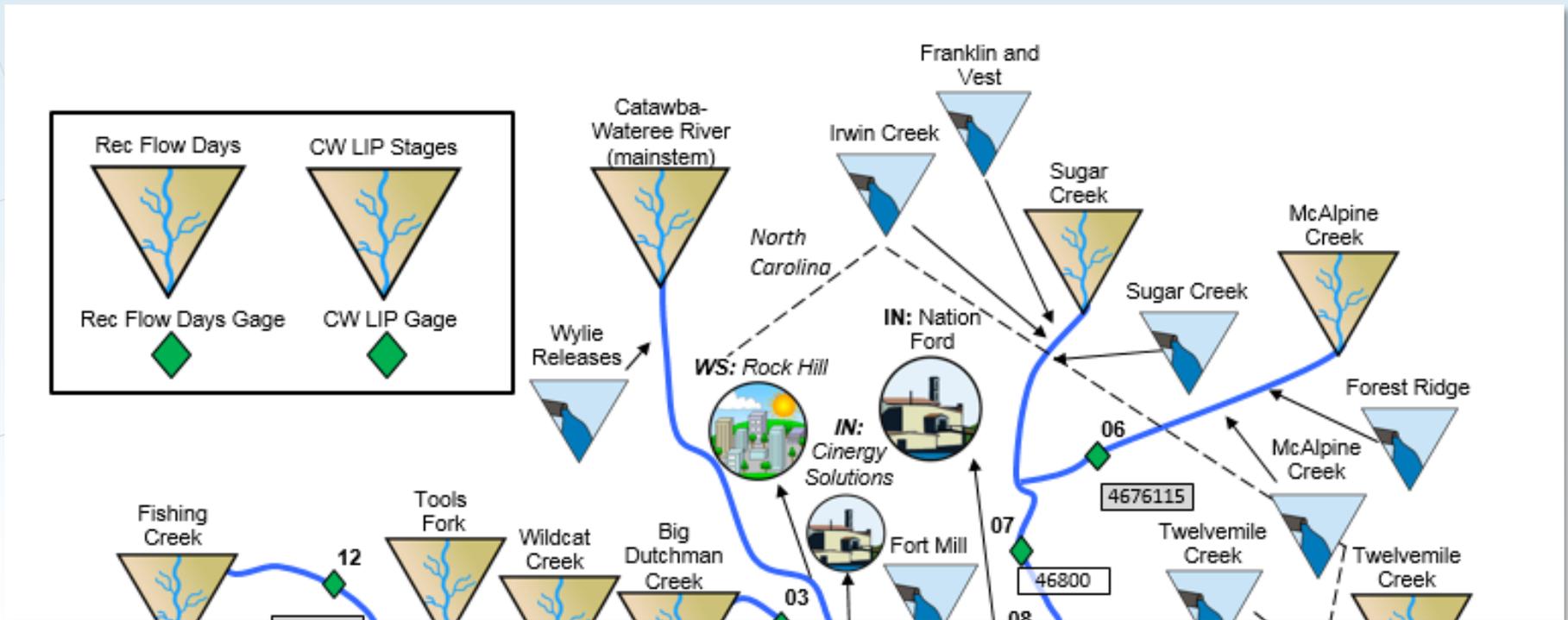
Framework Changes

- Original Framework included Lake Wylie and its major tributaries



Framework Changes

- Revised Framework begins at the outlet to Lake Wylie
- Wylie releases are specified as a discharge object and mainstem headwater flows are scaled from the inflow dataset
- Major NC dischargers were added on Sugar and McAlpine creeks



Modeling Report and Other Documents

- <http://www.dnr.sc.gov/water/waterplan/surfacewater.html>

The screenshot shows the website for the South Carolina Department of Natural Resources (DNR). The header includes the DNR logo and the slogan "Life's Better Outdoors". A navigation menu lists various topics: Buy, Boating, Education, Fishing, Hunting, Land, Maps, Regulations, Water, and Wildlife. The main content area is titled "Surface Water Modeling and Assessments" and contains several paragraphs of text, a "Project Documents" section with a list of links (Monthly Progress Reports, Legislative Quarterly Reports, Technical Reports, Technical Memorandums, Meeting Notes, Presentations, Videos, River Basins), and social media icons for Facebook, RSS Feed, Twitter, and YouTube. The footer contains contact information for the DNR and copyright notices.

The cover of the report features a large, detailed map of the Catawba-Wateree River Basin. The map shows the river network, major tributaries, and various sub-basins. The title "SOUTH CAROLINA SURFACE WATER QUANTITY MODELS CATAWBA-WATEREE RIVER BASIN MODEL" is prominently displayed at the top. The South Carolina Department of Natural Resources (DNR) and the Department of Health and Environmental Control (DHEC) logos are visible in the top right corner. The text "SUBMITTED TO: SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES SOUTH CAROLINA DEPARTMENT OF HEALTH & ENVIRONMENTAL CONTROL" is printed on the right side. The word "DRAFT" is written in large, bold letters. The date "OCTOBER 2016" and the preparer "CDM Smith" are also included.

Catawba-Wataree River Basin

MODEL CALIBRATION/VERIFICATION

Calibration Objectives

1. Extend hydrologic inputs (headwater UIFs) spatially to adequately represent entire basin hydrology by parameterizing reach hydrologic inputs
2. Refine initial parameter estimates, as appropriate
 - E.g., reservoir operating rules and %Consumptive Use assumptions
 - Gain confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use
 - Avoid being overly prescriptive

Potential Sources of Model Error and Uncertainty

- Gaged flow data ($\pm 20\%$)
- Gaged reservoir levels ($\pm ?\%$)
- Reported withdrawal data
- Consumptive use percentages
- Return flow lag times (if applicable, e.g. outdoor use)
- Basin climate and hydrologic variability
- *Reservoir operations (operator decision making)*
- *Reach hydrology: gains, losses, local runoff and inflow*

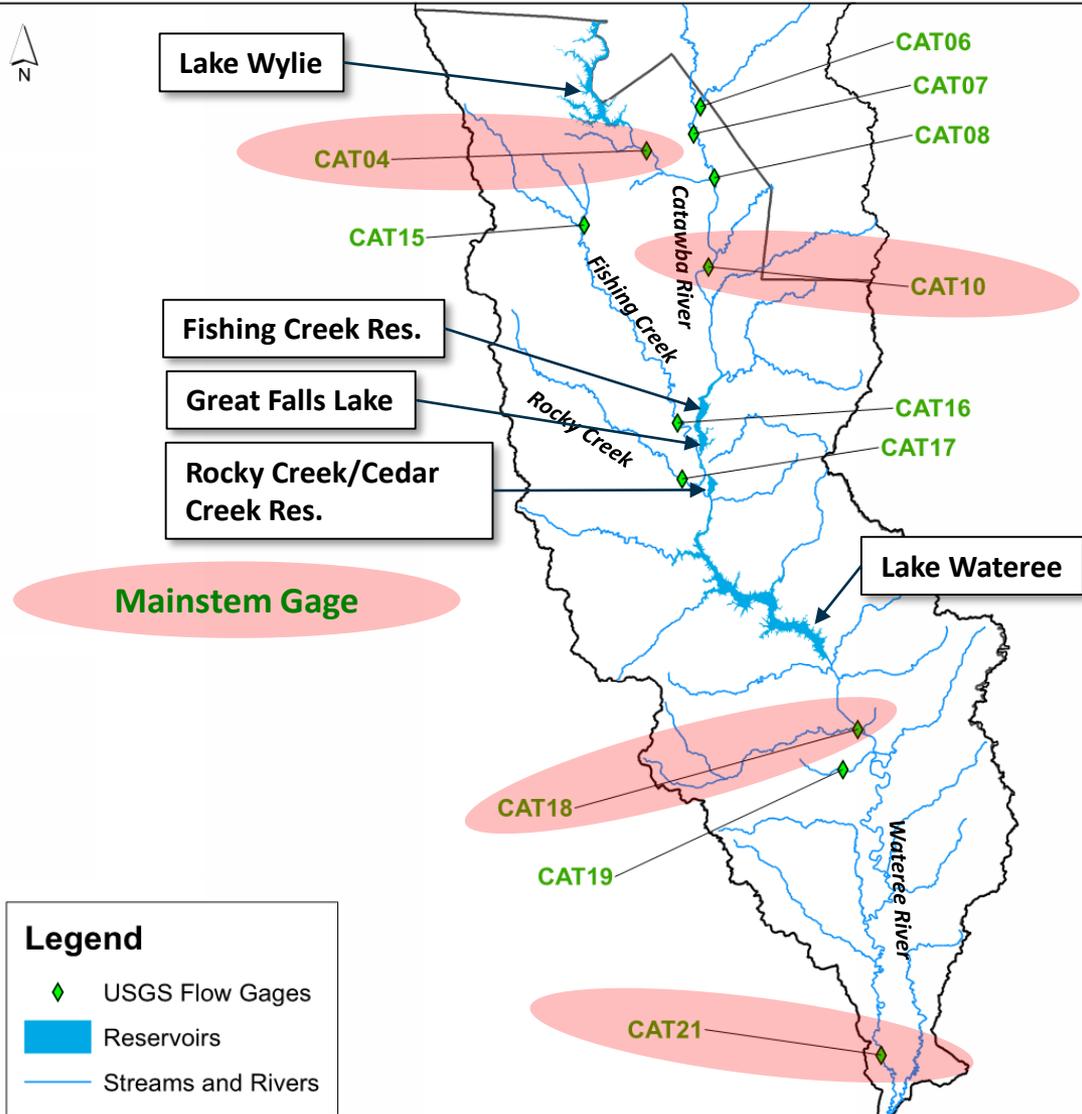
Calibration/Validation General Approach

- Two hindcast periods
 - 1983 – 2010 for **tributaries**
 - Includes droughts in both early and late 2000's
 - 2006 – 2010 on **mainstem** to reflect operating rules in the Comprehensive Relicensing Agreement (CRA)
 - Particular focus on 2007-2008 drought years
- Comparison to gaged (measured) flow or reservoir data
 - Operations and impairments are implicit in that data
- LIP Timeseries was included from CHEOPS model
 - Not exact match to actual historical LIP timeseries likely due slight differences in model vs. actual storage and the impact on storage index calculations which are a LIP trigger

Calibration/Validation General Approach

- Assess performance at (subject to gage data availability):
 - Multiple mainstem locations
 - All tributary confluence locations
 - Major reservoirs (where levels/storage are available)
- Multiple model performance metrics, including:
 - Timeseries plots (monthly and daily variability)
 - Annual and monthly means (water balance and seasonality)
 - Percentile plots (extremes and frequency)

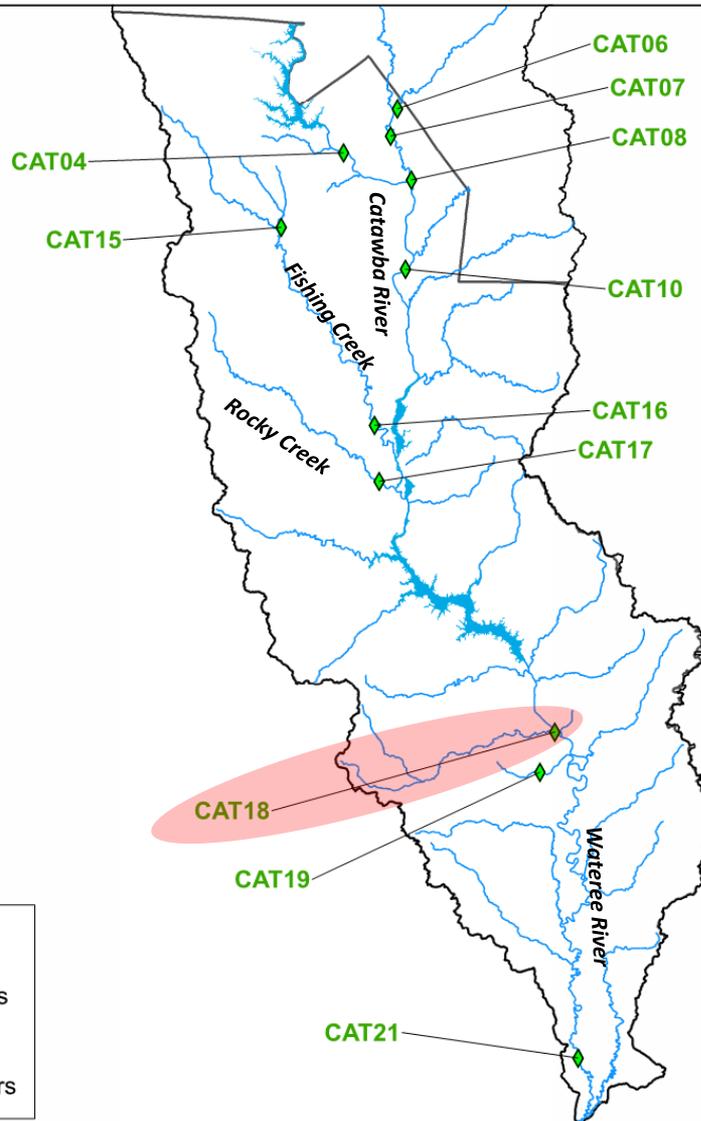
Calibration/Validation Locations



Project Gage ID	USGS Number	Tributary Object	Periods of Record	Basin Area (sq. mi.)	River Mile
CAT04	02146000	Mainstem	4/1942 - 8/1995 10/1995 - 12/2010	3048	4
CAT06	0214676115	McAlpine Creek	10/2005 - 12/2010	95	15
CAT07	02146800	Sugar Creek	4/2006 - 12/2010	263	24
CAT08	02146820	Sugar Creek	5/2001 - 9/2002	275	30
CAT10	02147020	Mainstem	1/1992 - 9/1994 10/1995 - 12/2010	3538	20
CAT15	021473428	Wildcat Creek	8/1998 - 6/2001 1/2006 - 12/2010	30	4
CAT16	02147403	Fishing Creek	2/2001 - 10/2003	280	40
CAT17	02147500	Rocky Creek	3/1951 - 9/1981 8/1986 - 12/2010	196	24
CAT18	02148000	Mainstem	10/1929 - 9/1983 5/1984 - 12/2010	5057	738
CAT19	02148071	Gillies Creek	4/1994 - 9/1997	8	3
CAT21	02148315	Mainstem	7/1968 - 2/1983 5/1983 - 12/2010	5554	131

Wateree River near Camden

USGS Gage 02148000



Legend

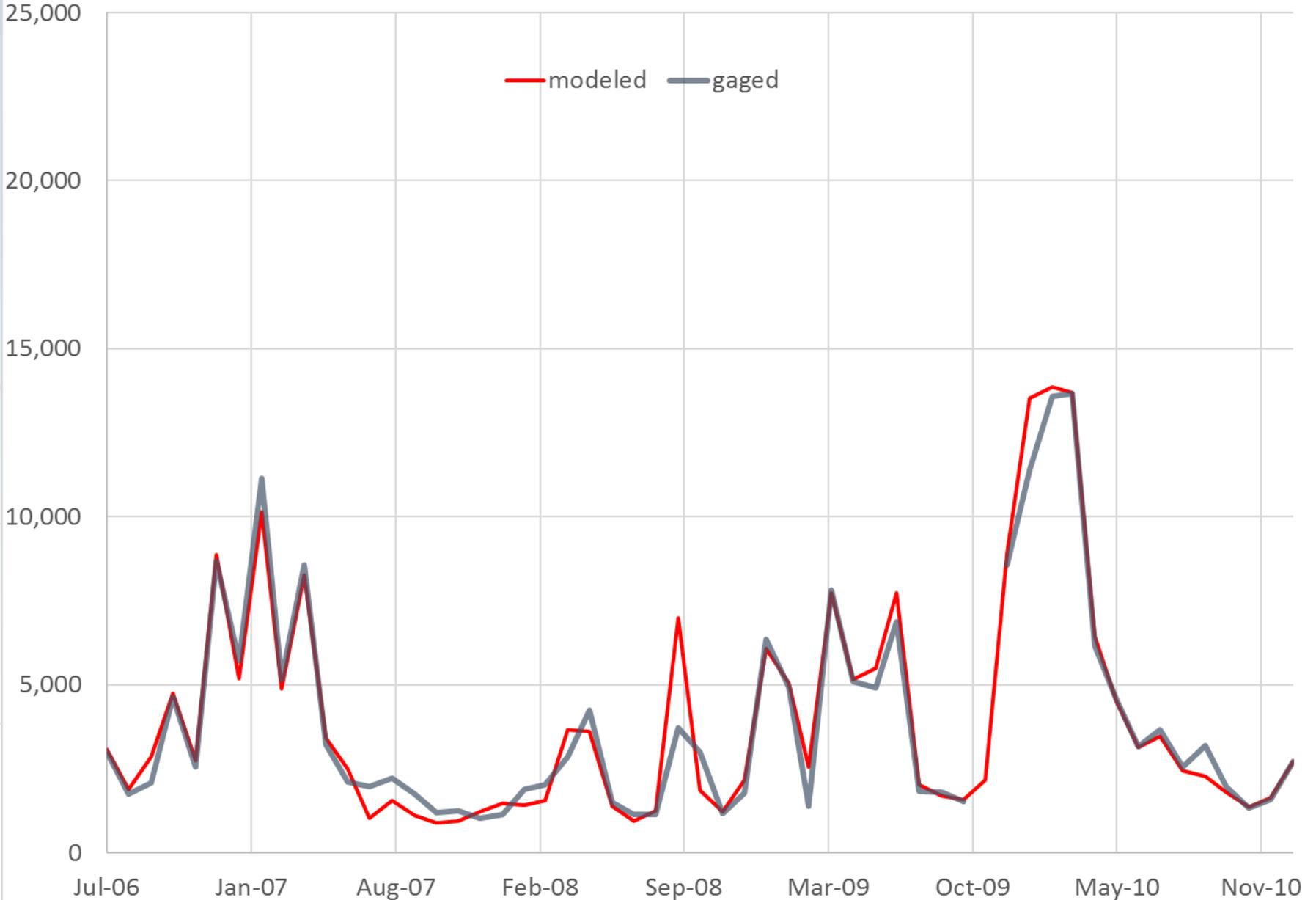
- ◆ USGS Flow Gages
- Reservoirs
- Streams and Rivers

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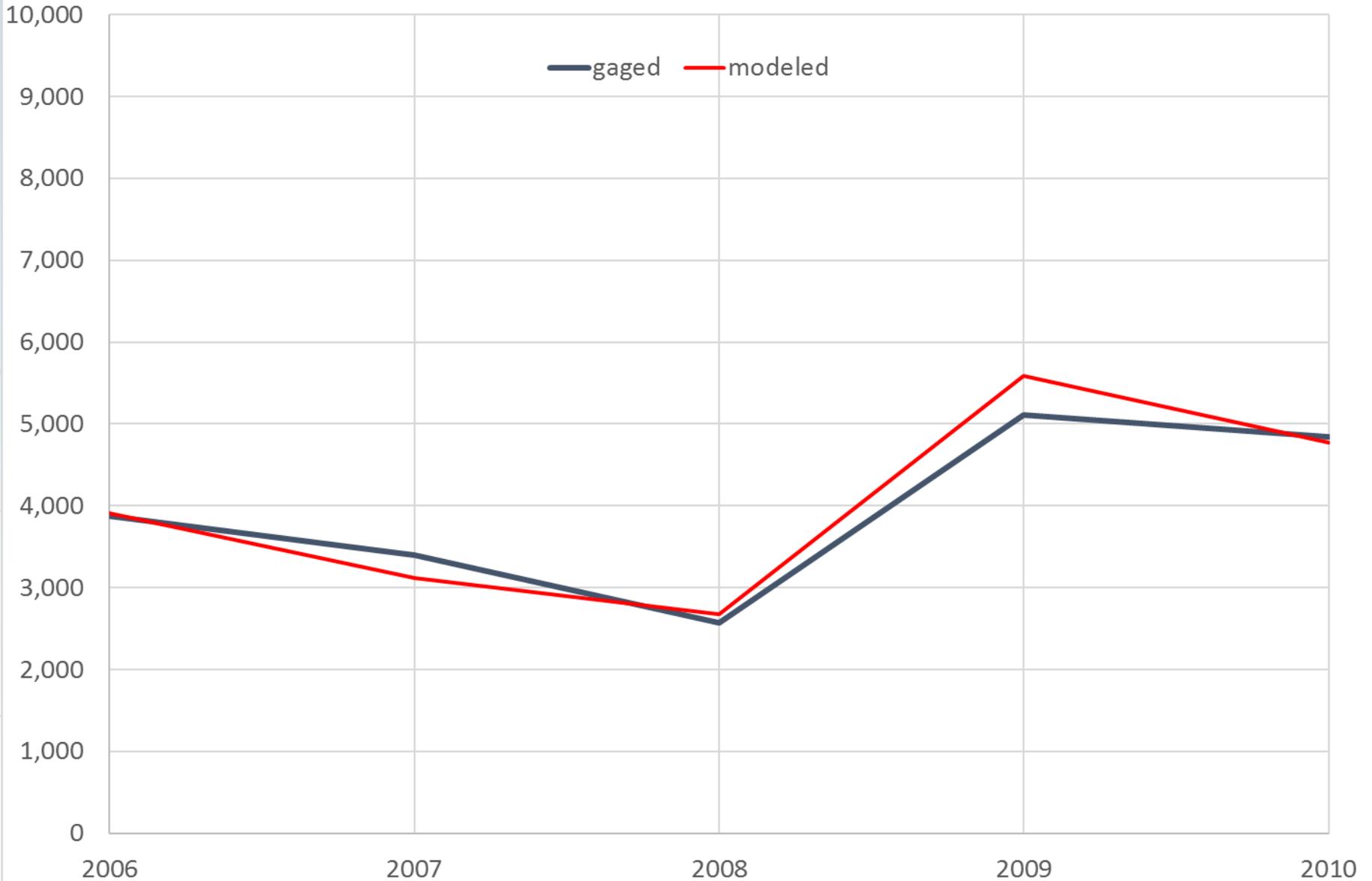
Monthly Flow Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC (CFS)



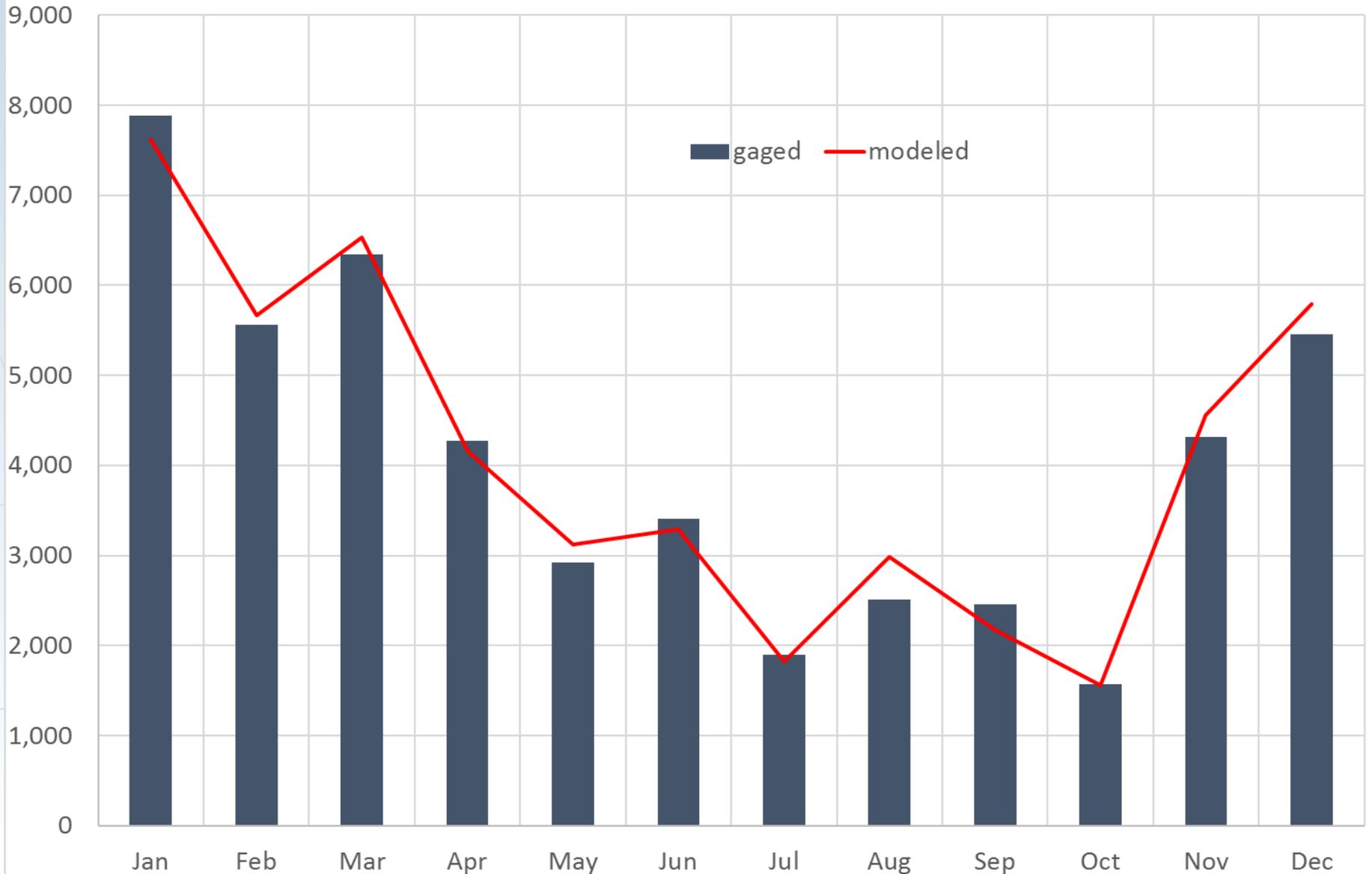
Annual Average Flow Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC (CFS)
Annual Average Flow



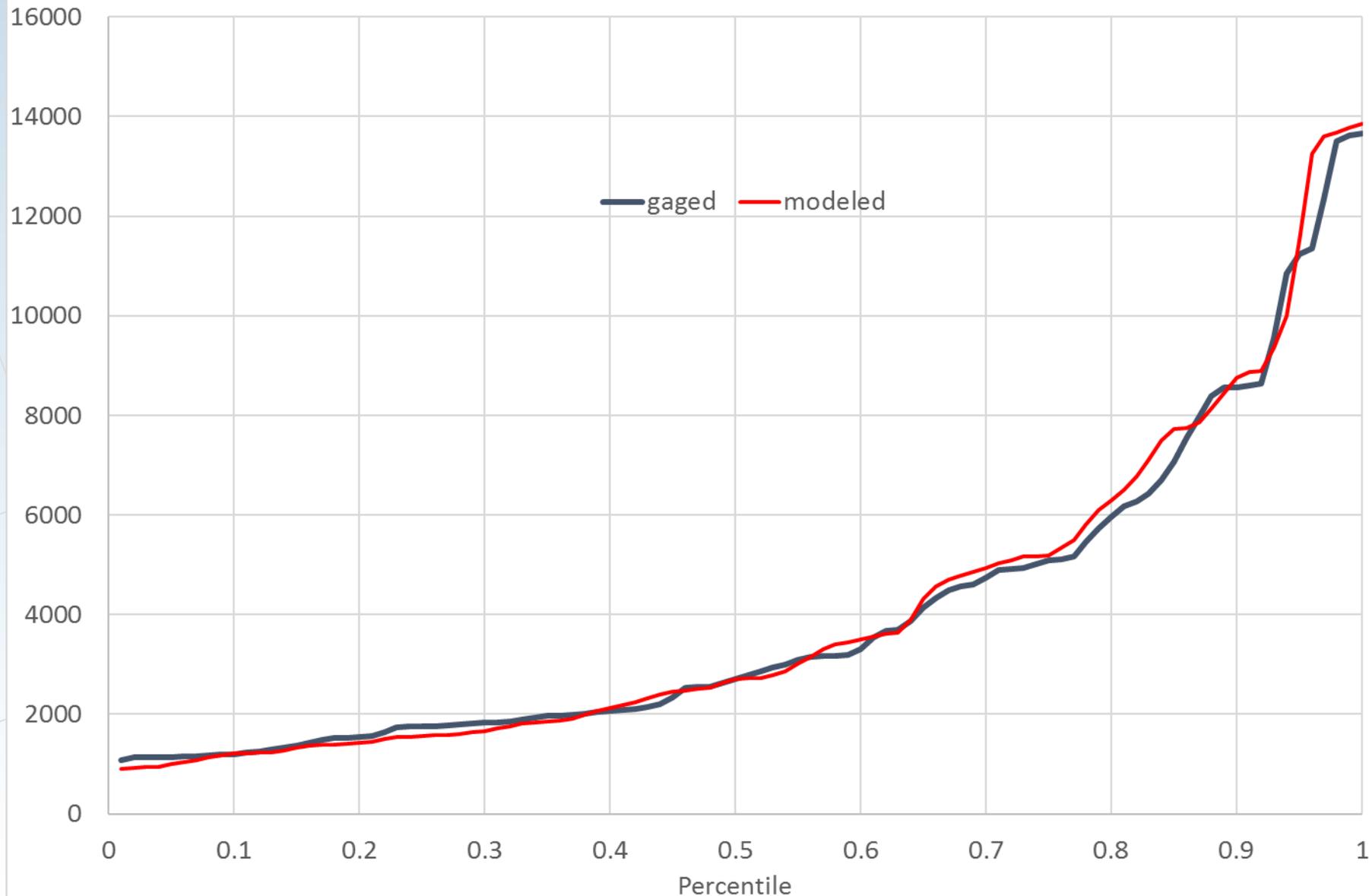
Monthly Mean Flow Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC
Monthly Mean Flow (CFS)



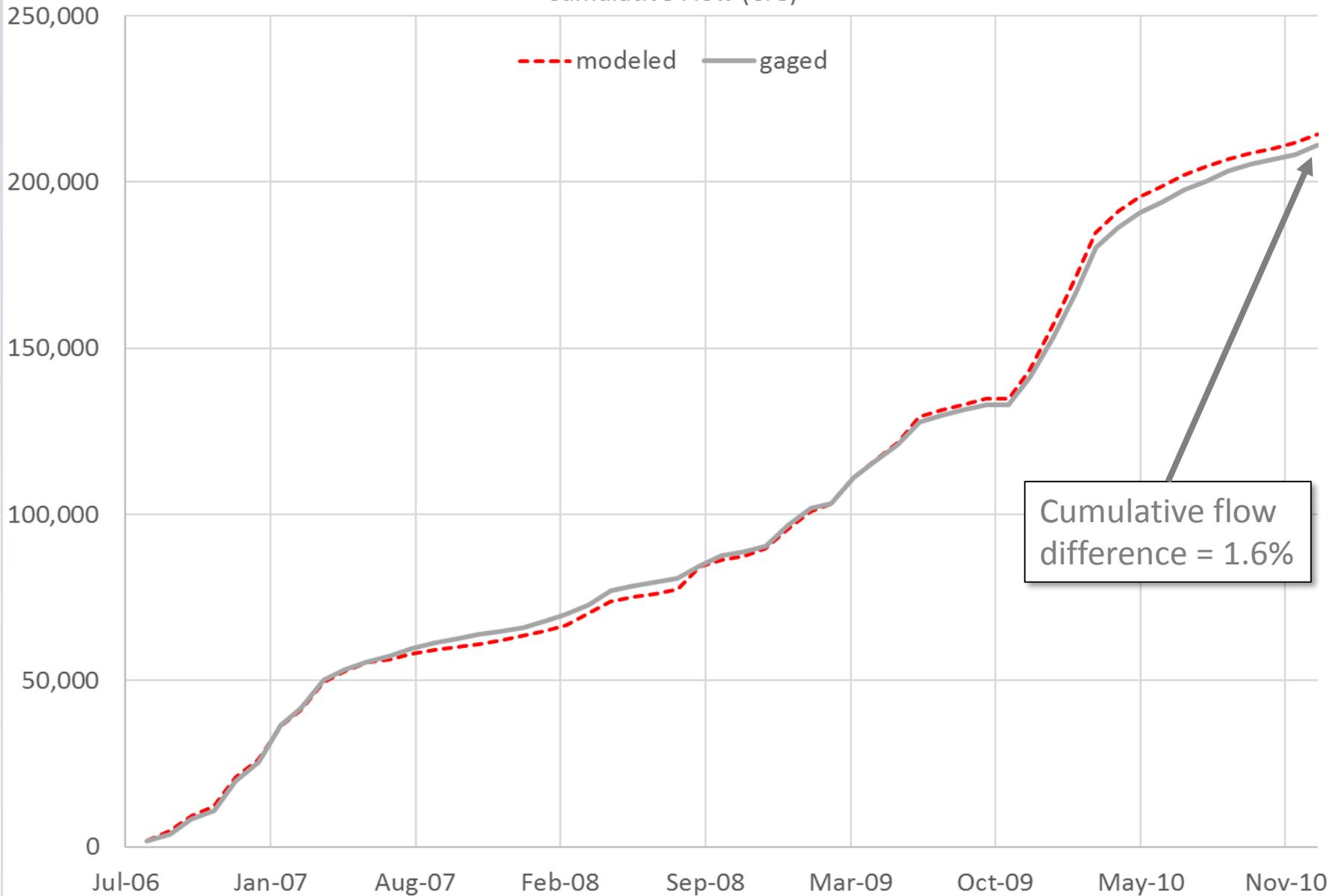
Monthly Flow Percentiles Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC
Monthly Flow Percentiles (CFS)



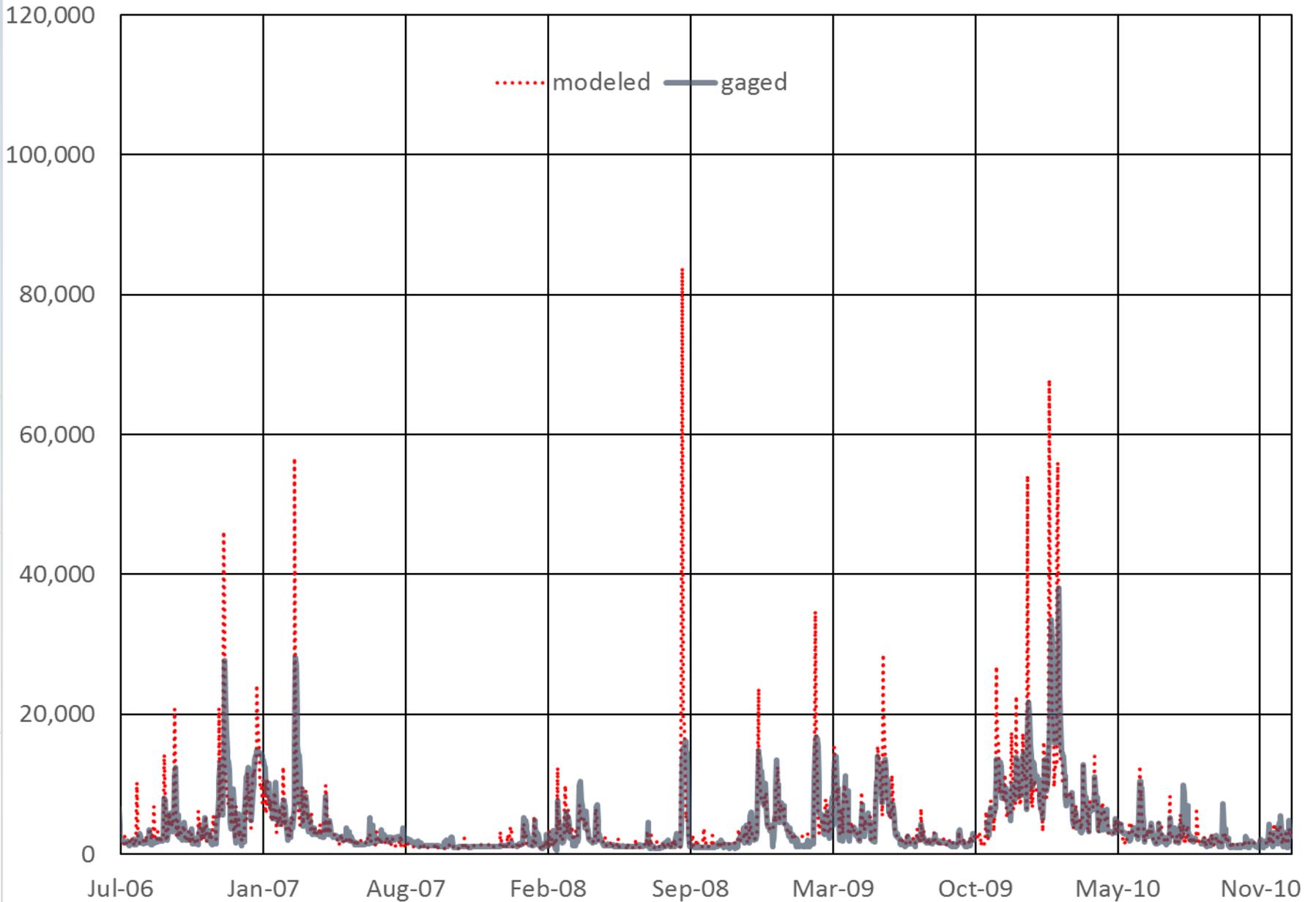
Cumulative Flow Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC
Cumulative Flow (CFS)



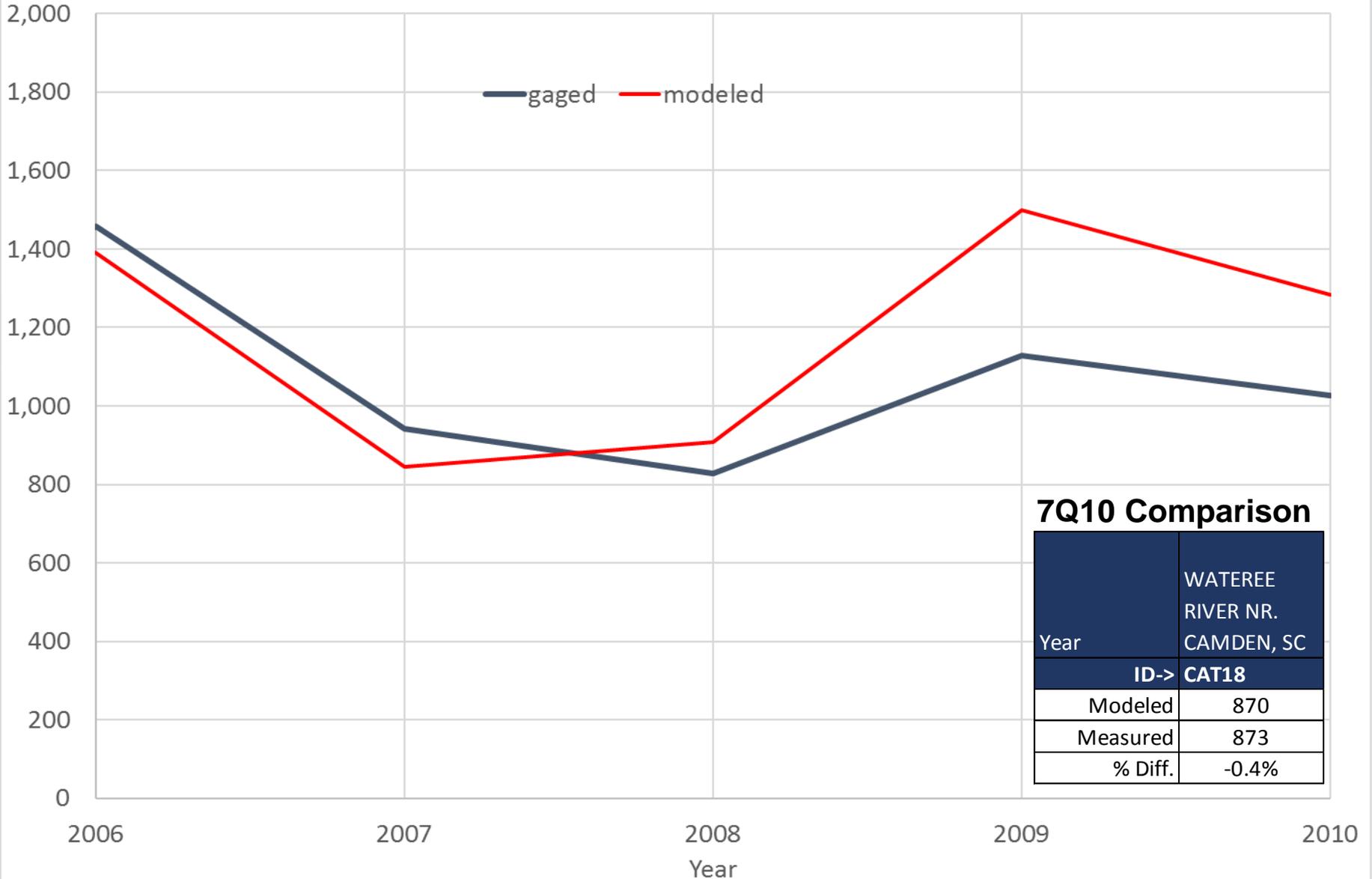
Daily Flow Comparison

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC (CFS)



Annual 7-Day Low Flows

CAT18 (02148000) WATEREE RIVER NR. CAMDEN, SC
Annual 7-day Low Flow (CFS)



7Q10 Comparison

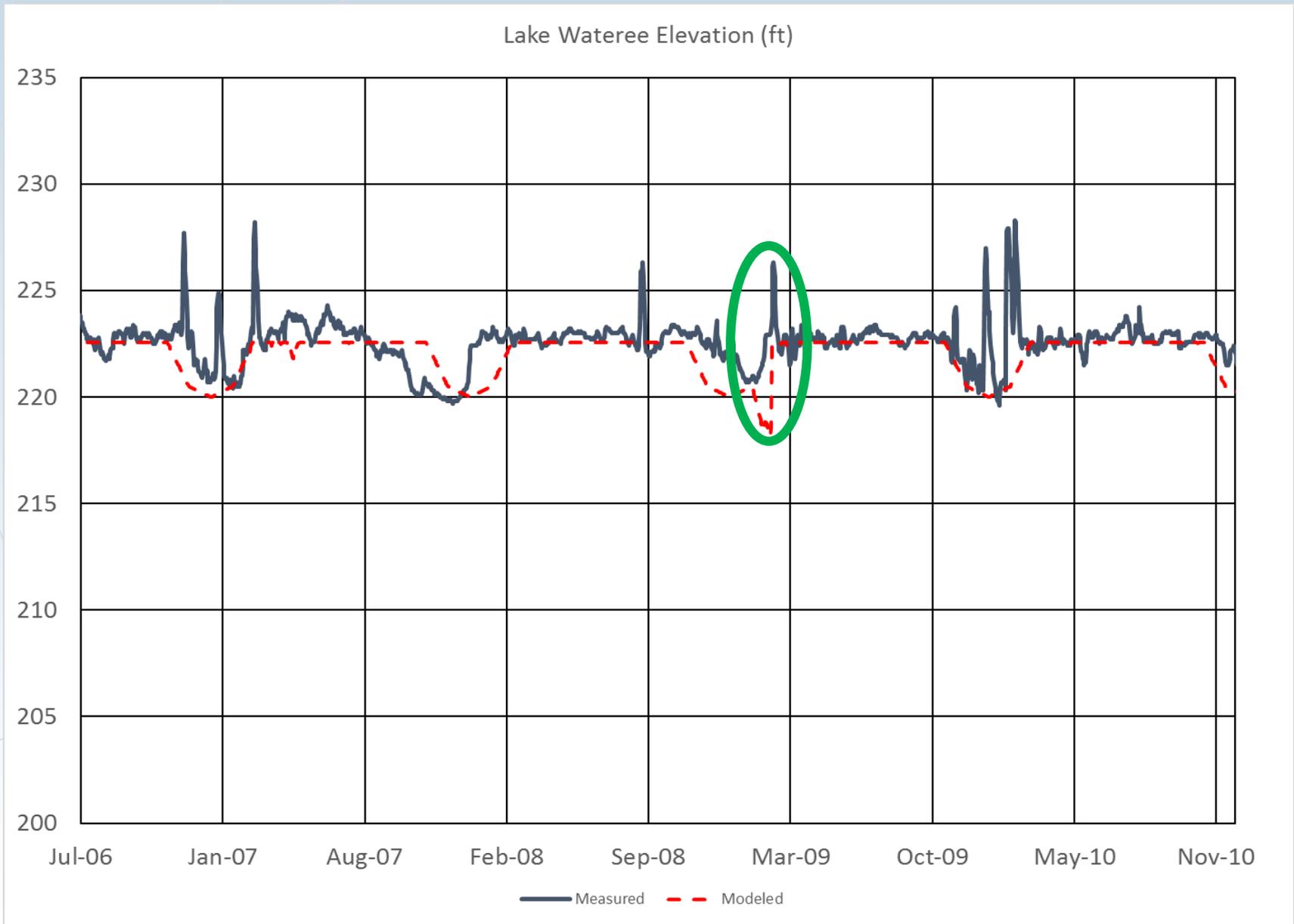
WATEREE RIVER NR. CAMDEN, SC	
Year	CAT18
Modeled	870
Measured	873
% Diff.	-0.4%

SWAM Calibration/Validation Summary

- For most sites, modeled mean flow values, averaged over the full period of record, are within 2% of measured mean flows

Project ID	Station	Modeled Average	Measured Average	% Diff Average	Years of Record	
CAT07	SUGAR CREEK NEAR FORT MILL, SC	359	384	-6.5%	5	} >5% difference
CAT16	FISHING CREEK BELOW FORT LAWN, SC	240	248	-3.1%	3	
CAT10*	CATAWBA RIVER BELOW CATAWBA, SC	3,259	3,353	-2.8%	19	} 5% or less diff.
CAT17	ROCKY CREEK AT GREAT FALLS, SC	147	149	-1.5%	25	
CAT15	WILDCAT CREEK BELOW ROCK HILL, SC	19	19	-1.1%	9	} 2% or less difference
CAT04*	CATAWBA RIVER NEAR ROCK HILL, SC	2,726	2,749	-0.9%	28	
CAT21*	WATEREE R. BL EASTOVER, SC	2,816	2,829	-0.5%	28	
CAT06	MCALPINE CREEK AT SR2964 NR CAMP COX, SC	111	112	-0.4%	6	
CAT19	GILLIES CREEK NEAR LUGOFF, SC	13	13	1.3%	4	
CAT18*	WATEREE RIVER NR. CAMDEN, SC	4,010	3,956	1.4%	28	} 5% or less diff.
CAT08	SUGAR CR. NR FT. MILL, S.C.	241	230	4.9%	2	

SWAM Calibration/Validation Summary



SWAM Calibration/Validation Summary

- Monthly mean flows percentile deviations are all generally within 5%-10% with no clear seasonal bias
- Modeled low flow values (as represented by 7Q10 flows) are within:
 - 0.4% and 7.2% on the Catawba-Wateree River
 - Rocky Creek (1.1 cfs modeled, 0.03 cfs observed)
- Modeled cumulative flows are within 0.1% and 2.1% of gaged flows for mainstem
- Modeled cumulative flows are within 0.5% and 6.3% of gaged flows for tributaries
- The model adequately hindcasts delivered water supply for each water user in the model (no significant shortfalls)

Catawba-Wateree River Basin

BASELINE MODEL AND USES

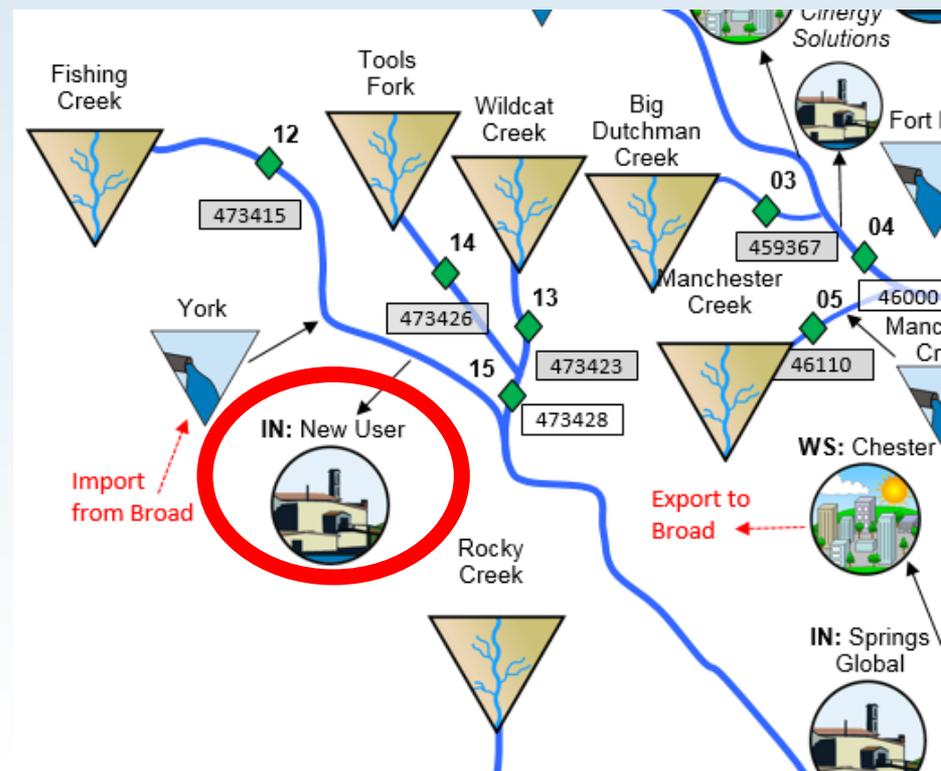
Baseline Model

- Will represent current demands and operations combined with an extended period of estimated hydrology
 - Most demands reflect 2004-2013 averages
 - Estimated hydrology from 1951 to 2010
 - Inactive users are not included
- The baseline model serves as the starting point for future predictive simulations
- Must be used in coordination with CHEOPS model to obtain flows from NC portion of the system (outflow from Lake Wylie)

Example Use

Adding a New User

- Add a new M&I permittee on Fishing Creek
 - Demand = 15 mgd
 - Consumptive Use = 50%
(return to Fishing Creek)
- *Is there enough water to support the new user?*



Add an Industrial Water User Object from the Palette

Object Palette

Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983
 End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

Monthly Planning
 Daily Planning
 Short Term Forecasting
 Firm Yield Calculator

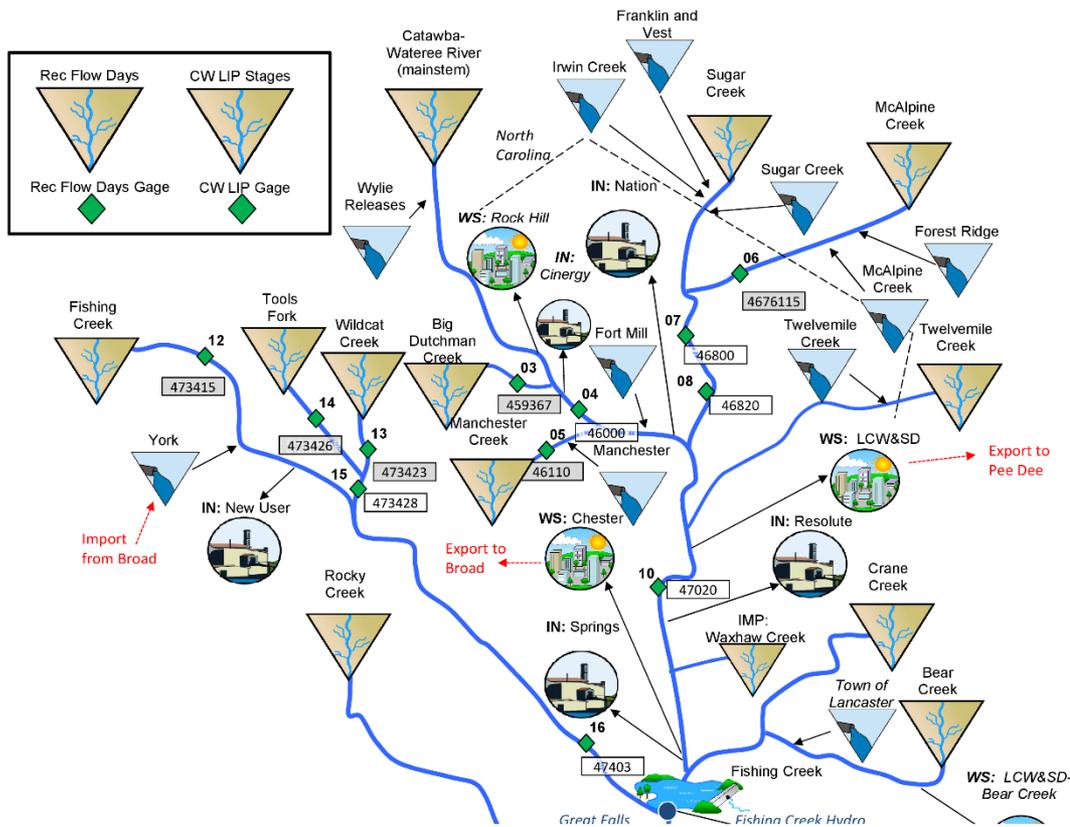
Prior Appropriations
 Riparian Water Rights

Input Summaries and Outputting

Node Priorities
 Node Locations
 Reservoir Accounts
 Output Specs

Input & Output Units

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



Add an Industrial Water User Object from the Palette



Simplified Water Allocation Model (SWAM)

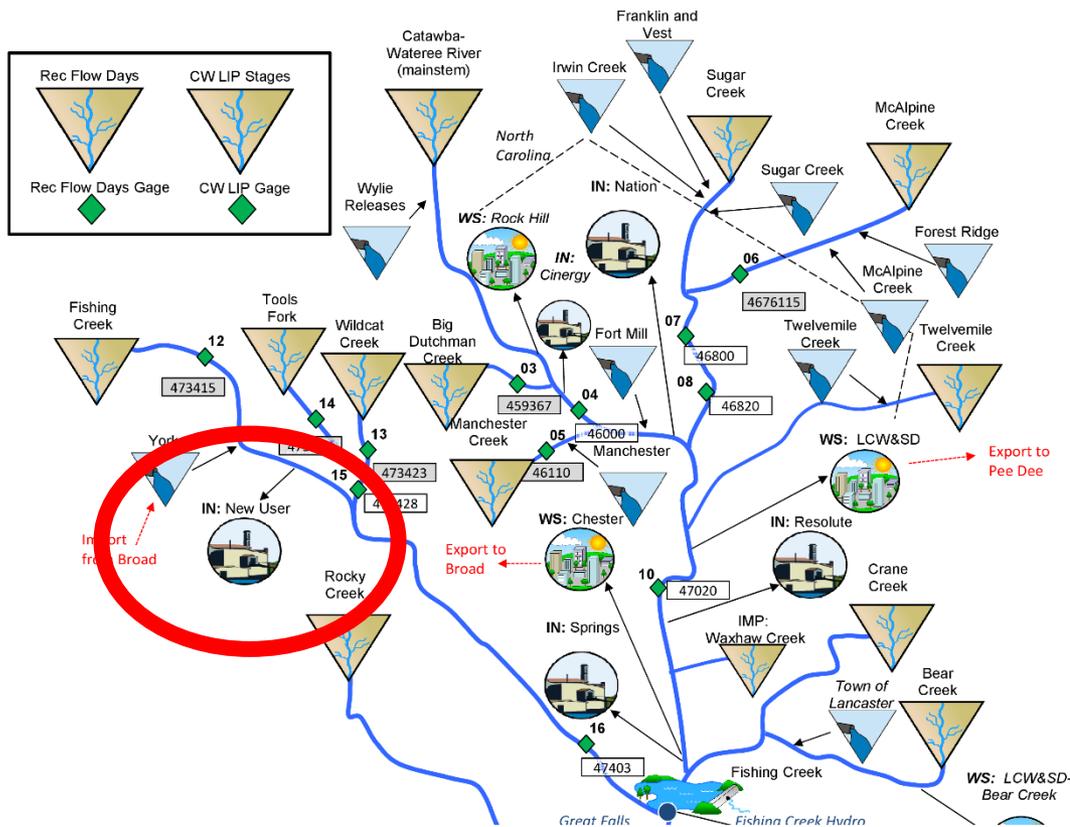
Simulation Period		Simulation Type	
Start Date (MM/DD/YYYY)	End Date (MM/DD/YYYY)	<input checked="" type="checkbox"/> Monthly Planning	<input type="checkbox"/> Prior Appropriations
01/01/1983	12/31/2010	<input type="checkbox"/> Daily Planning	<input checked="" type="checkbox"/> Riparian Water Rights
		<input type="checkbox"/> Short Term Forecasting	
		<input type="checkbox"/> Firm Yield Calculator	

Input Summaries and Outputting

Node Priorities	Node Locations	Reservoir Accounts	Output Specs
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Input & Output Units

<input type="checkbox"/> AF, AFM, AFD	<input checked="" type="checkbox"/> MG, MGD, CFS	<input type="checkbox"/> m3, m3/d, m3/s
---------------------------------------	--------------------------------------------------	-----------------------------------------



Add the New User in the Water User Dialogue

The screenshot displays the 'Simplified Water Allocation Model (SWAM)' software interface. On the left is an 'Object Palette' with various icons. The main window is titled 'Simplified Water Allocation Model (SWAM)' and contains a 'Simulation Period' section with 'Start Date (MM/DD/YYYY)' and 'End Date (MM/DD/YYYY)' fields, and a 'Simulation Type' section with 'Monthly Planning' (checked) and 'Prior Appropriations' (unchecked) options. A 'Water User' dialog box is open, showing a 'Water User Name' field with a dropdown menu containing 'IN: New User', which is circled in red. To the right of this field is a 'Delete Node' button and a 'Multiple Sources of Water?' checkbox. Below these are 'Supplemental Supply/Demand Alternatives' with checkboxes for 'Conservation', 'Transbasin Import', 'Recapture Reuse', 'Water Exchange', and 'Ag Transfer'. A 'Comments:' text area is also present. At the bottom of the dialog are 'Save' and 'Close' buttons. In the background, the 'Input Summaries and Outputting' panel shows buttons for 'Node Priorities', 'Node Locations', 'Reservoir Accounts', and 'Output Specs', along with 'Output Units' (MGD, CFS, m3, m3/d, m3/s). A diagram on the left shows 'Rec Flow Days' and 'Fishing Creek' with an 'Import from Broad' label.

Specify Water Use



Simplified Water Allocation Model (SWAM)

Simulation Period: Start Date (MM/DD/YYYY) 01/01/1983, End Date (MM/DD/YYYY)

Simulation Type: Monthly Planning, Prior Appropriations

Input Summaries and Outputting

Node Priorities, Node Locations, Reservoir Accounts, Output Specs

Water User

Main | Water Usage | Source Water | Return Flows

Monthly User Distribution: Manual, M&I, Agriculture

Annual Baseline Usage: Total Use (MGY) [] Distribute

Input Format: monthly means, timeseries

Monthly Baseline Usage

Month	Monthly Usage	% Indoor Use	% CU Indoor	% CU Outdoor
Jan	15	100	50	0
Feb	15	100	50	0
Mar	15	100	50	0
Apr	15	100	50	0
May	15	100	50	0
Jun	15	100	50	0
Jul	15	100	50	0
Aug	15	100	50	0
Sep	15	100	50	0
Oct	15	100	50	0
Nov	15	100	50	0
Dec	15	100	50	0

(MGD)

Save Close

Rec Flow Days, CW LIF, Rec Flow Days Gage, CWL, Fishing Creek, York, IN: N, Import from Broad

Specify Source and Withdrawal Location



Simplified Water Allocation Model (SWAM)

Simulation Period: Start Date (MM/DD) 01/01, End Date, Simulation Type: Monthly Planning, Prior Appropriations

Input Summaries and Outputting

Node Priorities, Node Locations, Reservoir Accounts, Output Specs

Units: FS m3, m3/d, m3/s

Water User

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

Source Stream: Fishing Creek

Source Water Type: Direct River, Reservoir, Groundwater

Diversion Location (mi): 20

Priority Date: 1/21/1900

Diversion Capacity (CFS): 10000

Permit Limit (MGM): 10000

Seasonal Permit

Minimum Flow

Save

Close

Identifying Notes:

Rec Flow Days

Rec Flow Days Gap

Fishing Creek

Import from Broad

Specify Return Location



Simplified Water Allocation Model (SWAM)

Simulation Period: Start Date: End Date: Simulation Type: Month: Day: Year:

Input Summaries and Outputting

Node Priorities Node Locations Reservoir Accounts Output Specs

Input & Output Units: F, AFM, AFD MG, MGD, CFS m3, m3/d, m3/s

Water User

Main | Water Usage | Source Water | Return Flows

Return Flow Locations

single point multiple

Receiving Stream: Fishing Creek

RF Location (mi): 21

RF Lag (months): 0

Save Close

Great Falls Fishing Creek Hydro

Run Model Scenario



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983

End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

- Monthly Planning
- Daily Planning
- Short Term Forecasting
- Firm Yield Calculator
- Prior Appropriations
- Riparian Water Rights

Input Summaries and Outputting

Node Priorities | Node Locations | Reservoir Accounts | Output Specs

Input & Output Units

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

Rec Flow Days | CW LIP Stages

Rec Flow Days Gage | CW LIP Gage

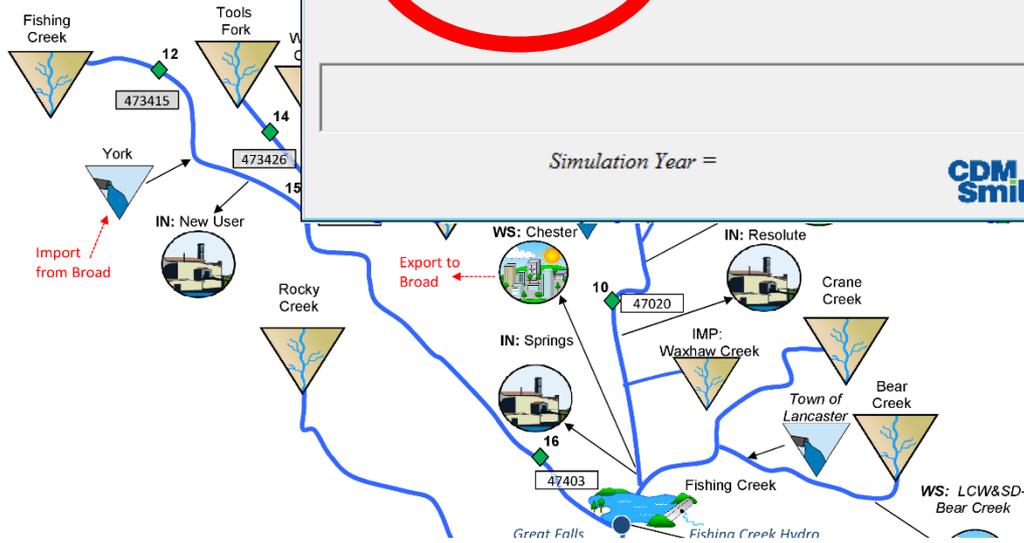
SWAM

Simplified Water Allocation Model (SWAM)

(Click on button:)

Run | **Cancel**

Simulation Year =



Build a Shortage Plot for the New User



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983
End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

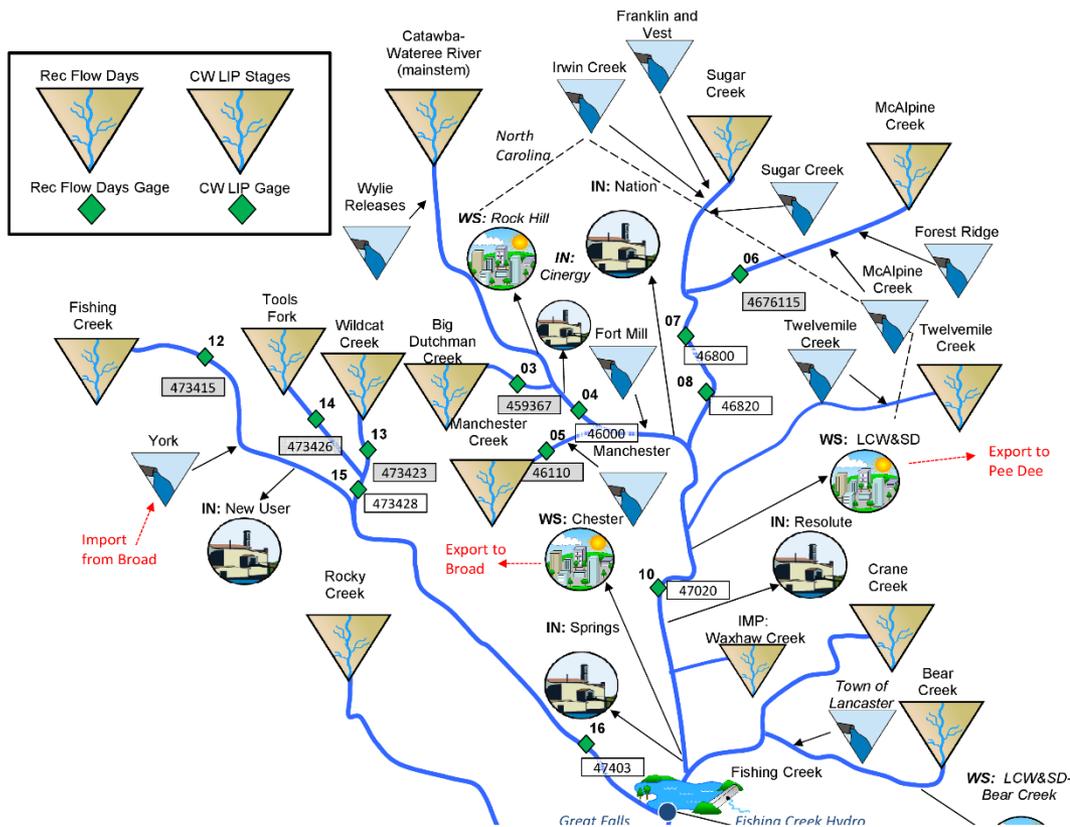
- Monthly Planning
- Daily Planning
- Short Term Forecasting
- Firm Yield Calculator
- Prior Appropriations
- Riparian Water Rights

Input Summaries and Outputs

Node Priorities | Node Locations | Reservoir Accounts | Output Specs

Input & Output Units

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- MG, MGD, CFS
- m3, m3/d, m3/s



Build a Shortage Plot for the New User



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983
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Monthly Planning
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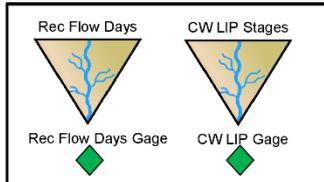
Prior Appropriations
 Riparian Water Rights

Input Summaries and Outputs

Node Priorities | Node Locations | Reservoir Accounts | Output Specifications

Input & Output Units

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



Output Plotting

Node: IN: New User

Output Parameter: Shortage (MGD)

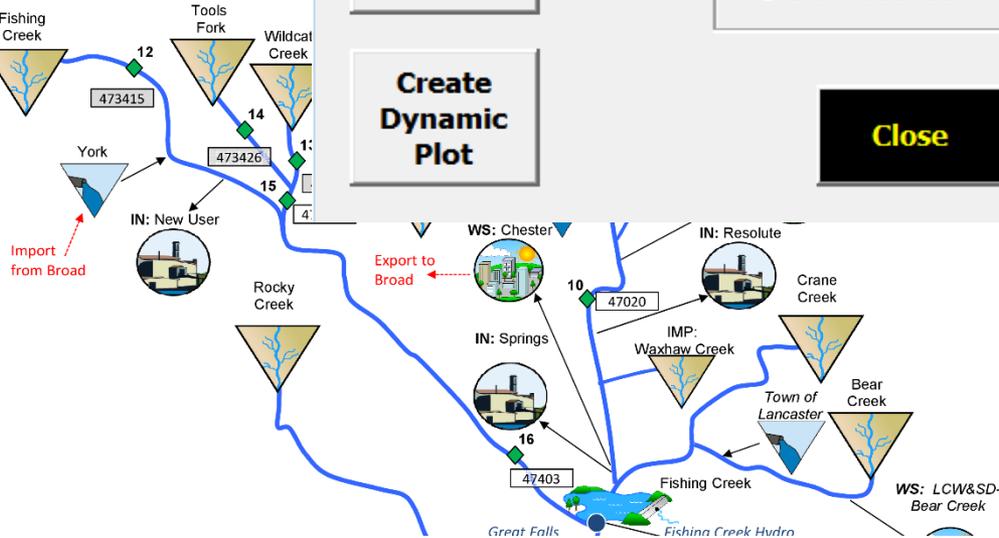
Plot Type

Time Series
 Exceedance

Clear Exceedance Links

Create Dynamic Plot

Close



Build a Shortage Plot for the New User



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983
 End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

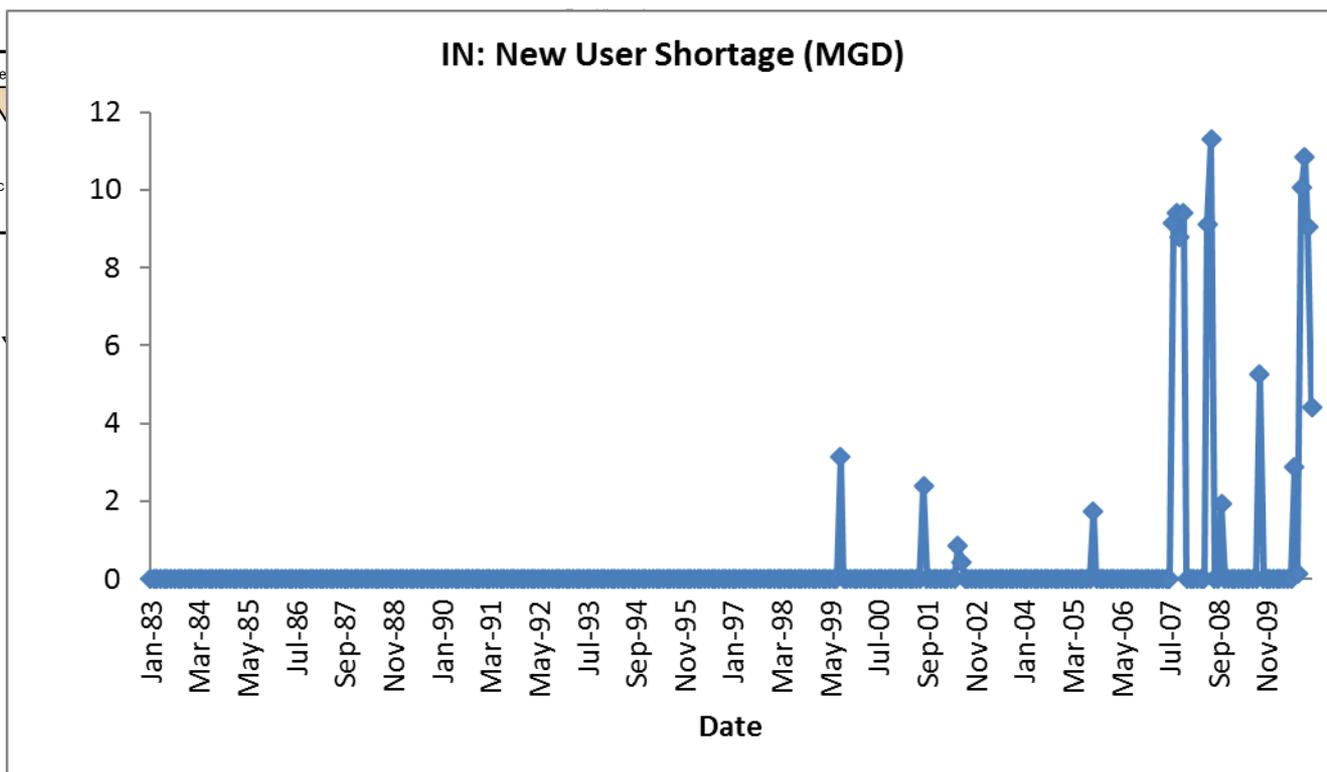
Monthly Planning
 Daily Planning
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 Riparian Water Rights

Input Summaries and Outputting

Input & Output Units

AF, AFM, AFD
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 m3, m3/d, m3/s



Shortages are Also Listed in the Node Output Table

Output			<u>Priority Rank</u>	<u>Reach</u>	<u>Location</u>	<u>Permit Limit (MGM)</u>	<u>Diversion Capacity (CFS)</u>	<u>Storage Capacity (MG)</u>	<u>Reservoir Withdrawal Permit (MGM)</u>
	<i>IN: New User</i>		22	<i>ishing Cree</i>	20	10000	10000	0	
Date	Physically Avail. (MGD)	Legally Avail. (MGD)	Demand (MGD)	River Withdrawal (MGD)	Storage (MG)	Groundwater Withdrawal (MGD)	Shortage (MGD)	Return Flow (MGD)	
Min	4	4	15	4	0	0	0	2	
Max	744	357	15	15	0	0	11	8	
Avg	89	87	15	15	0	0	0	7	
9/30/06	58	58	15	15	0	0	0	8	
10/31/06	26	26	15	15	0	0	0	8	
11/30/06	226	226	15	15	0	0	0	8	
12/31/06	75	75	15	15	0	0	0	8	
1/31/07	104	104	15	15	0	0	0	8	
2/28/07	68	68	15	15	0	0	0	8	
3/31/07	140	140	15	15	0	0	0	8	
4/30/07	71	71	15	15	0	0	0	8	
5/31/07	20	20	15	15	0	0	0	8	
6/30/07	27	27	15	15	0	0	0	8	
7/31/07	20	20	15	15	0	0	0	8	
8/31/07	6	6	15	6	0	0	9	3	
9/30/07	6	6	15	6	0	0	9	3	
10/31/07	6	6	15	6	0	0	9	3	
11/30/07	6	6	15	6	0	0	9	3	
12/31/07	32	32	15	15	0	0	0	8	
1/31/08	28	28	15	15	0	0	0	8	
2/28/08	55	55	15	15	0	0	0	8	
3/31/08	112	112	15	15	0	0	0	8	

Reduce the New User's Total Water User to 5 mgd



Simplified Water Allocation Model (SWAM)

Simulation Period: Start Date (MM/DD/YYYY) 01/01/1983, End Date (MM/DD/YYYY)

Simulation Type: Monthly Planning, Daily Planning, Prior Appropriations, Riparian Water Rights

Input Summaries and Outputting

Node Priorities, Node Locations, Reservoir Accounts, Output Specs

Input & Output Units: m3, m3/d, m3/s

Water User

Main | Water Usage | Source Water | Return Flows

Monthly User Distribution: Manual, M&I, Agriculture

Annual Baseline Usage: Total Use (MGY) [] Distribute

Input Format: monthly means, timeseries

Monthly Baseline Usage

Month	Monthly Usage	% Indoor Use	% CU Indoor	% CU Outdoor
Jan	5	100	50	0
Feb	5	100	50	0
Mar	5	100	50	0
Apr	5	100	50	0
May	5	100	50	0
Jun	5	100	50	0
Jul	5	100	50	0
Aug	5	100	50	0
Sep	5	100	50	0
Oct	5	100	50	0
Nov	5	100	50	0
Dec	5	100	50	0

(MGD)

Save Close

Rerun Model Scenario



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983

End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

- Monthly Planning
- Daily Planning
- Short Term Forecasting
- Firm Yield Calculator
- Prior Appropriations
- Riparian Water Rights

Input Summaries and Outputting

Node Priorities | Node Locations | Reservoir Accounts | Output Specs

Input & Output Units

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

Rec Flow Days | CW LIP Stages

Rec Flow Days Gage | CW LIP Gage

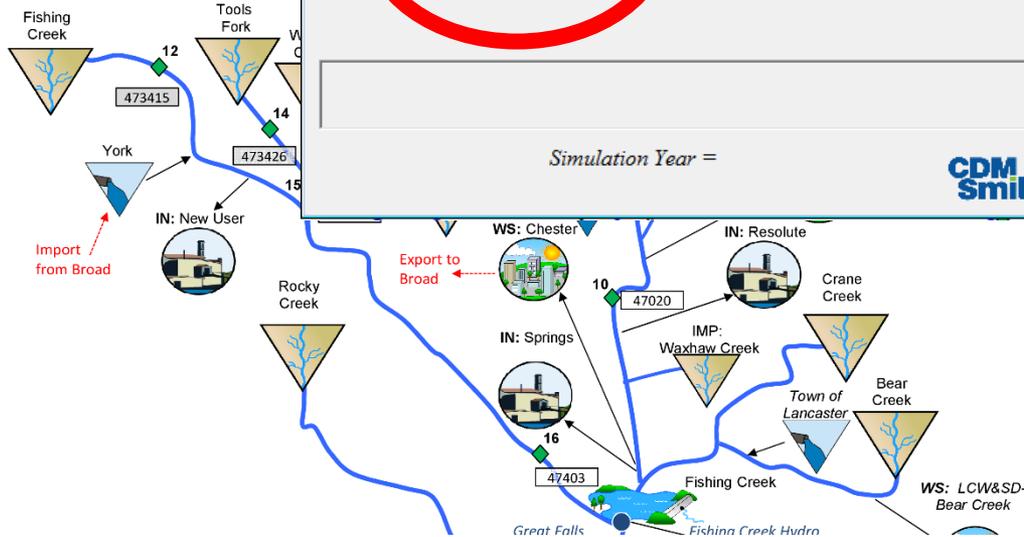
SWAM

Simplified Water Allocation Model (SWAM)

(Click on button:)

Run | **Cancel**

Simulation Year =



Dynamic Shortage Plots Update Automatically



Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY): 01/01/1983

End Date (MM/DD/YYYY): 12/31/2010

Simulation Type

Monthly Planning
 Daily Planning
 Short Term Forecasting
 Firm Yield Calculator

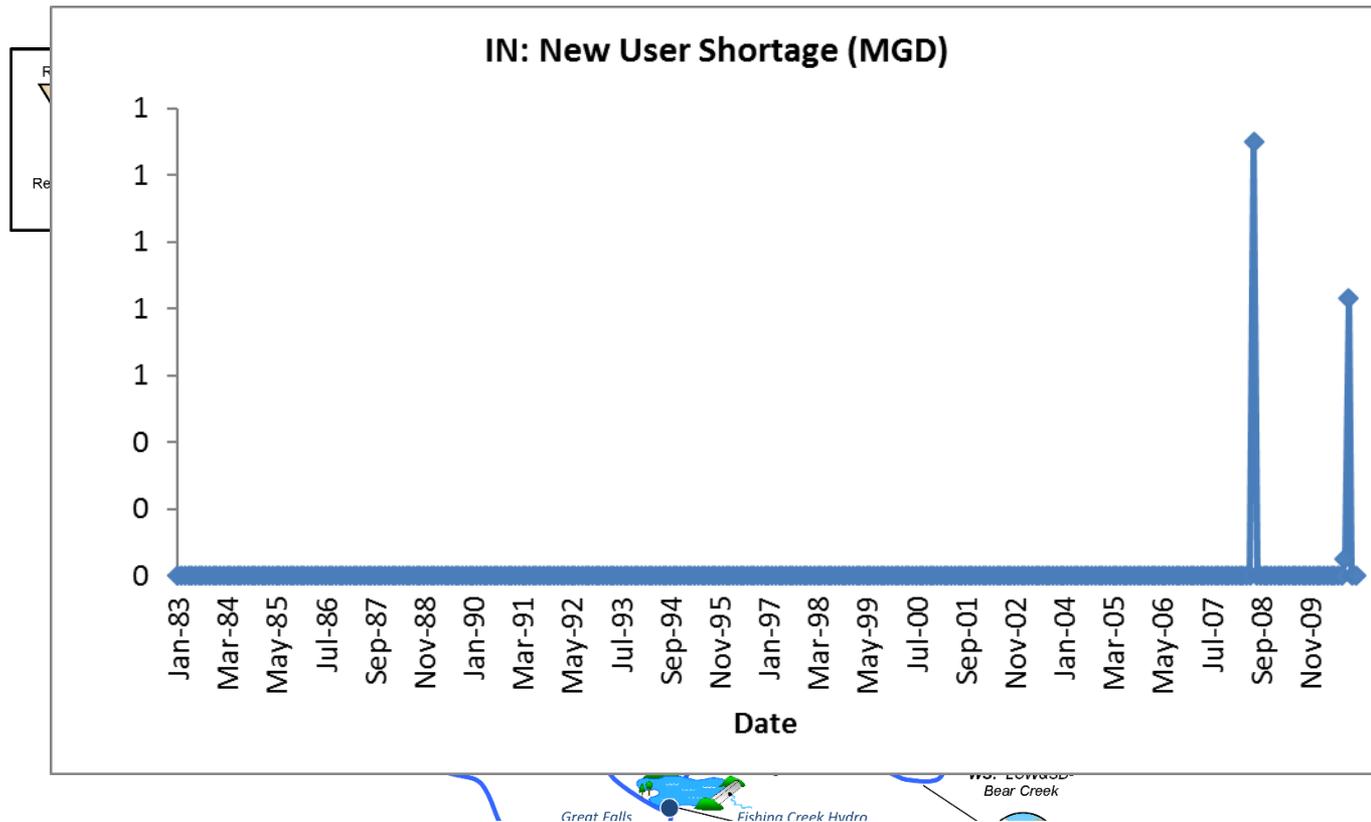
Prior Appropriations
 Riparian Water Rights

Input Summaries and Outputting

Node Priorities
 Node Locations
 Reservoir Accounts
 Output Specs

Input & Output Units

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



Demonstrations and Q&A

- Stations 1 (Nina) and 2 (John)

Add a new user and incorporate conservation measures

Explore impact of LIP adjustments

Catawba-Wateree River Basin

THANK YOU