South Carolina Surface Water Quantity Modeling Project
Edisto Basin Meeting No. 2 – Introduction to the Draft Model

Kirk Westphal, PE
John Boyer, PE, BCEE
Tim Cox, PE
December 1, 2015
Presentation Outline

• Project Background and Status

• Model Calibration/Verification
  • Calibration/Verification Philosophy and Approach
  • Calibration Results and Discussion

• Edisto Baseline Model
  • Overview and Uses
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.
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 – Edisto Basin

Data Collection
- Streamflow, M&I and ag withdrawals, discharges, precipitation, reservoir operations, interconnections, facility operation dates, etc.

Data Analysis
- Gap filling and record extension

Unimpaired Flow Development
- Daily mean UIFs

Basin Schematic
- Model framework development

Model Calibration
- Reproduce actual conditions

Baseline Model Run
- Simulate current conditions

Stakeholder Input

Meeting #1

Meeting #2
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
Edisto Basin – SWAM Framework

Figure 4-1. Edisto River Basin SWAM Model Framework

Model Objects
- Tributary
- Discharge
- USGS Stream Gage

Water User Objects
- Municipal
- Agriculture (Irrigation)
- Thermoelectric
- Industrial

Red shading indicates the Object is in the calibration model, but not the baseline model.

Import or Export (Interbasin Transfer)
Modeling Report and Other Documents

Edisto 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, %Consumptive Use assumptions, return flow locations

3. Gain confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use
   - without being overly prescriptive
Potential Sources of Model Error and Uncertainty

- Gaged flow data (± 20%)
- Gaged reservoir levels (± ?%)
- Basin climate and hydrologic variability
- Reported withdrawal data
- Consumptive use percentages
- Return flow locations (outdoor use)
- Return flow lag times (if applicable, e.g. outdoor use)
- Reach hydrology: gains, losses, local runoff and inflow
Calibration/Validation General Approach

- 1983 – 2013 hindcast period; monthly timestep
  - Includes droughts in both early and late 2000’s
- Comparison to gaged (measured) flow data only
  - operations and impairments are implicit in that data
- Assess performance at (subject to gage data availability):
  - multiple mainstem and tributary locations
  - major reservoirs (*none in the Edisto*)
- 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 Methodology

• Focus on characterizing natural hydrology throughout the basin by extending headwater flow inputs downstream
  – drainage area ratios for tributaries
  – gain/loss coefficients along the mainstem
  – adding in smaller ungaged tributaries (without nodes) as point sources

• If necessary, look at other “uncertain” parameters: e.g. reservoir operations (if applicable), %CU, return flow locations

• Limited number of calibration parameters (adjustment “knobs”) that are readily transferable to future applications
Calibration/Validation Locations
Monthly Flow Percentiles Comparison

EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC
Monthly Flow Percentiles (CFS)

DRAFT
Daily Comparison

EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)

5/01 – 4/02
Other Tributaries to N/S Forks and Edisto River

Same excellent calibration results due to little or no impairments and small drainage area.
North Fork Edisto River at Orangeburg

USGS Gage 02173500
Multiple upstream impairments
Basin Area: 686 sq. miles
Monthly Flow Comparison

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)

modeled  gaged

Jan-83  Jul-88  Dec-93  Jun-99  Dec-04  Jun-10
Monthly Mean Flow Comparison

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC
Monthly Mean Flow (CFS)

- gaged
- modeled
Annual Average Flow Comparison

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)
Annual Average Flow

- gaged
- modeled

DRAFT
South Fork Edisto River near Denmark

USGS Gage 02173000
Multiple upstream impairments
Basin Area: 733 sq. miles
Monthly Mean Flow Comparison

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Monthly Mean Flow (CFS)

- gaged
- modeled
Monthly Flow Percentiles Comparison

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Monthly Flow Percentiles (CFS)

gaged  modeled

DRAFT
Annual Average Flow Comparison

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)

Annual Average Flow

- **gaged**
- **modeled**
Edisto River Near Givhans

USGS Gage 02175000
Multiple upstream impairments
Basin Area: 2,714 sq. miles
Monthly Flow Comparison

EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)

- modeled
- gaged

DRAFT
Monthly Flow Percentiles Comparison

EDO13 EDISTO RIVER NR GIVHANS, SC
Monthly Flow Percentiles (CFS)

- gaged
- modeled

DRAFT
Annual Average Flow Comparison

EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)
Annual Average Flow

DRAFT
SWAM Calibration/Validation Summary

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

- Monthly mean flows percentile deviations are all generally within 10-20% with no clear bias at most locations.
  - S. Fork gages show slight summer/winter bias.

- Modeled low flow values (as represented by 7Q10 flows) are within 10% of measured values at mainstem gages EDO 06 and EDO13; 15% at EDO 05 and EDO 07; and 50% at EDO 10.

- The model adequately hindcasts delivered water supply for water user in the model (no significant shortfalls).
  - Select ag withdrawals near headwaters of tributaries are one exception.
Draft to Final Model – Areas of Focus

- Modeled peak flows > observed peak flows
  - Investigate alternative reference gages for UIFs
- 1988 - 1991 modeled flows < observed flows along N and S Fork Edisto
- Slight seasonal bias along S Fork Edisto River and Edisto River
- Modeled ag shortages in headwaters of select tributaries
  - Investigate disaggregating withdrawal locations
  - Investigate inclusion of storage where small impoundments exist
  - Use segmented reach gain/loss factor
Baseline Model

• Represents current demands and operations combined with an extended period of estimated hydrology
  • Most demands reflect 2005-2014 averages
  • Estimated hydrology from 1931 to 2013
  • Inactive users are not included
• The baseline model serves as the starting point for future predictive simulations
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
• 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
• Consolidate hydrologic data
Example Use
Adding a New Industry

• Add a new M&I permittee on the South Fork Edisto River
  • Demand = 7,000 MGY (19 mgd)
  • *Is there enough water for the new industry?*

• Add a new Instream Flow Object downstream
  • Instream Flow Target = 300 cfs
  • *Can this also be satisfied?*
Add an Industrial Water User Object from the Palette
Add an Industrial Water User Object from the Palette
Add the New Industry in the Water User Dialogue
Specify Water Use
Specify the Source and Diversion Location
Specify the Return Location
Run the Model Scenario

Simplified Water Allocation Model (SWAM)

Run [ctrl R]
Build a Shortage Plot for the New Industry
Build a Shortage Plot for the New Industry
Shortages are Also Listed in the Node Output Table

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>AK</th>
<th>AL</th>
<th>AM</th>
<th>AN</th>
<th>AO</th>
<th>AP</th>
<th>AQ</th>
<th>AR</th>
<th>AS</th>
<th>AT</th>
<th>AU</th>
<th>AV</th>
<th>AW</th>
<th>AX</th>
<th>AY</th>
<th>AZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In: New industry</td>
<td>58</td>
<td>Mainstem</td>
<td>51</td>
<td>10000</td>
<td>10000</td>
<td>0</td>
<td>3265829</td>
<td>In: Springfield Grain Co Totals</td>
<td>20000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physically Avail. (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Legally Avail. (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diverted (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage (MG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GW Pumping (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shortage (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Return Flow (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Release (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evap Losses (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physically Avail. (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Legally Avail. (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diverted (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage (MG)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GW Pumping (MGD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Add an Instream Flow Object from the Palette
Specify the Instream Flow Amount and Target Stream

**Instream Flow Details:**
- **Instream Flow Name:** Edisto Environmental Fl
- **Priority Date:** 1/1/2008
- **Flow Right:** 300 CFS
- **Target Stream:** Mainstem
Run the Model Scenario
Build a Shortage Plot for the Instream Flow Object
Build a Shortage Plot for the Instream Flow Object
Demonstrations and Q&A

- **Station 1 (Tim)**
  Evaluating an increase in WS User demands

- **Station 2 (John)**
  Evaluating a withdrawal with a minimum instream flow constraint

- **Station 3 (Kirk)**
  Adding new M&I user and an instream flow object
Edisto River Basin

THANK YOU