South Carolina Surface Water Quantity Modeling Project
Catawba-Wateree River Basin Meeting No. 1 – Model Framework

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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 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)
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
- Municipal
- Industrial
- Golf Courses
- Power Plants
- Agriculture
- Instream Flow
- Recreational Pool
- Aquifer
- USGS Gage
- Interbasin Transfer
Simplified Water Allocation Model (SWAM)

- Intuitive & Resides within and interfaces directly with Transparent Microsoft Excel
- Ease-of-Use Point-and-click setup and output access
- Simple & Robust Mass balance calculations, but handles operating rules, use priorities, etc.
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.
SWAM Model Main Screen

Simplified Water Allocation Model (SWAM)

Simulation Period
- Start Date (MM/DD/YYYY): 01/01/1983
- End Date (MM/DD/YYYY): 12/31/2013

Simulation Type
- Monthly Planning
- Daily Planning
- Riparian Water Rights
- Short Term Forecasting
- Film Yield Calculator

Run (ctrl R)

Input Summaries and Outputting
- Node Priorities
- Node Locations
- Reservoir Accounts
- Output Scales
- Input & Output
  - AF, AFM, AFD
  - mg, mgd, cfs
  - m3, m3/d, m3/s

Object Pallete

Map of water allocation system with various nodes and connections.
Catawba-Wateree 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 =**
  \[ \text{Measured Gage Flow} + \text{River Withdrawals} + \text{Reservoir Withdrawals} - \text{Discharge to Reservoirs} - \text{Return Flow} + \text{Reservoir Surface Evaporation} - \text{Reservoir Surface Precipitation} + \text{Upstream change in Reservoir Storage} + \text{Runoff from Previously Unsubmerged Area} \]

• **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
- Work Upstream to Downstream
- Perform these steps for incremental reaches and add UIFs from upstream
- 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)

**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, MOVES, 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 (ungaged 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 ungaged 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)

**Model Objects**
- Tributary
- Discharge
- Instream Flow (used with Hydropower)
- Reservoir
- Current or Former USGS Stream Gage (with last 5 to 6 digits of Gage ID)

**Water User Objects**
- Municipal
- Agriculture (Irrigation)
- Thermoelectric
- Industrial
- Golf Course
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
Primary and Secondary Tributaries

Legend
- Catawba USGS Gages
- Model Tributary Objects
  - Mainstem
  - Major Branch
  - Primary
  - Primary (Implicit)
  - Secondary
  - Higher Order Tribs

CDM Smith
Catawba-Wateree Basin

CHEOPS Model Coverage

SWAM Model Intended Coverage

Source: CWWMG Master Plan CHEOPS Model, HDR, Inc.
Surface Water Withdrawals for Irrigation

Legend
- Registered Agriculture
- Surface Water Permits
  - Golf Courses
- Model Tributary Objects
  - Mainstem
  - Major Branch
  - Primary
  - Primary (Implicit)
  - Secondary
  - Higher Order Tribs

- RIVER HILLS COUNTRY CLUB
- PEACH TREE THE
- TEGA CAY GOLF CLUB
- COLUMBIA COUNTRY CLUB
- THE MEMBERS CLUB AT WOODCREEK
- Belger Farms
- SC DEPT OF CORR WATERRR RIV CO
- TRIPLE J FARMS
Interbasin Transfers

Legend
- Catawba USGS Gages

Significant Dischargers
- Discharge to Pee Dee Basin
- Discharge to Broad Basin
- Discharge from Broad Basin

Model Tributary Objects
- Mainstem
- Major Branch
- Primary
- Primary (Implicit)
- Secondary
- Higher Order Tribs

LANCASTER COUNTY CO/CATAWBA RIVER WTP
YORK/FISHING CREEK WWTF
RW HEMPILL FILTRATION PLANT (CHESTER)
CHESTER/SANDY RIVER WWTF
KERSHAW/HANGING ROCK CREEK
Catawba-Wateree 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.

Import or Export (Interbasin Transfer)
Discharge from a Groundwater User*
Catawba-Wateree River Basin

MODEL SETUP
Tributary Input Form

**Tributary**

- **Tributary Name:**
- **Confluence Stream:**
  - **Confluence Location (mi):** 0
- **Spatial Flow Changes**
  - **Subbasin Flow Factor (unitless):** 1
  - **Reach Length (mi):** 10
- **Comments:**

**Submit**
- **Save**
- **Close**
Reservoir Input Form

[Image of a software interface titled "Reservoir Input Form"]

- **Reservoir Name:**
- **Storage Capacity (Af):**
- **Initial Storage (Af):**
  - Offline
  - Online

**Evaporation**
- **Inches/day**
- **% Volume**
- **Input Timeseries**

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

**Area-Capacity Table**
- **Simple**
- **Detailed**

**Reservoir Releases**
- **Receiving Stream:**
  - Simple
  - Advanced
- **Release Location (mi):**
- **User Defined Releases**
- **Month**
- **Min. Release (AFM)**
- **(CFS)**

**Comments:**

[Buttons: Save, Close]
Water User Input Form – Main
Agricultural Water User Input Forms
Catawba-Wateree River Basin

MODEL VALIDATION
SWAM Calibration/Validation

• Calibration targets = downstream flow gage records
• Calibration parameters =
  – reach gains/losses,
  – unaged 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