River Basin Hydrologic Modeling

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Ecological Flow Science Advisory Board

Tom Fransen
Division of Water Resources
NC Department of Environment and Natural Resources
“Water links us to our neighbor in a way more profound and complex than any other.“

- John Thorson
(3) Model. – Each basinwide hydrologic model shall:

a. Include surface water resources within the river basin, groundwater resources within the river basin to the extent known by the Department, transfers into and out of the river basin that are required to be registered under G.S. 143-215.22H, other withdrawals, ecological flow, instream flow requirements, projections of future withdrawals, an estimate of return flows within the river basin, inflow data, local water supply plans, and other scientific and technical information the Department deems relevant.

b. Be designed to simulate the flows of each surface water resource within the basin that is identified as a source of water for a withdrawal registered under G.S. 143-215.22H in response to different variables, conditions, and scenarios. The model shall specifically be designed to predict the places, times, frequencies, and intervals at which any of the following may occur:
   1. Yield may be inadequate to meet all needs.
   2. Yield may be inadequate to meet all essential water uses.
   3. Ecological flow may be adversely affected.

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c. Be based solely on data that is of public record and open to public review and comment.

(6) Approval and modification of hydrologic models.
Water Resources Planning & Basin Modeling

Water Resources Planning
(No EMC Approval)

River Basin Modeling
(EMC Approval)
Model Limits

- This model is not a water quality model.
  - The outputs can be used to define boundary conditions to a water quality model.

- The model can not be used for flood studies.

- The model does not simulate ground water.
OASIS – A modeling program for simulating water supply systems.

OASIS’ Flexibility In Simulating Reservoir Operations Is One Of The Reasons We Selected It As Our Preferred Model.
Questions To Answer

• Is there enough water to sustain expected uses now and in the future?
  • DWR does consider ecologic flows to be part of “expected uses”.
• Where, when and for how long could we expect to experience shortages?
River Basin Model Basics

- Water Balance Model
  - Inflow – Outflow = Change in Storage
- Model is like a checkbook
  - Inflow = Salary
  - Outflow = Expenses
  - Storage = Bank Account
- The complexity is developing the data and equations to describe the 3 variables.
What is a River Basin Hydrologic Model?

Hydrologic Model

Water Resources Plan

Inflows

"Unimpaired" Historical Streamflows

Alternative Streamflows
- Climate Change
- Landuse Changes
- Altered Baseflows

Operation Guidelines
- Current and Planned

Reservoir Operations
- Permitted Minimum Flows
- Drought Plans

Water Use
- Historical and Projected

Local Water Supply Plans
- Self-Supplied Industries
- Agricultural
- Other Registered Withdrawers

Evaluation Criteria
Is there enough water to sustain expected current and future uses?

Water Supply
- Ecological Flows
- Recreation
- Power Production

Changes in demand resulting from climate change.

Water Use
- Historical and Projected

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Hydrologic Model

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Inflow Dataset

- Inflow dataset is based on “unimpaired” USGS streamflow gage data.
- “Impairments” are modifications of the natural streamflow caused by reservoir storage changes (includes surface evaporation and precipitation) and consumptive withdrawals (includes withdrawals and discharges from municipal, industrial, and/or agricultural uses).
Unimpaired Inflow

Unimpaired Inflow =
- Measured Gage Flow
+ Upstream Withdrawals (municipal, industrial, agricultural)
- Upstream Discharges (municipal, industrial)
+ Upstream Reservoir Storage ( + Increase / - Decrease)
+ Upstream Reservoir Surface Evaporation
- Upstream Reservoir Surface Precipitation
Steps To Create Inflow Record

1. Unimpaired streamflow record.
   - The process was described in the previous slide.

2. Extend short records and fill in missing flows.
   - USGS extension of monthly streamflow records program *fillin* is used.

3. Disaggregate the monthly data from *fillin* into daily values.
   - The values are disaggregated by using the daily flows from a nearby gage.

4. Use the unimpaired extended streamflow records to create the local inflows for the nodes.
   - Upstream and drainage area adjustments.
Inflow Record Issues

How good is good enough?

_We’re not making watches._

- Lack of good long-term historical data to create the unimpaired flow record.
- Lack of adequate long-term streamflow gages.
- No adjustments for changes in land use.
- No adjustments for changes in the surface water ground water interactions.
Hydrologic Stationarity

- Key Assumption – The future will be statistically indistinguishable from the past.
- Is stationarity dead?
  - Climate change and coping with non-stationarity in water and ecosystem management.
Critical Assumptions:

- Ground water/surface water relationships are reflected in stream flows
- Withdrawals will come from current intake locations
- Sellers will continue to meet buyers’ needs
- Wastewater returns will continue at the same percent of withdrawals and same locations
- Agricultural withdrawals will not change significantly
Critical Assumptions:

- Stream flows will be within historical ranges
- Focus on normal and low-flow conditions
- Local water utilities are the best judges of distribution system growth
- Not a water quality model
- Not a ground water model
Nodes And Arcs

Nodes are locations of interest
- Reservoirs
- Demands
- Junctions

Arcs represent flow between nodes
- Stream reaches
- Canals
- Pipelines
- Groundwater seepage
- Etc.
**Water Demands**

### Annual Average Use

<table>
<thead>
<tr>
<th>Systems</th>
<th>2008 Demand (MGD)</th>
<th>2030 Demand (MGD)</th>
<th>2050 Demand (MGD)</th>
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<tr>
<td>Orange-Alamance</td>
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<td>Hillsborough</td>
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<td>Durham</td>
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<td>Raleigh</td>
<td>45.22</td>
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<tr>
<td>Wilson</td>
<td>8.92</td>
<td>11.214</td>
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<tr>
<td>Johnston County</td>
<td>7.201</td>
<td>11.854</td>
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<td>Smithfield</td>
<td>2.988</td>
<td>4.64</td>
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<tr>
<td>Progress Energy - Lee</td>
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<td>Goldsboro</td>
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<td>Weyerhaeuser</td>
<td>15.37</td>
<td>17.75</td>
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</table>

Source: NCDENR, Division of Water Resources
How well does the model replicate conditions?

Falls Lake 2007 water levels

Elevation at node 300 -- Falls Lake

Wake County DM Levels in 2007:
- 03/13/2007: D0 - Abnormally Dry
- 04/17/2007: No Drought
- 05/01/2007: D0 - Abnormally Dry
- 06/26/2007: D1 - Moderate
- 08/14/2007: D2 - Severe
- 09/04/2007: D3 - Extreme
- 10/02/2007: D4 - Exceptional
- 10/30/2007: D3 - Extreme
- 11/20/2007: D4 - Exceptional
How well does the model replicate conditions?

Clayton Flow

Flow (CFS)

Target 254 cfs

Target 184 cfs

Target Min Flow Seasonal Guide Curve: May - Oct, Nov - Apr

Month / Year
Impacts to reservoir water levels
Water Resources Policy Act of 2009 (not ratified)
The precursor to 5 2010 Ratified Bills, including SL 2010-143

Cape Fear River Basin Example

Summary Of The Work Done In June 2009

- 4 Model Simulations
  - Each simulation was daily with a record from 1/1/1930 through 12/31/2005
  - 672 input values change for the 4 simulations.
  - The baseline required approximately 150 simulations to determine the yield for the 14 reservoirs.
- Develop A Water Withdrawal Decision Support System (DSS)
  - For the 4 simulations the DSS processed 79,057,632 output data values.
  - DWR staff used their best professional judgment to develop a first cut at a simplified approach for the integrity criteria.
Modeling Baseline

Lake Townsend Releases

Flow, cfs

Date


- Modified Natural - Used
- Natural
- Modified Natural - Tested

1/18/2011 Slide - 25
Website – DSS

The Cape Fear is not over allocated. That is the WRONG conclusion.
Lessons Learned

- The basin model in combination with a decision support system could be a workable approach for basinwide allocation analysis.

- The current basin modeling approach will require adjustments after the integrity criteria are finalized.
Need Provisions To Handle Drought Conditions
Comparison Of Flow Thresholds

Cape Fear at Lillington, NC (Model Node 550)

Date

Flows, cfs

10,000

1,000

100

10

Historical Severe to Exceptional Drought Range
Jordan Target
80% 7Q10
SC's Proposed Monthly % of MAF
75% Twice Monthly Daily Median Flow, cfs
## Alternative WQ Approach That Did NOT Work

Compared Modeled 7Q10 to the 7Q10 used for NPDES Permits

<table>
<thead>
<tr>
<th>System</th>
<th>Permit</th>
<th>Permit 7Q10 cfs</th>
<th>Base 7Q10 cfs</th>
<th>2008 7Q10 cfs</th>
<th>2020 7Q10 cfs</th>
<th>2050 7Q10 cfs</th>
<th>Gage 7Q10 cfs</th>
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<td>-15.5%</td>
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<td>Fayetteville - Cross Creek WWTP</td>
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<td>Permit %dif</td>
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<td>Randleman WWTP</td>
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<td>369.8%</td>
<td>497.6%</td>
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</table>
7Q10 Is Not Constant

The Drought of 1998–2002 in North Carolina — Precipitation and Hydrologic Conditions
By J. Curtis Weaver
Why The WQ Permit Approach Should Not Be Used

- The only time you should compare actual and model data is during the validation process.

- The inflows are calibrated at the monthly level. The users need to be careful using indicators with a time-step shorter than a month.

- Modeling issues this approach highlighted.
  - We will need to have a local inflow at all nodes, not just the key calibration points.
  - The user needs to be careful about how the indicator is calculated.
    - Inflows into the node vs. Outflows leaving the node.
Modeling and Ecological Flows
Issues/Concerns

- Historically the models have focused on water supply (municipal and industrial) reliability.
  - Larger streams and rivers that support or the potential to support withdrawal and discharges of 100,000 gpd or greater.
  - Calibration and validation is concentrated on normal and low flow periods, when the water supplies are stressed.
Modeling and Ecological Flows

Modeling Issues That Needed To Be Reviewed

- Need to be sure the model scale works for the issue being evaluated.
  - Roanoke River Striped Bass spawning flowing a good fit.
  - Habitat needs for the Carolina heelsplitter in Goose Creek is not a good fit.

- Need to be careful if the ecological flow requirements includes one or more high flow statistic.
Questions

Contact Information

Tom Fransen, Deputy Director
Tom.Fransen@ncdenr.gov
919-715-0381