WMP Modeling Update and Results

WMP Committee Meeting
August 13, 2018

Presented by: Wilson Water Group

Agenda

- Modeling 101
- Gunnison Model Improvements
- Model Calibration
- Baseline vs Historic Datasets
- Output Examples
- Scenario/Project Examples
StateMod
Surface Water Planning Model

- Model used for the Colorado Decision Support System (CDSS)
- Generic water allocation model
- Can be adapted to any river basin through unique data sets
- Data sets define basin
- Operates based on Colorado’s water right system
Gunnison Basin StateMod History

- First developed in 1994, represented 75% of consumptive use, calibrated from 1975 to 1991
- Updated in late 90’s to include 100% of consumptive use and to extend data back to 1909
- Updated in 2005 to incorporate variable efficiency and soil moisture accounting
- Used in 2014 to support Gunnison BIP
- Updated in 2015 to extend through 2013 and represent Aspinall Unit Record of Decision
- Updated in 2018 to support Upper Gunnison WMP

StateMod Description

- Direct solution algorithm runs on water rights
- Model is a Predictive Model
- Most Appropriate for Comparison Purposes
- Can incorporate historical observed hydrologic variability, paleohydrology, and climate projected hydrology
StateMod Model

• Can answer questions like...
  – What is the Physical yield of water rights?
  – Water is Natural flow compared to depleted flow?
  – Where are Dry-up or near dry-up locations?
  – What are reasonable Instream flow targets?
  – What is the increased supply of new or enlarged reservoirs?

StateMod Model

• Can answer questions like...
  – What is the impact of full use of senior water rights/conditional water rights on junior diverters?
  – How do changes in diversion or irrigation methods impact flows in the river?
  – What are shortages to consumptive and non-consumptive demands?
  – What are impacts from changes in demands or hydrology?
**Strengths and Weaknesses**

- Water rights administration
- Estimates of supply and shortage
- Demand driven reservoir operations
- Tracking reusable supply
- Comparative analysis aka “what if” scenarios

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**Strength** | **Weakness/Requires Additional Effort**
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Rainfall-runoff model | Gentleman’s agreements
River routing model | Intentional shortage
Water quality model | One time only operations

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**StateMod Overview**

- Linked-Node Model
- Nodes are locations where you have or need information
  - Stream Gages
  - Diversion Locations
  - Reservoirs
  - Beginning/End of Instream Flow Reaches
  - Return Flow/Discharge Locations
StateMod Uses a Linked Network

- Links Carry Water from Node to Node
  - Rivers
  - Canals
  - Pipelines
Inflow Hydrology

- Model Starts with Hydrology
- Natural Flow (NF)
- Estimated by removing the effects of man
  - Diversions
  - Return Flows
  - Changes in Reservoir Storage
  - Evaporation

\[ NF = \text{Gaged} + \text{Diversions} - \text{Returns} +/\text{- Effects of Storage} \]
Physical System

- Diversion Structures
  - Location on the river
  - Headgate and canal capacities
  - Return flow location(s)

- Reservoirs
  - Location on river (or off-channel)
  - Location of carrier ditches (if off-channel)
  - Storage volume, outlet capacities, account sizes, area/capacity curve

- Instream flow reaches
  - Start and end of reach
### Current WMP Sub-basins

![Map of Current WMP Sub-basins]

### Modeled Physical System

<table>
<thead>
<tr>
<th></th>
<th>Ohio Creek</th>
<th>East/Slate Rivers</th>
<th>Lake Fork</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Irrigated Acreage</td>
<td>11,340</td>
<td>6,354</td>
<td>1,126</td>
</tr>
<tr>
<td>Irrigation Diversions (total)</td>
<td>79</td>
<td>67</td>
<td>40</td>
</tr>
<tr>
<td>Key</td>
<td>79</td>
<td>67</td>
<td>40</td>
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<tr>
<td>Aggregates</td>
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<tr>
<td>Municipal/Industrial Users</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Instream Flows</td>
<td>6</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Active Reservoirs</td>
<td>0</td>
<td>1 (Meridian)</td>
<td>1 (San Cristobal)</td>
</tr>
<tr>
<td>Stream Flow Gages*</td>
<td>3 (1 active)</td>
<td>3 (3 active)</td>
<td>1 (1 active)</td>
</tr>
</tbody>
</table>

*Other recent or historical gages used to inform calibration
WMP Model Revisions

- Irrigated acreage assessment improvements
  - Ditch assignments were done on a fairly high level: several fields were combined and assigned to multiple ditches
  - Worked with Water Commissioners to divide fields and re-assign to correct ditch
  - Met with larger ranchers to review irrigation operations and assure accurate representation of common irrigation practices in each tributary
  - Revised return flow locations and timing
  - Disaggregated diversions and represented each active ditch separately
Upper Ohio Creek Modeled Diversions

- Black nodes – in previous model and current model
- Purple nodes – not in previous model, in current model
- Green nodes – previously in aggregate, now explicitly modeled
- Made changes to about 70% of the irrigated parcels

<table>
<thead>
<tr>
<th></th>
<th>GM2015 Model</th>
<th>WMP Model</th>
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<tbody>
<tr>
<td>Included Tributaries</td>
<td>7</td>
<td>18</td>
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<tr>
<td>Irrigation Diversions (total)</td>
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<td>186</td>
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<tr>
<td>Key</td>
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<td>186</td>
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<td>Municipal/Industrial Users</td>
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<td>Instream Flows</td>
<td>11</td>
<td>20</td>
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<td>Active Reservoirs</td>
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<td>2</td>
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<tr>
<td>Stream Flow Gages</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

*Ohio Creek, East/Slate Creek, and Lake Fork Statistics*
Physical Systems – Data Sources

- Physical Structure Location Based on GIS, Available Straight-line Diagrams, and Water Commissioner Input
- Return Flow Locations Based on GIS, Water Commissioner, Rancher Interviews
- Ditch and Reservoir Capacity Information is Stored in HydroBase
- Additional Reservoir Capacities, Account Information, and Area Capacity Curves Obtained from Reservoir Owners/Operators

Water Demands

- Irrigation Demands
  - Full Irrigation Water Requirements from StateCU
- Municipal/Industrial Demands
  - Provided by Municipal Users/HydroBase
- Reservoir “Demands”
  - Reservoir Capacities or Operational Targets
Administrative Conditions

- Water rights (direct, storage, instream flow)
- Reservoir and carrier operations
- Policies and agreements (minimum bypass, fish flows, etc)

How Does it Work
(Water Availability Computations)

- Considers natural inflows and return flows from previous time steps
- Identifies most senior water right
- Estimates diversion = MIN(demand, water right, capacity, available flow)
- Adjusts downstream flows to reflect senior diversions and immediate return flows
- Calculates Future return flows
- Repeats for the next most senior water right
WMP Model Calibration

Calibration period = 1975 – 2013

Do simulated results equal the observed values?
Compare:
- Streamflow
- Reservoir contents
- Diversions

Goal is to correctly distribute ungaged flows, set return flow locations, and create operating rules
Model Calibration – East River

09112500 - East River at Almont

09112500 - East River at Almont

Model Calibration – East River

09112500 - East River at Almont

Model Calibration – East River

09112500 - East River at Almont
Model Calibration – Lake Fork

![Graph showing streamflow at Lake Fork at Gateway with observed and historical simulation lines]

Model Calibration – Lake Fork

![Graph showing the relationship between USGS observed streamflow and simulated streamflow with a linear regression line and correlation coefficient]

\( y = 1.000x \\ R^2 = 0.9998 \)
Model Calibration – Ohio Creek

Baseline Model

Current Demand with Historical Hydrology
Baseline vs Historical

- Historical Demands represent historical use, supply limitations, and irrigation practices
- Baseline Demands represents current demands over a longer hydrologic period (current Irrigated Acreage, Crop Types, and Irrigation Methods)
- Historical quantifies shortages: Baseline shows why there are shortages
- Important for planning not to limit users to historical practices, only Beneficial Use and Water Rights
Shortage Comparison – Ohio Creek

WMP Model Output

What does the model tell us?
Types of Output (a short list)

- Historical Streamflow
- Baseline Streamflow
- Stream Diversions
- Returns Flows
- Crop Irrigation Demand
- Consumptive Use
- Consumptive Shortage
- Instream Flow Shortages

Total Diversions – East River

[Graph showing East River at Almont, Monthly with labels for "Average", "Wet", and "Dry" flow conditions over the years 2009-2010 to 2011-2012, with natural flow, baseline flow, and total US diversions represented by different lines.]
Total Diversions – Ohio Creek

Instream Flow – Example

5901401 - Mill Creek
Consumptive Shortage – Example

Baseline Physical Shortage and Legal Shortage

Streamflow (cfs)

Consumptive Shortages – Example

Physical Shortage and Legal Shortage

Legal Limitation

Physical Limitation (partial)
Irrigation Practice Limitation

Historical vs Baseline Demand


Historical Total Demand Baseline Total Demand

Modeling Examples

Hypothetical examples that demonstrate model’s ability to evaluate potential projects or possible future hydrologic conditions
What happens if irrigation efficiency is increased at a small scale?

Example:
- Ditch Loss eliminated for single ditch on Ohio Creek
- High efficiency flood irrigation practices implemented (increase from 40% to 60%)
What opportunities exist to increase dry year flows?

Example: Upper Slate River irrigators participate in dry year lease program.
  ◦ 100% participation
  ◦ 1,060 acres fallowed
Example 2 – Dry Year Leasing

![Graph of 09111500 - Slate River near Crested Butte, showing streamflow in cubic meters (m³)]

Example 2 – Dry Year Leasing

![Graph of 09111500 - Slate River near Crested Butte, showing streamflow in cubic meters (m³)]
Example 3 – Upper East Storage

- Can winter time flows in the Upper East be increased?

- Example: Add storage at strategic location on the Upper East River.
  - 700 acre-foot reservoir
  - Divert during spring runoff to supply winter demands

![Graph showing End of Month Contents with Reservoir Storage trend]
What would happen to the storage if historical hydrology was resequenced?

Example:
- Two Dry Years
  - 2002 hydrology followed by another 2002
- Dry Year Followed by Average
  - 2002 hydrology followed by 2007 hydrology
- Dry Year Followed by Wet Year
  - 2002 hydrology followed by 2011 hydrology
Example 4 – Back to Back Dry Years

Simulated Taylor Park Reservoir Contents

Simulated Blue Mesa Reservoir Contents