Jordan River Water Quality Modeling: Applications and Simulations

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Background and Motivation

Introduction, Jordan River Water Quality Impairment, State of Utah WQ Standards
Jordan River DO Impairment (DWQ 2016)

- Surplus Canal to North Temple
- North Temple to Farmington Bay
State of Utah DO Standards (R317)

- DO in mg/L (for Class 3 (Aquatic Life)):

<table>
<thead>
<tr>
<th>Period</th>
<th>Class 3A (Cold Water Game Fish)</th>
<th>Class 3B (Warm Water Game Fish)</th>
<th>Class 3C (Nongame Fish)</th>
<th>Class 3D (Waterfowl, Shore Birds, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-day Avg</td>
<td>9.5 / 5.0</td>
<td>6.0 / 4.0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>30-day Avg</td>
<td>6.5</td>
<td>5.5</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>8.0 / 4.0</td>
<td>5.0 / 3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Jordan River Identification by State of Utah (R317)

- Effluent from Utah Lake to Turner Dam: Class 2B, 3B
- Turner Dam to Little Cottonwood Creek: Class 2B, 3A
- Little Cottonwood Creek to North Temple: Class 2B, 3B; Site Specific
- North Temple to Farmington Bay: Class 2B, 3B, and 3D; Site Specific

<table>
<thead>
<tr>
<th>Time Period</th>
<th>7-day Avg</th>
<th>30-day Avg</th>
<th>Instantaneous Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>May to July</td>
<td>5.5 mg/L</td>
<td>5.5 mg/L</td>
<td>4.5 mg/L</td>
</tr>
<tr>
<td>August to April</td>
<td>N/A</td>
<td>5.5 mg/L</td>
<td>4.0 mg/L</td>
</tr>
</tbody>
</table>
Jordan River Impairment?

• Factors/Characteristics to consider...
  • Sources (Point/Nonpoint)
    • WWTPs
    • Groundwater
    • Stormwater
  • Environmental/Human Characteristics
    • Eutrophication
    • Population/Land Use Development (e.g., Hydrologic Runoff)
  • Atmospheric Characteristics
    • Climate Change
    • Atmospheric Deposition
Project Work at the University of Utah

Introduction to University of Utah Project, EPA Model Workflow, Simulations Planned
EPA Project Introduction

• **Title:** Prediction of Nonlinear Climate Variations Impacts on Eutrophication and Ecosystem Processes and Evaluation of Adaptation Measures in Urban and Urbanizing Watersheds

• **Major Goal(s):** Evaluate/Assess the performance of the Jordan River/Utah Lake Watershed
  
  • **Performance:** Water Quantity (e.g., Flow), Water Quality (constituents, experimental/sampling analyses, model experimental rates, environmental processes, etc.)
  
  • **Based on:** Population/Land Use Development, Climate Change Projections
Simulation Periods

• **Historical Baseline Simulation**
  • **Begin Date:** October 1, 2000
  • **End Date:** September 30, 2009

• **Future Simulation**
  • **Begin Date:** October 1, 2035
  • **End Date:** September 30, 2044

• **Time Period Selection Factors**
  • Availability of Climate Data
  • Land Use Development Scenarios
Number of Simulations Expected

- **Historical Baseline Simulations:** 2 runs total
  - **RCP 6.0:** Dynamically-Downscaled Climate Data from Dr. Court Strong (Atmospheric Sciences, University of Utah)
  - **RCP 8.5:** Multivariate Adaptive Constructed Analogs (MACA) Statistically-Downscaled Climate Data (Temporal Disaggregation required) from Dr. John Abatzoglou (University of Idaho)

- **Future Simulation:** 6 runs total (2 Land Use * 3 RCPs per Land Use = 6 total)
  - **Climate Scenarios:** RCP 4.5, RCP 6.0, RCP 8.5
    - **Dynamically-Downscaled:** RCP 6.0
    - **Statistically-Downscaled:** RCP 4.5, RCP 8.5
  - **Development Scenarios:** “Business-as-Usual”, “Optimal”
General Information on WASP

General Theory, Processes Involved, Effects/Sensitivity Assessment upon Water Quality Simulations of the Jordan River WASP
WASP

• **Water Quality Assessment Simulation Program**
  • Version 8.2 (EPA; June 2018)
  • Open Source Program (NO source code available)
  • Separate Routines
    • **Eutrophication**
      • Nutrients
      • DO
      • Temperature
      • Solids
  • **Toxicants (Organics and Metals)**
Basic Structure of WASP Segment

- Atmospheric Processes
- Atmospheric-Water Column Processes
- Sediment-Water Column Processes
Model/Nodes Setup in WASP
Model/Node Setup in WASP

• “Boxed” Model

• Flows as **Inputs** into WASP
  • Uni-directional flow only in WASP
  • Hydrodynamic Linkage Required for Lakes and Reservoirs
  • Hydrologic Processes NOT included/simulated in WASP
  • Precipitation/Evaporation Processes as inputs but only impact **flows** into model
  • Mass Constituent Loadings (Mass Rates) and Sources (e.g., WWTP sources) as **inputs** into model
Supplementary WASP Materials


Several Presentations over different characteristics, model setup, processes, and constituents of WASP 8.2
Supplementary WASP Materials (continued)

• Website for User Manuals:  
  http://epawasp.twoool.com/docs/

• Website for Tutorials:  
  http://epawasp.twoool.com/tutorials/

• Website for Installers:  
  http://epawasp.twoool.com/installers/  (Open-Source)
General Description of Jordan River WASP Model

Model Setup, Inflows of Interest and Provided by “Upstream” Models
Jordan River WASP
Jordan River WASP Model Setup

- **166 Surface Water Segments**
  - **System Modeled:** Main Jordan River Stream
  - **Length:** 82.7 kilometers (Approximately 51.4 mi)
  - **Most Upstream:** Utah Lake Effluent
  - **Most Downstream:** Burton Dam
  - **200 meters for Upstream Segment (Utah Lake Effluent); 500 meters for all others**
  - **Rectangular Channel (WASP only):** Hydraulic Cross-Sectional Properties from Utah Division of Water Quality TMDL Qual2K Model
  - **Flow Routing Method:** Kinematic Wave (allows for “flow non-tracking”)

...
Jordan River Model
Jordan River Model- WWTP
Jordan River Model- Diversions
Jordan River - Creek Outflows
Jordan River- Drains/Conduits/Other Canals
Water Quality Constituents

List of Water Quality Constituents simulated in the Jordan River WASP
The “Basics”

• Water Temperature
• pH
• Alkalinity
• Total Suspended Solids (TSS)
• Nutrients (next slide)
Nutrient Species

- **Nitrogen Species**
  - Ammonia-Nitrogen
  - Inorganic Nitrogen (Nitrate and Nitrite)
  - Organic Nitrogen (Dissolved)

- **Phosphate Species**
  - Dissolved Inorganic Phosphate
  - Organic Phosphate (Dissolved)
Particulate Organic Matter (POM)

• Particulate Organic Carbon (POC) / Detrital Carbon
• Particulate Organic Phosphate (POP) / Detrital Phosphate
• Particulate Organic Nitrogen (PON) / Detrital Nitrogen
• Total Detritus / Particulate Organic Matter (POM)
“Oxygen-Related”

- **Carbonaceous Biochemical Oxygen Demand (CBOD)**
  - Ultimate CBOD
  - Up to 5 Groups allowed (e.g., River CBOD, WWTP CBOD, Stormwater CBOD)
  - Distinguishes between CBOD and Soluble CBOD by “Detritus Dissolution into CBOD”

- **Dissolved Oxygen**
  - Dissolved Oxygen Concentration
  - Dissolved Oxygen Saturation
Phytoplankton and Algae

• **Phytoplankton**
  - Chlorophyll-a
  - Up to 5 Groups allowed

• **Macro/Benthic Algae**
  - Chlorophyll-a
  - Nitrogen
  - Phosphorus/Phosphate
  - Up to 5 Groups Allowed
  - Benthic (“non-transported”) or Macro (“transported”) algae per group (e.g., can NOT be both per group)
Previous Modeling Work

Previous Studies Conducted, Model Calibration and Sensitivity Period, Measured Data
Previous Model Development (Jordan River)

- **Total Maximum Daily Load (TMDL) Qual2K (Utah Division of Water Quality); Steady-State**
  - February 2007
  - August 2009

- **University of Utah Work: Water Quality Assessment Simulation Program (WASP)**
  - **Calibration Periods:** August 2009 (Steady-State), Water Year 2009 (supplementary; ongoing)
  - **EPA Project Simulations:** Historical Baseline, Future
Measured Data...

- **Ambient Water Quality Monitoring System (AWQMS)**
  - Measured WQ Data for several Jordan River sites by the Utah Division of Water Quality
  - Model Calibration/Validation (for “Dynamic” Models)

- **Database Development**
  - Steady-State (August 2009)
    - Diurnal Measured Data for DO, Water Temperature, pH
    - Measured Data for other constituents
    - Non-detects removed (for model calibration/validation)
    - Non-detects approximated (85% of Lower Quantification Limit)
Model Sensitivity and Calibration

Simulated vs. Measured Data, Model Calibration Approaches
Model Sensitivity/Calibration Approaches

• Sensitivity
  • Increasing/Decreasing 50%, Doubling, etc. for selected model inputs
  • Water Quality Model Parameters (Temperature-Correction Coefficients, Half Saturation, Kinetics, Sediment Diagenesis Parameters)
  • Meteorological Time Functions (Solar Radiation, Cloud Cover, Air Temperature, Dewpoint Temperature, Wind Speed, Topography/Canopy Shading)
  • Steady-State Model (August 2009) Extended to 2 months simulation period for sensitivity analyses

• Calibration
  • Steady-State: Visual Inspection (“Lack” of Measured Data)
  • Dynamic: Visual Inspection + Statistical Analyses (Planned/Ongoing)
Water Temperature Sensitivity (Steady-State)
Water Temperature Sensitivity (Steady-State)
Dissolved Oxygen Sensitivity (Steady-State)
Dissolved Oxygen Sensitivity (Steady-State)

Dissolved Oxygen Sensitivity for Segment 84 (South Valley WWTP)
Example Model Validation (Steady-State)
Example Model Validation (Steady-State)
Work Moving Forward

• Water Year 2009 Jordan River Model Calibration (ongoing)
• Utah Lake Model Calibration/Validation (EFDC + WASP)
• Historical Baseline Simulations (Model Integration)
• Future Simulations (Model Integration, Land Use Development, Climate Projections)
Questions?

Thank you for viewing the presentation!