Raritan River Basin TMDL Study: Model Calibration and Validation

September 17, 2007

Presented to: Raritan Basin Watershed Alliance Technical Advisory Committee

Presented by: Jim Cosgrove and Tom Amidon Omni Environmental LLC
Purpose and Agenda

- **Purpose**
  - Review calibration of Raritan TMDL Models

- **Agenda**
  - Overview
  - Watershed Model
    - Development and Calibration of Flow Models
    - Development and Calibration of Water Quality Models
  - Next Steps and Discussion
Raritan River Basin Overview

- **Pollutant Sources**
  - > 80 STPs
  - Highly varying land uses
  - Generally nonpoint source dominated

- **Impairment Designations**
  - Phosphorus
  - Temperature
  - pH
  - TSS

- **Key Issues**
  - Where is phosphorus causing impairment?
  - What measures would solve the problem?
  - What is natural condition?
  - What are causes of other impairments?
Raritan River Basin TMDL Study

- Provide technical basis for NJDEP to develop TMDLs as necessary to address phosphorus and other conventional impairments in the Raritan River Basin
  - Identify nutrient impairments and critical locations
  - Develop, calibrate, and verify watershed models to relate nutrient sources to water quality targets at critical locations

- Complements Phosphorus Evaluation Studies
  - Beden Brook Nutrient Study 2000-2001
  - Lower Millstone / Mainstem Raritan 2003
  - South Branch Raritan River in Washington Township 2004
  - Matchaponix Brook at Pine Brook 2004
Water Supply Issues

- Major water supply storage features
  - Spruce Run and Round Valley Reservoirs

- Major water supply intake
  - Confluence of Millstone and Raritan Rivers

- Diversions and releases throughout system impact flow and water quality
  - Model must account for diversions and releases
Watershed Model Purpose

- **Purpose**
  - To relate point and nonpoint sources of nutrients to water quality impacts under a variety of conditions, including critical conditions

- **Critical Water Quality Indicators**
  - Dissolved oxygen
  - Phosphorus
  - Nitrogen components (ammonia and nitrate)
  - Phytoplankton (chlorophyll-a)
Watershed Model Overview

- **Flow Model**
  - Hydrologic Model (HydroWAMIT)
  - Hydraulic Model (DA-FLOW)
  - Five Basin Sub-models

- **Water Quality Model**
  - One-Dimensional dynamic simulation using WASP
  - Five Basin Sub-models

- **Watershed Model Integration (HydroWAMIT)**
  - Nonpoint source simulation
    - flow-weighted runoff EMCs
    - area-weighted baseflow concentrations
  - Hydrologic, Hydraulic, and Water Quality integration
Hydrologic Simulation

- Continuous flow components required
  - Surface runoff
  - Baseflow
  - Streamflow

- Direct simulation using precipitation-based hydrologic model (HydroWAMIT)
  - Allows changes in flow and pollutant loads due to changes in land use distribution and perviousness
  - Subject to inherent modeling uncertainties such as precipitation inputs

- HydroWAMIT features
  - Hybrid of GWLF and HSPF
  - Daily time step and long term simulations
  - Area of interest can be subdivided into multiple interconnected sub-watersheds
  - Hydrologic simulation unit is the land use type within each sub-watershed
Conceptual Hydrologic Model
Hydrologic Model Calibration Gages

- SB RARITAN RIVER AT FOUR BRIDGES NJ
- SB RARITAN RIVER NEAR HIGH BRIDGE NJ
- SB RARITAN R AT STANTON NJ
- NB RARITAN RIVER NEAR RARITAN NJ
- NI SHANIC RIVER AT REAVILLE NJ
- PIKE R N AT BELLE MEAD NJ
- STONY BROOK AT PRINCETON NJ
- LAMINGTON RIVER NEAR POTTERSVILLE NJ
- NB RARITAN RIVER NEAR FAR HILLS NJ
- RARITAN RIVER AT MANVILLE NJ
- BOUND BROOK AT MIDDLESEX NJ
- RARITAN R. BL CALCO DAM AT BOUND BROOK NJ
- MILLSTONE RIVER AT BLACKWELLS MILLS NJ
- MILLSTONE RIVER AT PLAINSBORO
Upper Millstone River at Plainsboro

Percent of Time Discharge Exceeded

Flow (cfs)

Observed Gage
Simulated
North Branch Raritan River at Burnt Mills (NBRR6)

Flow (cfs)

Date


Simulated

Measured
Omni Environmental

Hydrologic Model Calibration Results

Daily $R^2$ (average $R^2 = 0.75$)
Global Water Balance
(-1.35% overall)

Calibration Stations

Percent Mean "Error"
Water Quality Model
Water Quality Model: WASP 7.1
Model Limitations

- **Boundary Condition Uncertainties**
  - temperature estimated based on correlation with air temperature
  - actual STP, NPS, and baseflow loadings

- **Unified System Kinetics within each model**
  - global decay rates
  - global growth rates
Nonpoint Source Load Calculations

- NPS loads are associated with the surface runoff, interflow, and baseflow simulated by the hydrologic model.

- Runoff concentrations are defined for each land use type.

- Baseflow/interflow concentrations are defined for each sub-watershed.
  - NOT the same as groundwater
  - Phosphorus concentrations also influenced by land use type
Stormwater Concentrations

**Total Phosphorus**

- Residential: 0.20 mg/l
- Other: 0.20 mg/l
- Urban: 0.40 mg/l
- Agricultural: 0.40 mg/l
- Forest: 0.10 mg/l
- Wetlands: 0.10 mg/l

**Nitrate**

- Residential: 2.0 mg/l
- Other: 1.0 mg/l
- Urban: 1.0 mg/l
- Agricultural: 1.0 mg/l
- Forest: 0.5 mg/l
- Wetlands: 0.1 mg/l
Tributary Baseflow / Interflow Concentrations (Average)

**Total Phosphorus**

<table>
<thead>
<tr>
<th>Location</th>
<th>Concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Millstone</td>
<td>0.08</td>
</tr>
<tr>
<td>Stony Brook</td>
<td>0.06</td>
</tr>
<tr>
<td>Lower Millstone</td>
<td>0.04</td>
</tr>
<tr>
<td>North/South Branch</td>
<td>0.02</td>
</tr>
<tr>
<td>Mainstem Raritan</td>
<td>0.00</td>
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</table>

**Nitrate**

<table>
<thead>
<tr>
<th>Location</th>
<th>Concentration (mg/l)</th>
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</thead>
<tbody>
<tr>
<td>Millstone</td>
<td>1.60</td>
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<tr>
<td>South Branch</td>
<td>1.20</td>
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<tr>
<td>Lamington</td>
<td>0.80</td>
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<tr>
<td>North Branch</td>
<td>0.40</td>
</tr>
<tr>
<td>Mainstem Raritan</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Water Quality Calibration Results

- Upper Millstone River
  - Upper Millstone River in Plainsboro (UMR3)

- Stony Brook
  - Stony Brook at Princeton (SB3)

- Beden Brook / Lower Millstone River
  - Beden Brook Downstream SBRSA –Hopewell STP (BB2)
  - Lower Millstone River at Manville (M7)

- North and South Branch Raritan River
  - South Branch Raritan River at Middle Valley (SBR4)
  - Lamington River Downstream Roxbury STP (LR2)
  - South Branch Raritan River at South Branch (SBRR10)

- Mainstem Raritan River
  - Raritan River Upstream Fieldville Dam (R4)
Calibration Parameters

- Total Phosphorus
- Nitrate Nitrogen
- Dissolved Oxygen
  - Long-term
  - Diurnal
Upper Millstone River in Plainsboro (UMR3)
Total Phosphorus

Concentration (mg/l)

Predicted
Observed
Upper Millstone River in Plainsboro (UMR3)
Nitrate

Concentration (mg/l)

Predicted  Observed

Date:
5/15/2004
5/29/2004
6/12/2004
6/26/2004
7/10/2004
7/24/2004
8/7/2004
8/21/2004
9/4/2004
9/18/2004
10/2/2004
10/16/2004
10/30/2004
11/13/2004
11/27/2004
Water Quality Model Calibration Results

Upper Millstone River in Plainsboro (UMR3)
Dissolved Oxygen

Concentration (mg/l)


Predicted

Observed

Concentration (mg/l)
Upper Millstone River Downstream of Railroad Crossing near Princeton Junction (UMR3)

Dissolved Oxygen July 2004 Event

Dissolved Oxygen September 2004 Event

Dissolved Oxygen November 2004 Event
Stony Brook at Route 206 in Princeton (SB3)
Total Phosphorus

Concentration (mg/l)


Predicted Observed
Stony Brook at Route 206 in Princeton (SB3)

Nitrate

Concentration (mg/l)

Predicted

Observed

[Graph showing nitrate concentration from 5/20/2003 to 11/18/2003]

[Legend: Predicted, Observed]
Stony Brook at Route 206 in Princeton (SB3)
Dissolved Oxygen

Concentration (mg/l)

Predicted
Observed


Predicted
Observed
Stony Brook at Route 206 in Princeton (SB3)

Dissolved Oxygen July 2003 Event

Dissolved Oxygen August 2003 Event

Dissolved Oxygen September 2003 Event

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

Concentration (mg/l)
Beden Brook Downstream SBRSA-Hopewell STP (BB2)

Total Phosphorus

Concentration (mg/l)

Predicted Observed

<table>
<thead>
<tr>
<th>Date</th>
<th>Predicted</th>
<th>Observed</th>
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<tbody>
<tr>
<td>5/20/2003</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>6/17/2003</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>7/15/2003</td>
<td>0.6</td>
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<tr>
<td>8/12/2003</td>
<td>0.8</td>
<td></td>
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<tr>
<td>9/9/2003</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>10/7/2003</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>11/4/2003</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>12/2/2003</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
Beden Brook Downstream SBRSA-Hopewell STP (BB2)

Nitrate

Concentration (mg/l)

Predicted

Observed

5/20/2003
6/17/2003
7/15/2003
8/12/2003
9/9/2003
10/7/2003
11/4/2003
12/2/2003

0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Beden Brook Downstream SBRSA-Hopewell STP (BB2)
Dissolved Oxygen

Concentration (mg/l)

Predicted  Observed

Water Quality Model Calibration Results

**Beden Brook at Province Line Rd. in Hopewell (BB2)**

**Dissolved Oxygen July 2003 Event**

**Dissolved Oxygen August 2003 Event**

**Dissolved Oxygen September 2003 Event**

**Dissolved Oxygen November 2003 Event**
Lower Millstone River at Manville (M7)
Nitrate

Concentration (mg/l)

Predicted
Observed

5/20/2003
6/17/2003
7/15/2003
8/12/2003
9/9/2003
10/7/2003
11/4/2003
12/2/2003
Lower Millstone River at Manville (M7)
Dissolved Oxygen

Concentration (mg/l)

[Graph showing dissolved oxygen levels from 1/10/2002 to 9/1/2005, with predicted and observed data points.]
Lower Millstone River at Manville Causeway (M7)

Dissolved Oxygen July 2003 Event

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

Dissolved Oxygen August 2003 Event

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

Dissolved Oxygen September 2003 Event

- Predicted DO
- Observed Diurnal DO
- Observed Grabs
South Branch Raritan River at Mount Olive (SBRR1)
Total Phosphorus

Concentration (mg/l)

[Graph showing concentration trends over time, comparing predicted vs. observed values.]
South Branch Raritan River at Mount Olive (SBRR1)

Nitrate

Concentration (mg/l)

Predicted

Observed

NO3 APPNOHEADS
India Brook at Mountainside Road in Mendham (IB1)
Total Phosphorus

Concentration (mg/l)

5/15/2004
7/24/2004
10/2/2004
12/11/2004
2/19/2005
4/30/2005
7/9/2005

[Graph showing concentration of Total Phosphorus over time, with data points for Observed and Predicted values]
India Brook at Mountainside Road in Mendham (IB1)

Nitrate

Concentration (mg/l)

- Predicted
- Observed

Dates:
- 5/15/2004
- 7/24/2004
- 10/2/2004
- 12/11/2004
- 2/19/2005
- 4/30/2005
- 7/9/2005
Water Quality Model Calibration Results

South Branch Raritan River at Mill Rd. in Middle Valley (SBR4)

Total Phosphorus

Concentration (mg/l)

Predicted
Observed

5/1/2004
5/29/2004
6/26/2004
7/24/2004
8/21/2004
9/18/2004

Concentration (mg/l)

Predicted
Observed
South Branch Raritan River at Mill Rd. in Middle Valley (SBR4)

Nitrate

Concentration (mg/l)

Predicted

Observed

[Graph showing nitrate concentration from 5/1/2004 to 10/16/2004 with predicted and observed data points]
South Branch Raritan River at Mill Rd. in Middle Valley (SBR4)
Dissolved Oxygen

Concentration (mg/l)

Predicted
Observed

0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0


[Graph showing predicted vs. observed dissolved oxygen concentrations from 1/10/2002 to 6/23/2005]
South Branch Raritan River at Mill Rd. in Middle Valley (SBR4)

Dissolved Oxygen June 2004 Event

Dissolved Oxygen July 2004 Event

Dissolved Oxygen August 2004 Event

Dissolved Oxygen August 2005 Event
Lamington River Downstream of Roxbury STP (LR2)
Total Phosphorus

Concentration (mg/l)

Predicted  Observed
Lamington River Downstream of Roxbury STP (LR2)

Nitrate

Concentration (mg/l)

Predicted Observed

NO3 APPNOHEADS
Lamington River at Ironia Road Downstream of Roxbury STP (LR2)

**Dissolved Oxygen Summer 2004 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

**Dissolved Oxygen Winter 2004 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

**Dissolved Oxygen Summer 2005 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs
South Branch Raritan River at South Branch (SBRR10)
Total Phosphorus

Concentration (mg/l)

Predicted
Observed

0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35


Predicted
Observed
South Branch Raritan River at South Branch (SBRR10)
Nitrate

Concentration (mg/l)

Predicted
Observed

[Graph showing nitrate concentration with dates and concentration ranges]
South Branch Raritan River at South Branch (SBRR10)
Dissolved Oxygen

Concentration (mg/l)

Predicted
Observed

0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0

1/10/2002
4/4/2002
6/27/2002
9/19/2002
12/12/2002
3/6/2003
5/29/2003
8/21/2003
11/13/2003
2/5/2004
4/29/2004
7/22/2004
10/14/2004
3/31/2005
6/23/2005

Predicted
Observed
South Branch Raritan River at Studdiford Dr. in South Branch (SBRR10, USGS 01398102)

Dissolved Oxygen Summer 2004 Event

Dissolved Oxygen Winter 2004 Event

Dissolved Oxygen Summer 2005 Event
Raritan River at Fieldville Dam (R4)
Total Phosphorus

Concentration (mg/l)

Predicted vs. Observed

[Graph showing Total Phosphorus concentration from 5/15/2003 to 11/27/2003]
Raritan River at Fieldville Dam (R4)
Nitrate

Concentration (mg/l)

Predicted
Observed

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0


[Graph showing nitrate concentrations with predicted and observed data points]
Raritan River at Fieldville Dam (R4)

Dissolved Oxygen

Concentration (mg/l)

Predicted

Observed

1/10/2002
4/25/2002
8/8/2002
11/21/2002
3/6/2003
6/19/2003
10/2/2003
1/15/2004
4/29/2004
8/12/2004
11/25/2004
3/10/2005
6/23/2005
Water Quality Model Calibration Results

Raritan River Upstream Fieldville Dam (R4)

**Dissolved Oxygen July 2003 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

**Dissolved Oxygen August 2003 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

**Dissolved Oxygen September 2003 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs

**Dissolved Oxygen November 2003 Event**

- Predicted DO
- Observed Diurnal DO
- Observed Grabs
Raritan River Upstream Fieldville Dam (R4)

Dissolved Oxygen July 2004 Event

Dissolved Oxygen August 2004 Event

Dissolved Oxygen August 2005 Event
Next Steps

- Review Future Scenarios
  - What happens when NPS is reduced?
  - What happens when STPs increase to permitted flows?
  - What happens when STPs decrease effluent concentrations?

- Determine critical locations and water quality targets

- Calculate TMDLs based on achieving water quality targets at critical locations

- Complete Lake TMDLs
  - Duhernal Lake (Matchaponix Brook)
  - Carnegie Lake
  - Upper Millstone (Peddy Lake, Grovers Mill Pond, Plainsboro Pond, Gordon Pond)
  - Ravine Lake
  - Solitude Lake
Discussion