BISCAYNE BAY NUTRIENT LOADS AND WATER QUALITY BOX MODEL

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Study Objectives

• Divide Biscayne Bay for box model use
• Estimate existing freshwater and nutrient loads to each box
• Upgrade an existing salinity box model for nutrient calculations
• Calibrate and run model for various load scenarios
• Compare to existing data and results of other studies
• Estimate the effects of changing land use
Existing Water Quality Data
# Existing Water Budget Data

<table>
<thead>
<tr>
<th>Receiving Water (box)</th>
<th>Revised Drainage Basin Used in This Study</th>
<th>SFWMD Basins Comprising Drainage Basin</th>
<th>SFWMD Canal</th>
<th>SFWMD Structure</th>
<th>DERMS Canal Stations</th>
<th>Open Water Monitoring Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central Inshore (NCI)</td>
<td>Coral Gables Waterway, Brickell, Snapper Creek, Cutler Drain</td>
<td>Tamiami East*, Coral Gables Waterway*, DA-1, C-2 / Snapper Creek / Area B*, C-100 / Cutler Drain / DA-3 / Area B*</td>
<td>C-3, C-2, C-100</td>
<td>G93, S22, S123, CD02</td>
<td>CG07, SP04</td>
<td>126, 127, 128, 129</td>
</tr>
<tr>
<td>South Central Inshore (SCI)</td>
<td>Black Creek, Princeton Canal, Military Canal, Mowry Canal</td>
<td>Military, C-102 / DA-4*, C-103 / North Canal / Florida City Canal, C-111* / DA-4*</td>
<td>S20G, S-21, S21A, S20F</td>
<td>BL-03, PR-03, MI-02, MW-04</td>
<td>None</td>
<td>101, 102, 103, 110, 122</td>
</tr>
<tr>
<td>Card Sound</td>
<td>South Card Sound</td>
<td>Model Land / DA-4* (Turkey Point Power Plant)</td>
<td>L-31E ditch</td>
<td>S-20</td>
<td>None</td>
<td>135, 121</td>
</tr>
<tr>
<td>Barnes Sound and Manatee Bay</td>
<td>Manatee Bay</td>
<td>C-111*</td>
<td>C-111</td>
<td>S197</td>
<td>AR03</td>
<td>1, 2, 3, 4</td>
</tr>
</tbody>
</table>

* indicates a nested or part of a nested basin.
Box Model Domain Development

• Biscayne Bay divided into boxes using bathymetry/geography and areas of similar water quality from a Principal Components Analysis

• Important:
  – Domain of box model is Biscayne Bay
  – Watershed basins not part of box model
  – Watershed basin loads aggregated by box
Principal Component Analysis (PCA)

• PCA used to identify areas of similar water quality
• 4 methods used to develop clusters
  – PC extraction
  – Euclidean distance
  – Varimax rotation
  – Oblique solution
Similar to classification of Florida Bay by Briceno & Boyer (2010) and Caccia and Boyer (2007)
Water Budget – Single Box

Net Freshwater Supply, $Q_R$

Evaporation
Rainfall
Runoff
Ocean exchange

Diversion inflow

Average discharge, $Q$

$h$

$S, A$

$S_O$

$X$

Ocean exchange

$O$
Precipitation

Precip & evap: highly area-dependent

Evaporation

Biscayne Bay Load Boxes

Pollution From Biscayne Bay and Monatser Bay not shown.
Step 1: Calibrate Salinity, Estimate Exchange Flux
Nutrient Loads

• Focusing on loads to nearshore basins and NOx
• North Central Inshore (NCI) – predominately urban and built-out
• South Central Inshore (SCI) – mostly active agriculture (high fertilization) with encroaching urban
Compare Loads to Caccia and Boyer (2007)

Note: Boxes differ in size between studies but are similar
Nutrient Loading Simulations

- Tot. Phosphorous
  - Base Case
  - No Load
  - 2X Load

- NOx*
  - Base Case
  - Atmospheric Load minus 45%
  - Post Development Loads

- DIN
  - Base Case
  - Calibrated Denitrification Rate
  - Post Development Loads

* Only NOx discussed today at INTECOL
NOx

Existing Conditions

Development Build-out

Scale of plot below
Existing Condition Simulation - NOx

S26, S25, S25B
G93, S22, S123
S21, S21A, S20G, S20F
S197

0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70

1993 1995 1997 1999 2001 2003 2005 2007
NOx2

0.00
0.10
0.20
0.30
0.40

1993 1995 1997 1999 2001 2003 2005 2007
NOx3
Existing Condition Simulation - NOx

- S26, S25, S25B
- G93, S22, S123
- S21, S21A, S20G, S20F
- S197, S20

Graph with nodes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, connected by arrows indicating flow or interaction.

Graph includes compounds labeled X0, X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12, X13, X14, X15, X16, X17, X18.

Graph also includes rectangles labeled NOx4, NOx5, NOx6, with time series data for 1993 to 2007.
Existing Condition Simulation - NOx
NOx Nitrogen - South Central Inshore Box

1. Base Case
2. Atmospheric Load minus 45%
3. Post Development Loads

<table>
<thead>
<tr>
<th>NOx (mg/l)</th>
<th>DATA NOx2</th>
<th>NOx3</th>
<th>NOx4</th>
<th>NOx5</th>
<th>NOx6</th>
</tr>
</thead>
<tbody>
<tr>
<td>avg</td>
<td>0.0198</td>
<td>0.0165</td>
<td>0.0985</td>
<td>0.0563</td>
<td>0.0105</td>
</tr>
<tr>
<td>std</td>
<td>0.0274</td>
<td>0.0153</td>
<td>0.1237</td>
<td>0.0595</td>
<td>0.0118</td>
</tr>
</tbody>
</table>

Base Case

| avg       | 0.1549    | 0.1082 | 0.4230 | 0.1662 | 0.1001 |
| std       | 0.0796    | 0.0464 | 0.3361 | 0.1240 | 0.0439 |

Rain -45%

| avg       | 0.1876    | 0.0958 | 0.4409 | 0.2048 | 0.1202 |
| std       | 0.0942    | 0.0406 | 0.3247 | 0.1323 | 0.0507 |

Post Dev.

| avg       | 0.0629    | 0.0514 | 0.0825 | 0.0617 | 0.0472 |
| std       | 0.0304    | 0.0239 | 0.0519 | 0.0321 | 0.0212 |
The case of the missing NOx...
Hypotheses

• The model is wrong
• Base case NOx estimated loads too high
• Measured NOx box-averaged concentrations too low
• Assumed rate of denitrification/transformation of N is too low
• Biological uptake of N (macroalgae, epiphytes)
• Circulation patterns wash nutrients out of Bay
Biscayne Bay Simulation Model
Biscayne Bay
Symptoms of Eutrophication

- Low dissolved oxygen
- Decreased clarity
- Increased chlorophyll a concentrations
- Phytoplankton blooms (nuisance or toxic)
- Problematic epiphyte growth
- Problematic macroalgae growth
- Submerged aquatic vegetation (SAV) community change or loss
- Emergent or shoreline vegetation community changes or loss
- Coral or hardbottom community changes or loss
- Fish kills

From FL Dept of Environmental Protection, nutrient criteria development studies
Summary

• Time-varying nutrient loads to Biscayne Bay have been developed

• Some uncertainty in some water budget loads, ex. GW

• Nothing new in loads – elevated NOx loads in South Central due to ag, elevated NHx in North Central due to urban; DIN dominated by high Nox
Summary

• Mass balance calculations have been implemented for Biscayne Bay hydrology/salinity box model
• Nutrient box model was able to simulate response of the Bay to various scenarios of nutrient loads
Summary

• High NOx from South Central canals not showing up in water quality data – several hypotheses for reason

• Box model shows promise for continued study of Biscayne Bay nutrients
Thanks!