Modeling seasonal nutrient transformations and losses in the Delta:

Project findings on the effects of using time-and-space-varying DICU concentrations in DSM2 V8.1.2

Marianne Guerin
Associate, Resource Management Associates
February, 2013
Funding and Acknowledgements:

• Project funded through IEP/DWR

• Acknowledgments to co-PI’s and collaborators:
  • David Senn (lead-PI) and Emily Novick from SFEI
  • Carol Kendell (PI) and Megan Young from USGS

• Thanks to Nicki Sandhu, DWR-DMS, for increasing the # of allowable QUAL input variables (> 250 DICU locations, 10 constituents in QUAL-nutrient)
IEP Project Background

• Project goal is to quantitatively explore the role the Delta plays in transforming, assimilating, and removing nutrients (ammonium, nitrate, phosphate):
  • To inform important/potentially costly management decisions aimed at reducing nutrient loads to the Delta and Suisun Bay

• By synthesizing:
  • Long-term nutrient-related monitoring data from DWR-EMP sites within the Delta (1975-2011 or 2012)
  • Existing stable isotope data from 2005-2012
  • Results from DSM2 hydrodynamic and water quality models

• Specific outcomes:
  • Quantify nutrient loads to the Delta and loads from the Delta to Suisun Bay
  • Identify long-term and seasonal trends in nutrient forms (e.g., NH4 vs. NO3), concentrations, and ratios, and explore the factors contributing to spatial, seasonal and temporal variability
  • Identify additional monitoring and special studies needed to address critical data gaps.
  • Refine QUAL nutrient model calibration using stable isotope and nutrient measurement data to constrain QUAL parameters
Work to date:

• Senn and Novick have calculated mass balances of selected nutrient entering and leaving Delta

• DSM2:
  • Ported nutrient model (1990 – 2008) to Version 8.1.2
  • Split DSM2 into pre- and post-Liberty grids *
  • Implemented spatially and temporally-varying DICU nutrient concentration *
  • Delivered preliminary results to SFEI to use in load calculations
DICU Regions

DICU has 3 components:
Drain, Seep and Diversion

Drainage is the component from the Delta islands back into Delta waters

Analysis of drain nutrient concentrations compiled in DWR report to give monthly-varying concentrations in 3 regions:

*Representative Delta Island Return Flow Quality for Use in DSM2 Memorandum Report, May 1995. Modeling Support Branch, Division of Planning, DWR.*

We’ll look at examples from Mildred, Franks Tract, RSAC101 and RMID023.

Summarize at D-16 and P8, EMP locations
Black dashed lines are the previous constant concentration values; new values - Blue is North, Red is South East and Green is West
Findings Using Time-varying DICU vs. Constant

• Seasonal changes by region were as expected – higher where the time-varying DICU constituent was higher, and lower where it was lower

• Changes in the Southeast region were greatest as percent differences on monthly average model output

• Example % Diff (Constant – Monthly) at D16-EMP:
  • Modeled algae spikes up to 30% difference, frequently 10 %
  • NH3 +/- 10% difference

• Example % Diff (Constant – Monthly) at P8-EMP:
  • Modeled algae spikes at 20% difference seasonally
  • Modeled Organic-N spikes at -10 to -20% difference seasonally
The Effect of Liberty Island on Nutrient Cycling

• Levee failed in 1995, then was repaired
• Levee failed again in 1997, and was NOT repaired
• Two DSM2-HYDO scenarios:
  • Grid without Liberty Island, 1990 – 1998 (assumed time for 100% flooding, changes to bathymetry)
  • Grid with flooded Liberty, 1999 – 2008
• Stage and flow compared for years when both models were run (1995-1999) show that neither model does significantly better at matching flow at Rio Vista
• With better information, can easily change timing on scenarios
Liberty Scenario Comparisons w/new DICU – Nutrient Concentrations Downstream of Liberty

• Comparisons 1996 – 1999, all Wet water year types

• Both scenarios have the time-varying DICU concentrations

• Liberty Island has a significant effect on seasonal nutrient concentrations

• Next few slides give local effects of increased residence time of waters downstream of Liberty Island at Rio Vista
Liberty Increases Algae

Liberty Decreases NO3

Liberty Increases Organic-N

Liberty Decreases NH3
Atmosphere - Exchange Heat and O\(_2\), Pressure Influences DO Saturation in Water

Water – Depth Influences Sediment

NH\(_3\), NO\(_2\), NO\(_3\), Dissolved Oxygen, Algal Settling

Organic-N

NH\(_3\), NO\(_2\), NO\(_3\)

Chlorophyll-a (Algae)

Organic-P

Dissolved-P

Sediment – Supplies Dissolved-P, NH\(_3\) to Water

Receives Algae, CBOD, Organic-N; Uses O\(_2\)

Bacterial Decay

Respiration

Oxidation

Growth+Photosyn

Benthic Source, Demand

Settling

Mortality

Simplified story – Algae consume NO\(_3\) and NH\(_3\) and Algae die to produce Organic-N
Next steps in the IEP Project for DSM2

• Use stable isotope and nutrient concentration data to constrain some boundary conditions and parameters in QUAL-nutrient
  • Extend the nutrient model past 2008 (2011/2-12)

• Isotopes act as a tracer
  • Isotopic ratios can identify the source of a constituent as agricultural vs. waste water
  • Isotopic information used in transects can identify the fate of constituents through time

• Rate parameters – nutrient concentration data can help identify the correct process leading to changes in nutrient concentrations

• Use the refined calibration to investigate trends in nutrient concentrations
  • Spatially and seasonally
  • As influenced by hydrodynamic conditions
Carol Kendall (USGS) plot illustrates the cycling of nutrients at Rio Vista and near the confluence of the Sacramento and San Joaquin Rivers – increased residence time in open water areas, additional sources
<table>
<thead>
<tr>
<th>Tracer type</th>
<th>Interpretive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate organic matter (POM)</td>
<td>δ¹⁵N, δ¹³C, δ³⁴S, C:N, C:S information about the source of the C, N, and S -- and the biogeochemical reactions that cycle the elements -- even after incorporation into algal biomass; quantify algal vs terrestrial contributions to biomass; use for calculation of phytoplankton isotopic composition; evaluate role of algal-based foodwebs, contributions of marine-derived sources of POM and nutrients.</td>
</tr>
<tr>
<td>Nitrate δ¹⁸O and δ¹⁵N</td>
<td>quantify nitrate from different sources (fertilizer, wastewater, wetlands, etc); role in the production of algae, and degree of recycling; evidence for denitrification or assimilation.</td>
</tr>
<tr>
<td>Ammonium δ¹⁵N</td>
<td>quantify ammonium from different sources (fertilizer, wastewater, wetlands, etc); role in the production of algae, and degree of recycling; evidence for nitrification or assimilation.</td>
</tr>
<tr>
<td>Water δ¹⁸O and δ²H</td>
<td>ideal conservative tracer of water sources and mixing; useful for quantifying flow contributions from different tributaries and groundwater.</td>
</tr>
<tr>
<td>Dissolved organic carbon (DOC) δ¹³C</td>
<td>information on sources of DOC; evidence for degradation of organic matter; quantify algal vs terrestrial contributions to DOC.</td>
</tr>
<tr>
<td>Dissolved organic matter (DOM) δ¹⁵N, δ¹³C, δ³⁴S, C:N, C:S</td>
<td>information about the source of the C, N, and S -- and the biogeochemical reactions that cycle the elements -- even after incorporation into bacteria biomass; quantify algal vs terrestrial contributions to DOM; use for calculation of bacteria isotopic composition; evaluate role of microbial foodweb, contributions of marine-derived sources of POM and nutrients.</td>
</tr>
<tr>
<td>Dissolved inorganic carbon (DIC) δ¹³C</td>
<td>information on sources of DIC; evidence for in situ algal productivity; evidence for degradation of organic matter, degree of gas exchange with atmosphere, nitrification.</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO) gas δ¹⁸O</td>
<td>information about the ratio of productivity to respiration in the water column, source of the O₂, degree of gas exchange with atmosphere, biological oxygen demand (BOD) mechanism.</td>
</tr>
<tr>
<td>Sulfate δ³⁴S and δ¹⁸O</td>
<td>quantify sulfate from different sources (soil, wastewater, wetlands, etc), source of algae, and extent recycling.</td>
</tr>
<tr>
<td>Phosphate δ¹⁸O</td>
<td>quantify phosphate from different sources; information about the extent of algal production, recycling of material within the river reach, and P limitation.</td>
</tr>
</tbody>
</table>
Thanks for your attention!