Briefing for advisory group:
Sediment-Water Interactions for Salish Sea Dissolved Oxygen Modeling (QAPP)

Mindy Roberts and Greg Pelletier
(Dept. of Ecology)
Tarang Khangaonkar and Wen Long (PNNL)
Overview

- General background and purpose – Mindy
- Overview of existing Salish Sea model – Tarang
- Proposed sediment diagenesis model setup and testing – Greg
- Proposed sediment diagenesis model calibration – Wen
- Schedule – Mindy
- Questions – All
Recent reports evaluate oxygen impacts from human activities

October 15, 2013 briefing on both
We measure low dissolved oxygen. Are human activities contributing?

• Human activities add nitrogen through wastewater, manure, fertilizer, etc.
• Nitrogen fuels algae blooms in Puget Sound
• As algae decomposes, it draws down oxygen
• Fish, and other aquatic life, need oxygen to breathe

➢ Same questions as in Chesapeake Bay, Long Island Sound, Gulf of Mexico
Water Quality Standards for dissolved oxygen in Puget Sound

- Oxygen > 7 mg/L (varies by location)

- If naturally < 7 mg/L, total human impact cannot cause oxygen to decline more than 0.2 mg/L

Minimum DO by location

DO is naturally lower than the numeric criteria
What are the key questions?

• How much low oxygen is natural or due to the ocean and how much is human?
  – Need sophisticated computer models to distinguish

• How much reduction is needed to meet water quality standards?
  • Cannot be determined yet with the existing models
    – Salish Sea or South/Central Puget Sound
South (and Central) Puget Sound findings: Current human sources cause oxygen to decline as much as 0.4 mg/L

- Wastewater discharges to marine waters have bigger influence than river sources
- South Sound depletions influenced by a combination of:
  - South Sound sources
  - Central Sound sources
  - Other external human sources (North Sound and beyond?)

(does not include the effect of the Capitol Lake dam on Budd Inlet)
Future population growth will increase oxygen impacts; ocean trends would make it worse.

**Current human sources, circulation, ocean conditions, air temperature**

**Average depletion** (mg/L of oxygen decline compared with current conditions)

- 0.00 – 0.10
- 0.11 – 0.20
- 0.21 – 0.50
- 0.51 – 0.80
- 0.81 – 1.10
Relative impacts on dissolved oxygen

Pacific Ocean trends

- Increased air temperature
- Changes in circulation due to changes in freshwater inflows
- Increased wastewater from future population
- Higher river nitrogen concentrations from land cover change
- Sediment-water exchanges

... more study needed.
Local sources of nitrogen (US and Canada)

- Pacific Ocean is the largest source of nitrogen
- Sediment-water exchanges highly influential

Do these sources contribute to dissolved oxygen depletion in South and Central Puget Sound?
If so, how much?

Mohamedali et al. (2011)
What is sediment diagenesis?

Previous approach: externally calculate changes in bottom fluxes.

Proposed approach: calculate internally using diagenesis.
Purpose of adding sediment diagenesis to Salish Sea model

- Develop water column and sediment boundary conditions for the South and Central Puget Sound model
- Calculate relative influences of local human nutrient sources and the Pacific Ocean on low concentrations of dissolved oxygen
- *Plan to evaluate similar questions related to acidification ... stay tuned!*
Salish Sea Model (SSM)
for the simulation of
Hydrodynamics and Biogeochemical Processes

Tarang Khangaonkar
- slides for inclusion in the

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6/23/2014
NEP Project (EPA / Ecology - 2008)

- Evaluate the effects of current and potential future nutrient loads on dissolved oxygen (DO) levels in Puget Sound
  - Development of a 3-D Hydrodynamic Model of Puget Sound
  - Development of an associated Water Quality and DO Model
- Models
  - Hydrodynamics
    - FVCOM (Chen et al 2003)
  - Water Quality
    - CE-QUAL-ICM (Cerco et al. 1995)
Open boundaries – Tides, Salinity and Temperature

Year 2006

Tidal Elevations – Xtide

_Harmonic tide predictor_ (Flater 1996)
Calibration: Velocity

Dana Passage (example)

Surface Velocity

Middle Velocity

Bottom Velocity
Year 2006 Mean Annual Flow

<table>
<thead>
<tr>
<th>Subbasin and reach</th>
<th>Mean annual tidal inflow (m³/s)</th>
<th>Station name</th>
<th>Residence time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strait of Juan de Fuca</td>
<td>129,300</td>
<td>Pillar Point</td>
<td>61</td>
</tr>
<tr>
<td>Admiralty Inlet to Puget Sound</td>
<td>17,117</td>
<td>Admiralty Inlet</td>
<td>160</td>
</tr>
<tr>
<td>Main Basin – Puget Sound</td>
<td>12,051</td>
<td>Jefferson Point</td>
<td>257</td>
</tr>
<tr>
<td>Whidbey Basin (inflow through Possession Sound)</td>
<td>6,111</td>
<td>Saratoga Passage</td>
<td>228</td>
</tr>
<tr>
<td>Hood Canal (inflow over the sill)</td>
<td>5,066</td>
<td>Eldon Point</td>
<td>282</td>
</tr>
<tr>
<td>South Puget Sound (inflow over Tacoma Narrows sill)</td>
<td>814</td>
<td>Devils Head</td>
<td>292</td>
</tr>
</tbody>
</table>
Surface Salinity (April 2006 conditions)
Biogeochemical model of Salish Sea
CE-QUAL-ICM

- Eutrophication model (Cerco and Cole, 1994)
- 32 water quality state variables
- Aquatic vegetation
- Predictive sub-model to calculated interactive fluxes between sediment and water columns
- Parallelized operation

Carbon, Algae, Nitrogen and DO cycles in CE-QUAL-ICM
Nutrient Loads to Puget Sound

Rivers, Streams, Outfalls (Industrial and WWTP)

River and Point Source Loads in SSM

River and watershed loads

WWTP Outfalls
(point source loads)
Simulated Surface Constituents (2006)
Sediment flux loads – specified values

Existing setup in Salish Sea Model

Benthic Sediment Fluxes (5-cm depth)
Nutrients and Dissolved Oxygen

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Nitrate (NO$_3$+NO$_2$)</th>
<th>Ammonium (NH$_4$)</th>
<th>Phosphate (PO$_4$)</th>
<th>Dissolved Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benthic Flux</td>
<td>-0.011</td>
<td>0.064</td>
<td>0.02</td>
<td>-0.1$^a$</td>
</tr>
<tr>
<td>(g m$^{-2}$ d$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td>-2.0$^b$</td>
</tr>
<tr>
<td>Range</td>
<td>-0.004</td>
<td>0.03</td>
<td>0.0</td>
<td>-0.24</td>
</tr>
<tr>
<td>(g m$^{-2}$ d$^{-1}$)</td>
<td>to</td>
<td>to</td>
<td>to</td>
<td>to</td>
</tr>
<tr>
<td></td>
<td>-0.016</td>
<td>0.12</td>
<td>0.05</td>
<td>-1.71</td>
</tr>
</tbody>
</table>

$^a$ Value specified in most of Salish Sea domain, $^b$ Value specified in selected shallow regions of Puget Sound known for low values of near bed DO

To be replaced by
Internally Computed Fluxes

Sediment Diagenesis Flux Model
Model Setup and Testing

Greg Pelletier (Ecology)
Basic structure of sediment flux model
Inputs to the sediment flux model

• Settling of particulate organic C and N from the water into the sediment (phytoplankton and detritus)

• Concentrations of water quality variables in the water overlying the sediment (DO, temperature, salinity, ammonium, nitrate+nitrite, DOC)
Outputs from the sediment flux model

- Sediment water fluxes of DO (SOD), ammonium, nitrate, DOC, sulfide
- Pore water concentrations of solutes (ammonium, nitrate, DOC, sulfide)
- Particulate organic C and N concentrations in the sediment
- Thickness of the aerobic layer of the sediment
Implementing the sediment flux model

• Subroutine originally written in Fortran written by Hydroqual (Fitzpatrick, Cerco, DiToro) for Chesapeake Bay model

• CE-QUAL-ICM and WASP use nearly identical subroutines.

• Standalone Excel/VBA and Fortran versions will be used as QA check. Standalone version by Dr. James Martin was extensively tested by EPA for WASP

• Conduct QA tests to compare results of Subroutine with Standalone version
QA tests of the sediment flux model

• Steady-state solution of constant deposition and constant overlying water quality
• Time-variable solution of
  – assumed initial conditions, constant deposition, and constant overlying WQ
  – assumed initial conditions, constant deposition, and time-varying overlying WQ
  – steady-state initial conditions, constant deposition, and constant overlying WQ
  – steady-state initial conditions, constant deposition, and time-varying overlying WQ
• One-year simulation of linked model at one or more locations comparing SFM with standalone
FVCOM-ICM Sediment Diagenesis Model Validation and Calibration

Wen Long (PNNL)

1. Validate with analytical solution
2. Validate with Excel VBA code
3. Calibrate with available data
4. Calibrate Puget Sound
Calibrate Puget Sound Model

• Calibration would be based on simulation of Puget Sound with 2006-2007.

• Recalibrate NH4, NO3, PO4 and DO simulation based on water column profile measurements. Phytoplankton parameters may also be re-calibrated as needed

• Tuning parameters: solids concentration, and burial velocity from data, 3G classes, settling velocity, reaction rates, diffusion rates, mass transfer rates, thickness, partitioning constants, particle mixing half-sat
Project Components and Schedule

Mindy Roberts (ECY)

- Finish QAPP: Jul-Sep 2014
- Calibrate model: Apr-Sep 2015

Revisit South and Central Puget Sound model in 2015 - 2016
Comments on QAPP
Andrew Kolosseus (ECY)

- Email to Andrew.Kolosseus@ecy.wa.gov by July 23, 2013
- For more information:
- Thank you!