

South Puget Sound Dissolved Oxygen Study

Circulation Modeling Overview

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Ahmed, Greg Pelletier

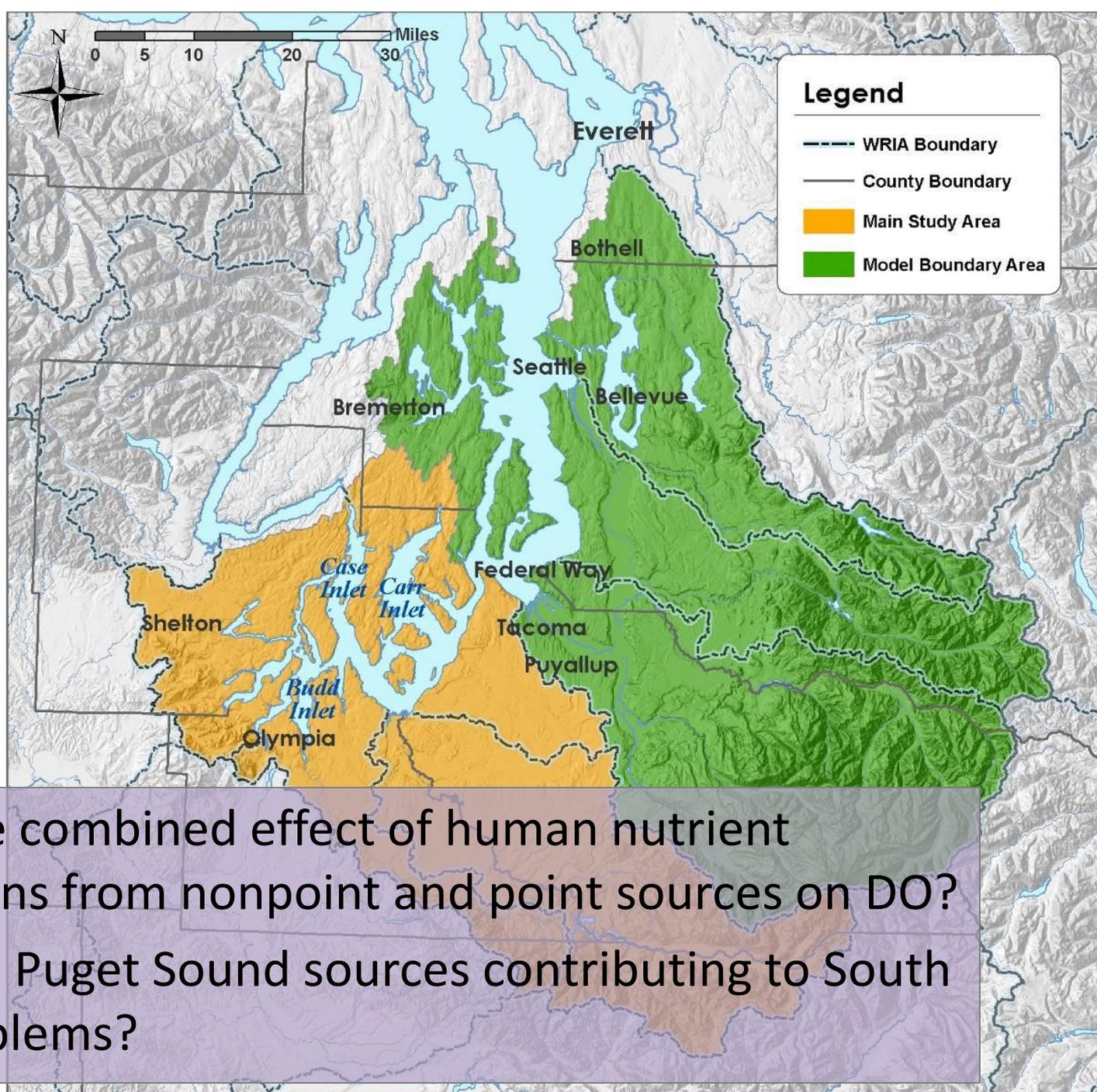
October 28, 2009

Briefing for Advisory Committee

What we cover

1. Project overview
2. Hydrodynamic model and report development
 - Since May 20, 2009 briefing
3. Upcoming steps
 - Water quality model development
 - Scenarios
 - Advisory Committee
 - Final report

Study area



Project components

- Data collection
- Circulation model
- Water quality model
- Scenarios
- Reports
 - Data (done)
 - Circulation (pending)
 - Water quality (2010)



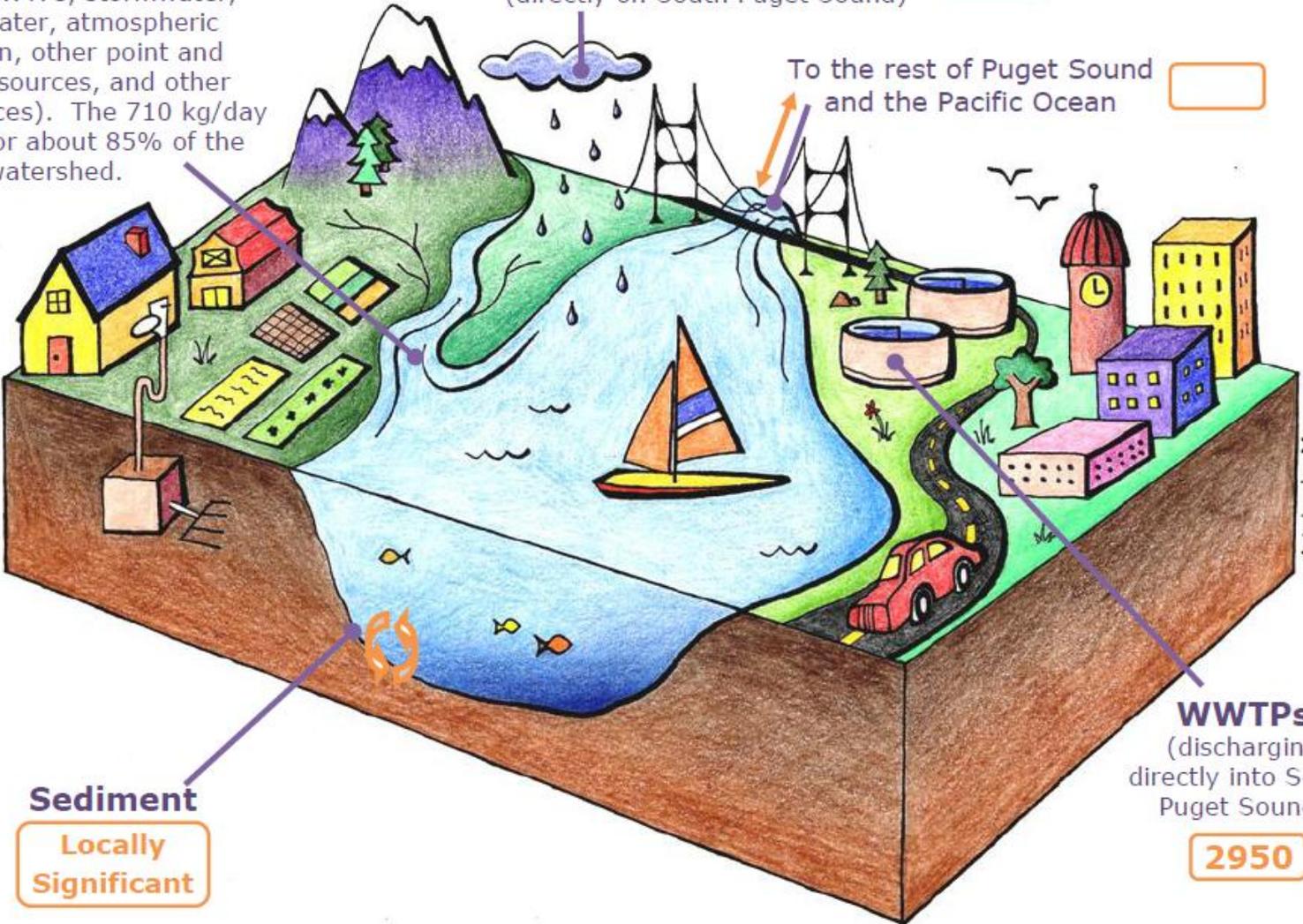
Annual

2720

Rivers (includes upstream septics, WWTPs, stormwater, groundwater, atmospheric deposition, other point and nonpoint sources, and other natural sources). The 710 kg/day accounts for about 85% of the watershed.

Atmospheric Deposition (directly on South Puget Sound) 170

To the rest of Puget Sound and the Pacific Ocean



Sediment
Locally Significant

WWTPs
(discharging directly into South Puget Sound)
2950

Art: Jessica Moyer

September

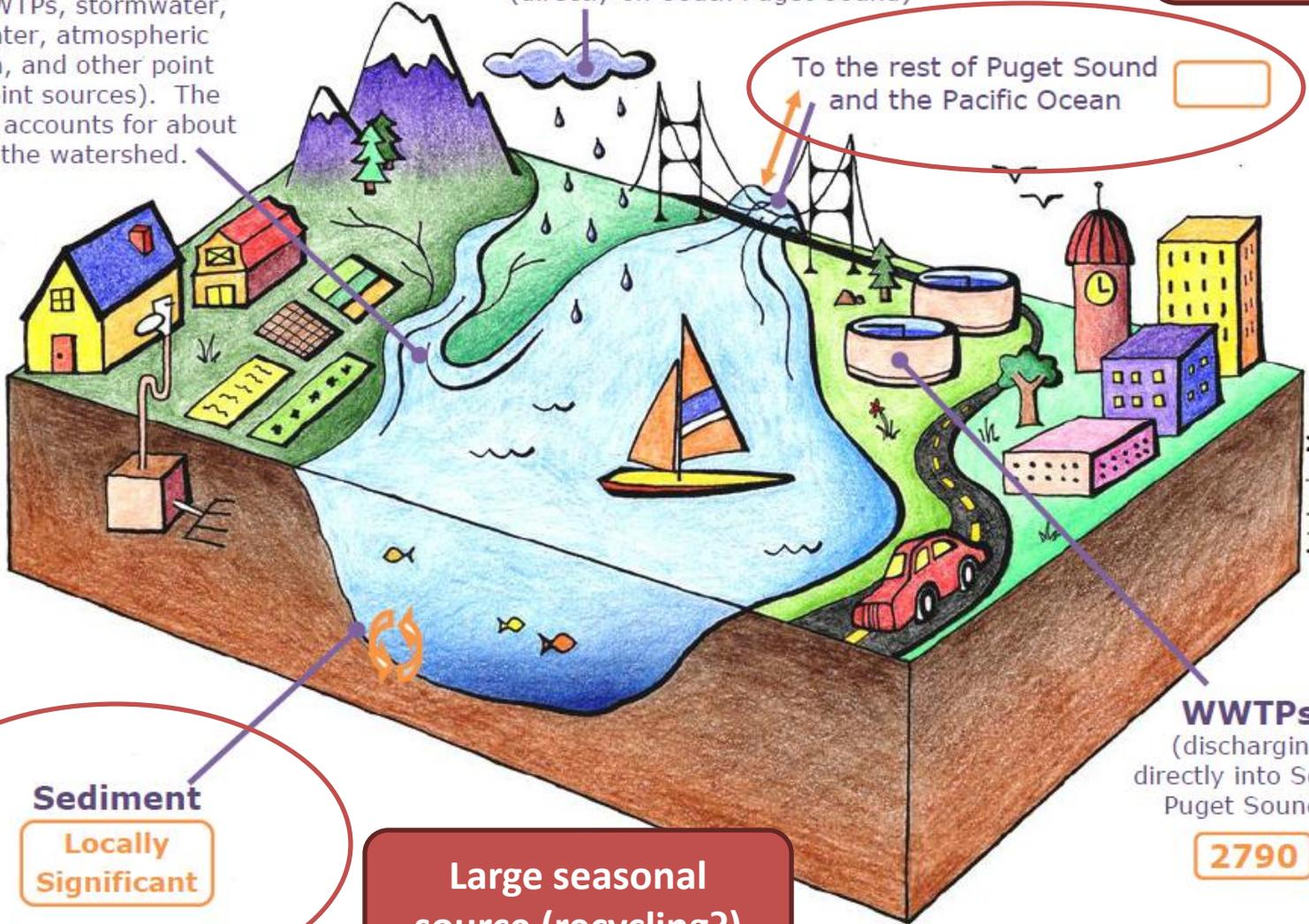
Model-derived value

710

Rivers (including upstream septics, WWTPs, stormwater, groundwater, atmospheric deposition, and other point and nonpoint sources). The 710 kg/day accounts for about 85% of the watershed.

Atmospheric Deposition (directly on South Puget Sound) **170***

To the rest of Puget Sound and the Pacific Ocean



Art: Jessica Moyer

Sediment
Locally Significant

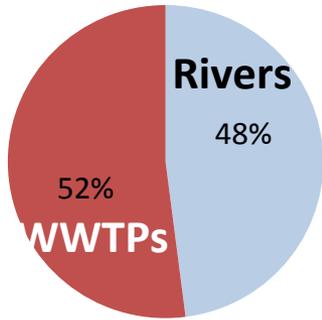
Large seasonal source (recycling?)

WWTPs
(discharging directly into South Puget Sound)
2790

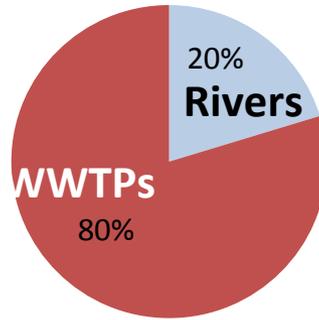
*The atmospheric deposition load is an annual average

South Puget Sound (south of Tacoma Narrows)

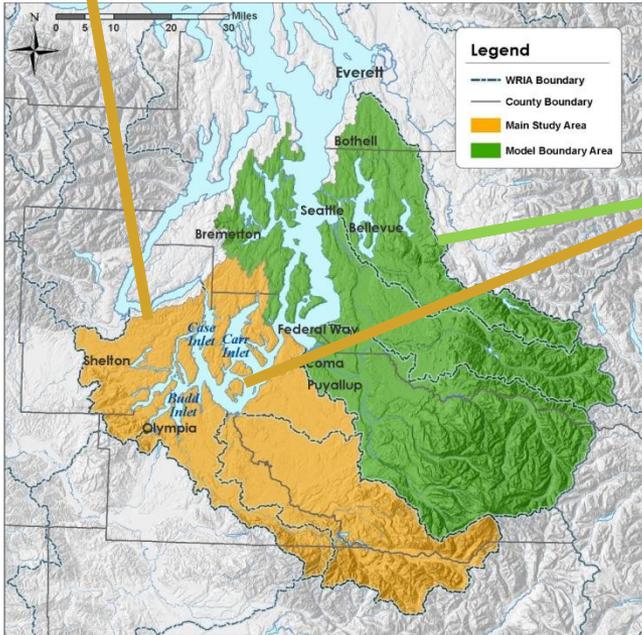
Annual



Sept 2007

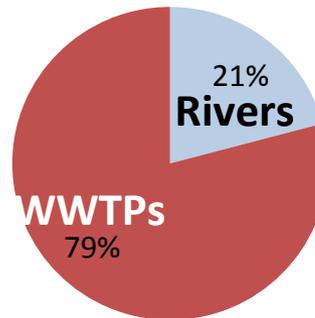


Nutrient sources

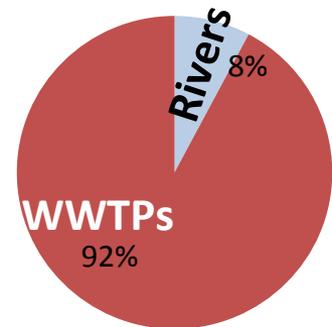


South and Central Puget Sound (south of Edmonds)

Annual

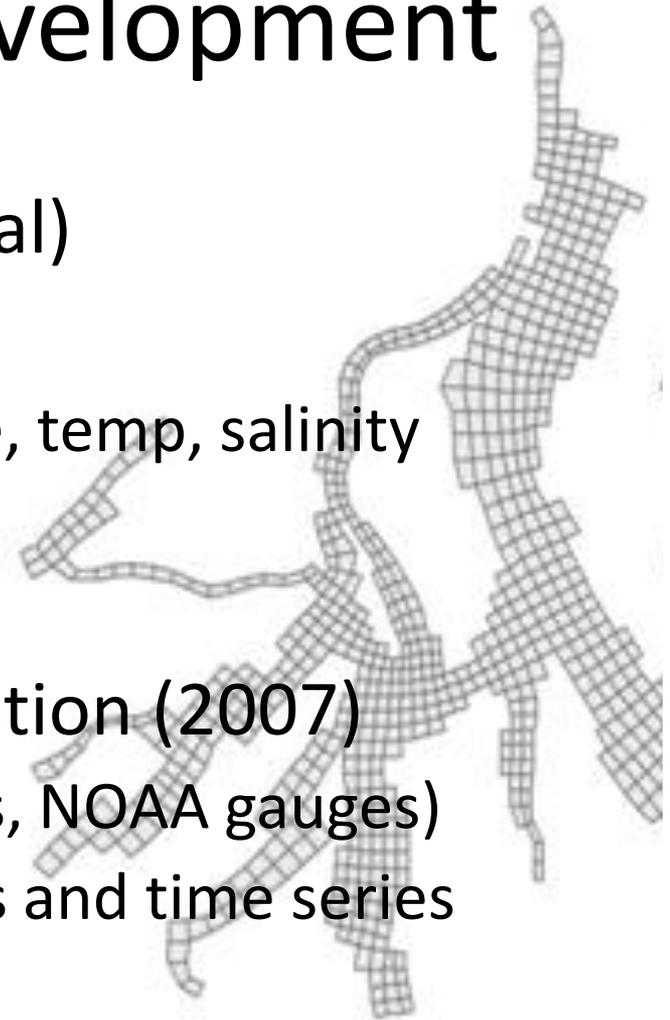


Sept 2007

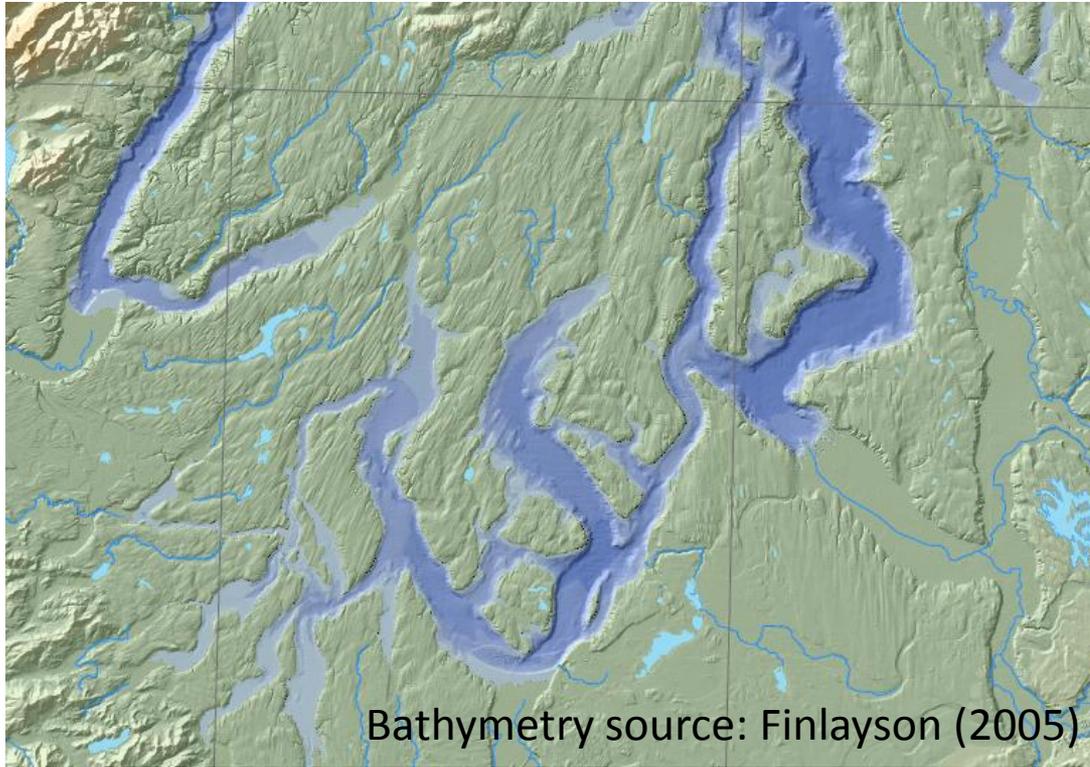


Circulation model development

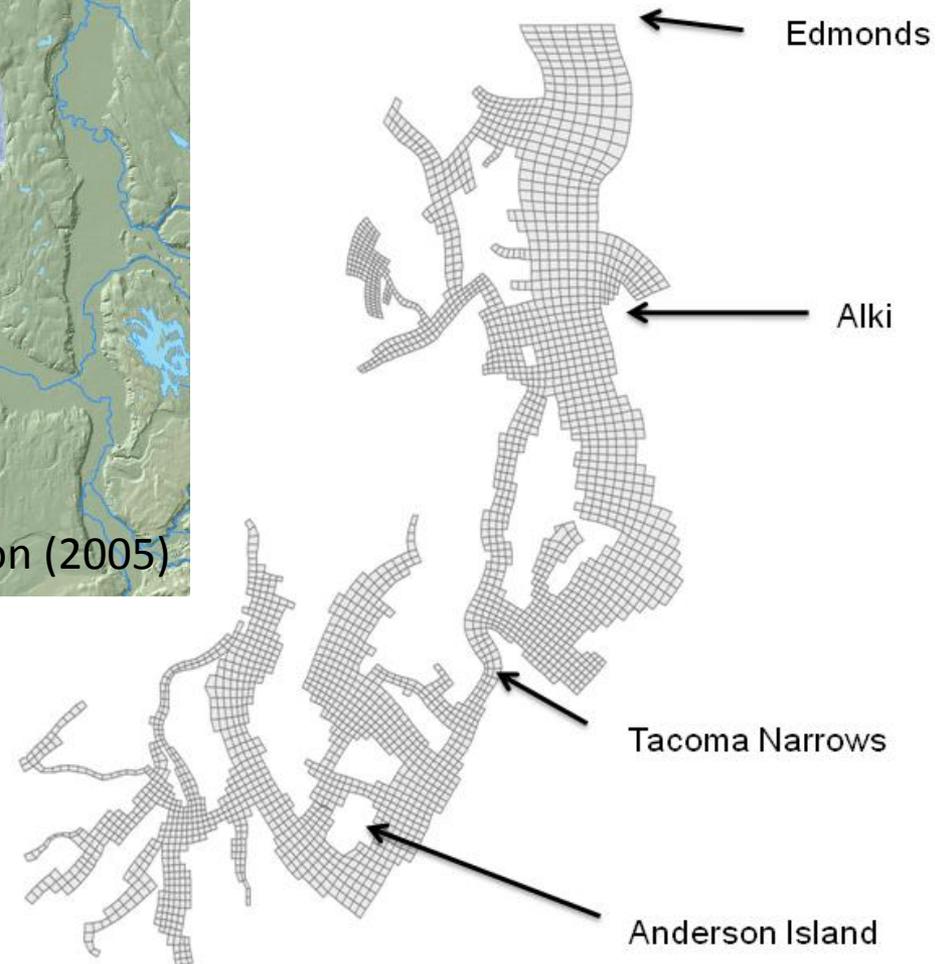
- Build grid (horizontal and vertical)
- Boundary conditions
 - Northern boundary water surface, temp, salinity
 - Meteorology
 - Rivers and WWTPs
- Calibration (2006) and confirmation (2007)
 - Water surface elevations (PSTides, NOAA gauges)
 - Temperature and salinity patterns and time series
 - Temperature and salinity profiles
 - Current velocities



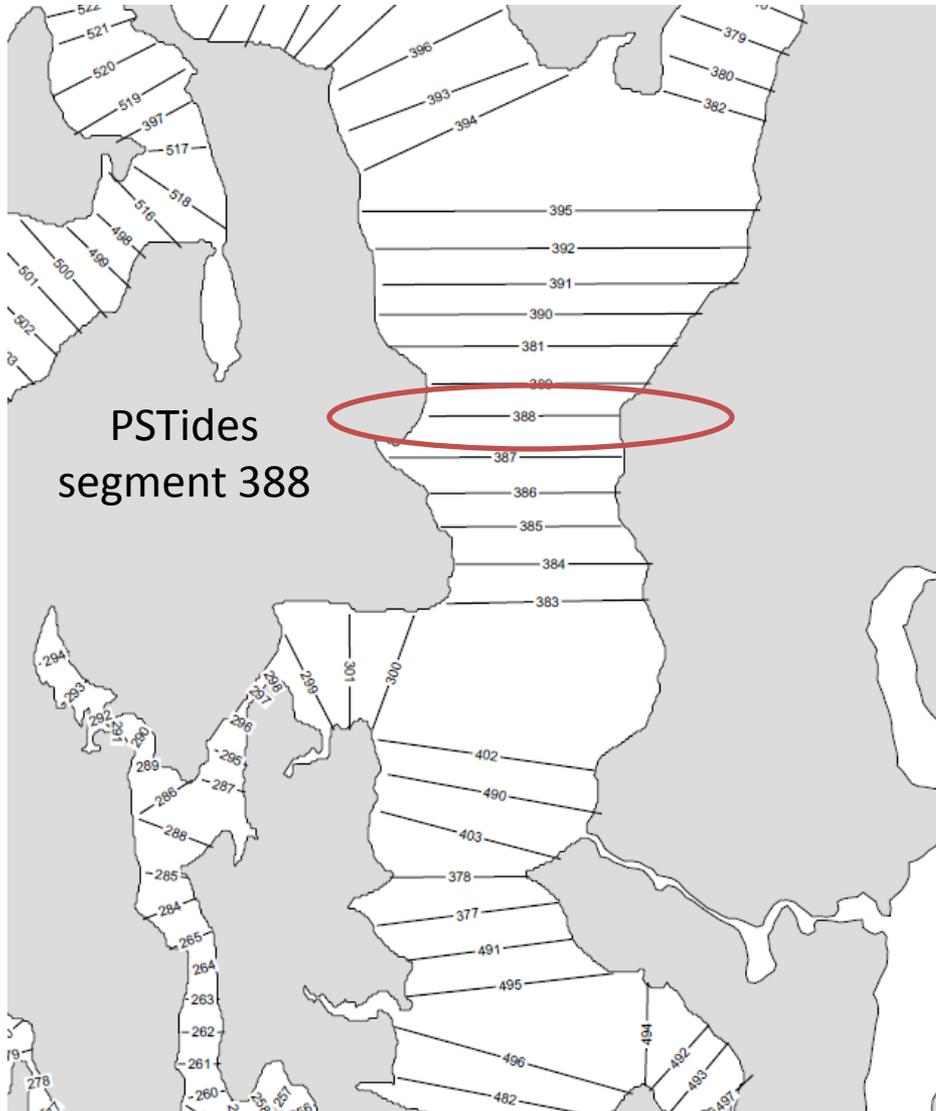
3-D Circulation Model



- 2623 grid cells
- 500 m X 500 m (nominal)
- Up to 17 layers



Northern boundary conditions

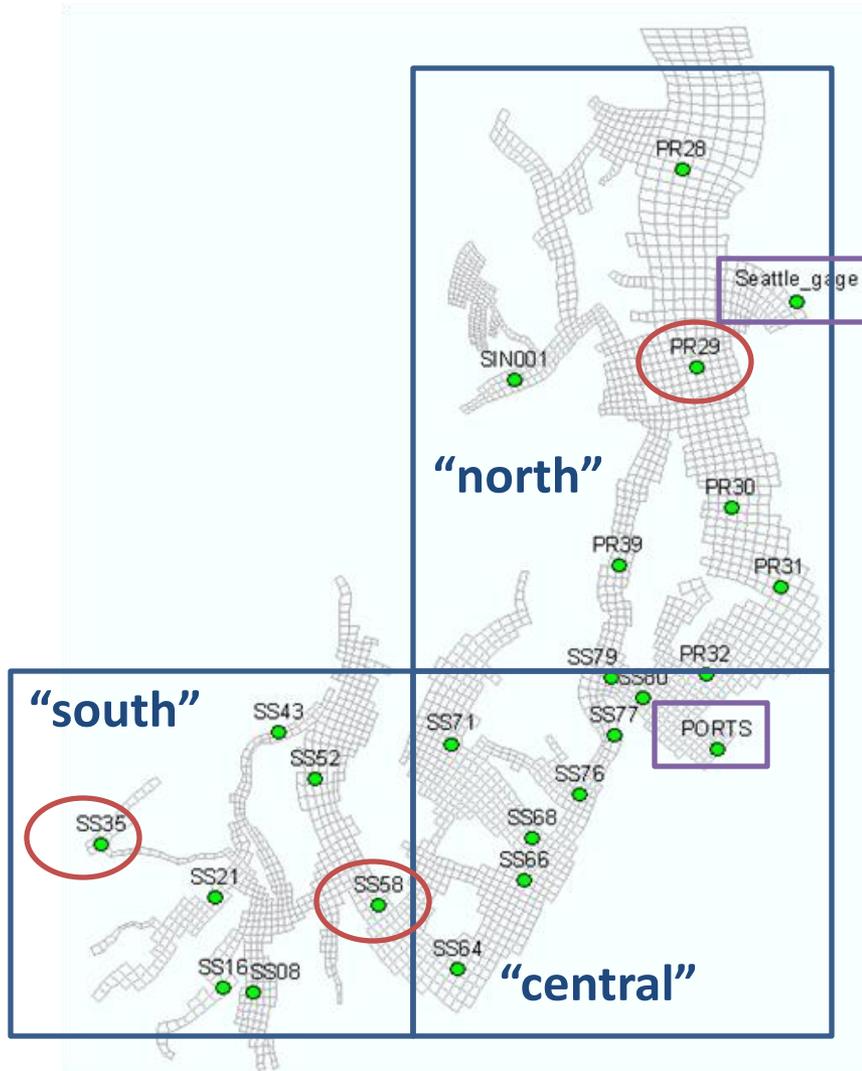


Water surface elevations:

PSTides

- Specialized tidal model
- Detailed predictions not available from other sources
- Selected segment closest to the northern (Edmonds) boundary

Water surface elevations (PSTides)



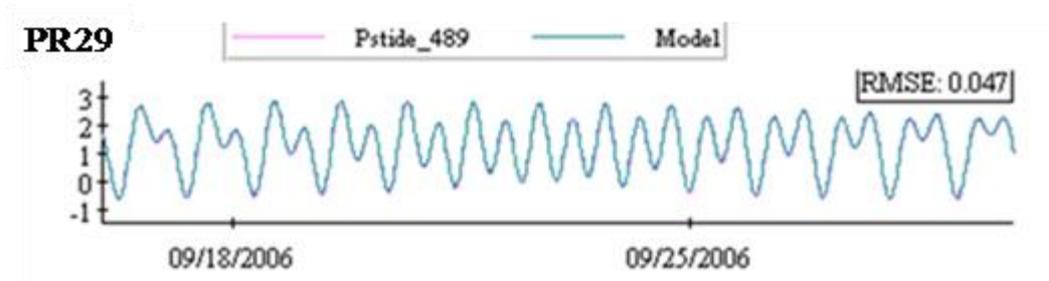
- Root mean square error (RMSE) is the square root of the mean square error:

$$RMSE = \sqrt{\sum (\text{model} - \text{data})^2}$$

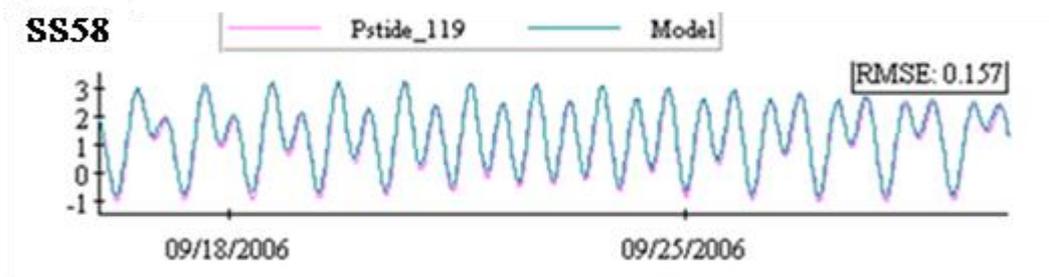
- Goal: minimize RMSEs

Water surface elevations (cont'd)

- Central Puget Sound (3 to 12 cm)

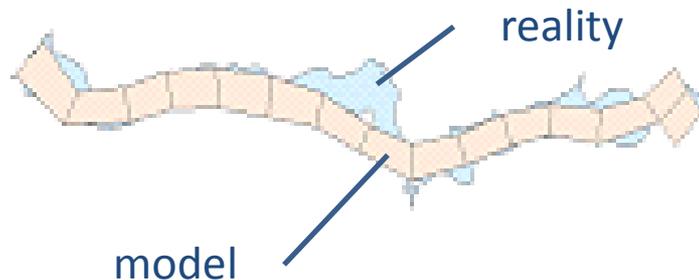
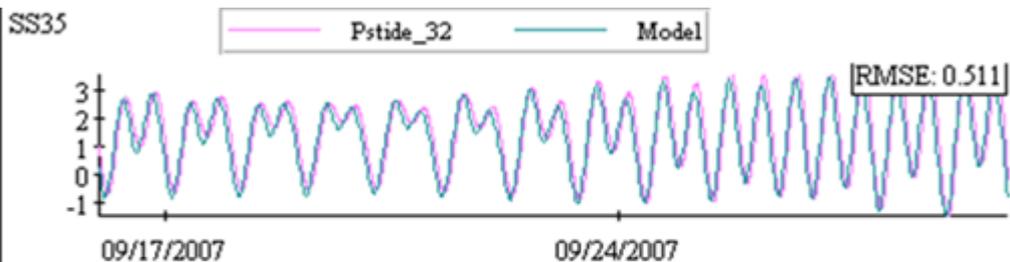
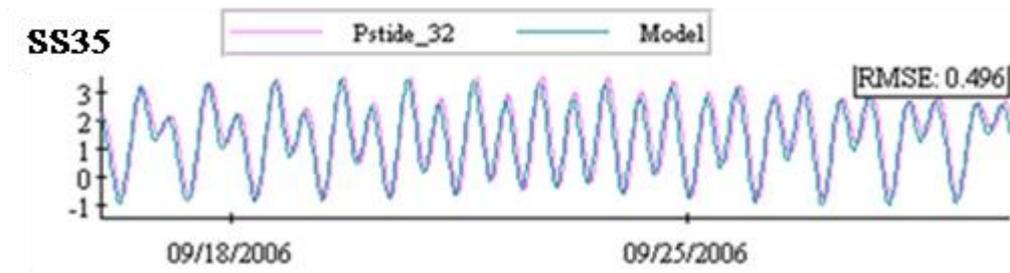


- South Puget Sound (10 to 16 cm)



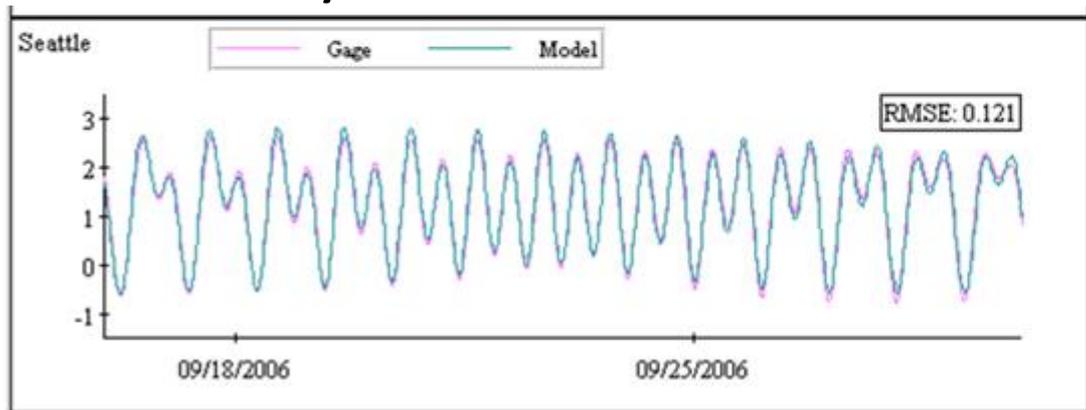
Oakland Bay

- RMSE 50 cm
 - 10% of 5-m tidal range
- Phasing off by 40 minutes
 - Two 90° elbows that grid smooths out
- Amplitude good
- Limited to immediate area of Oakland Bay

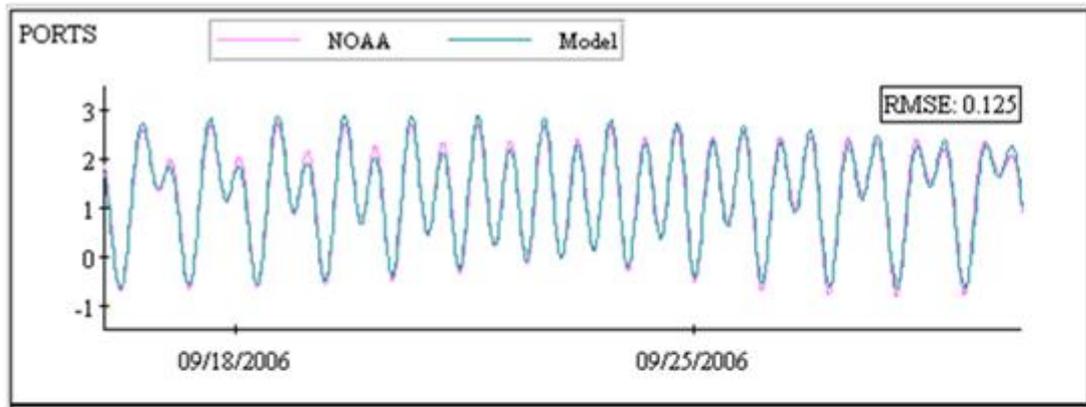


Water surface elevations (gauges)

- Elliott Bay

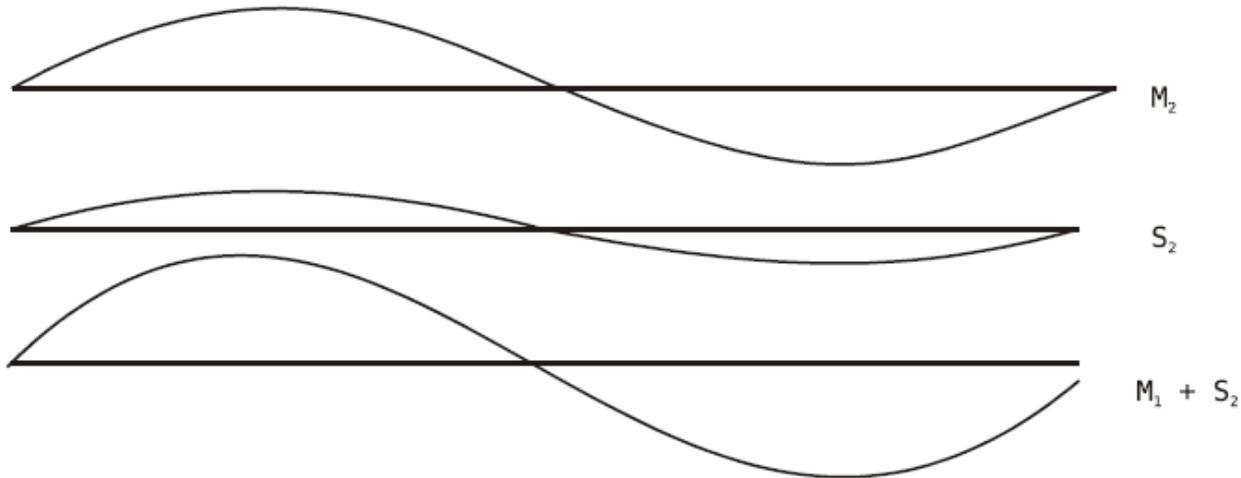


- Commencement Bay



Tidal constituents

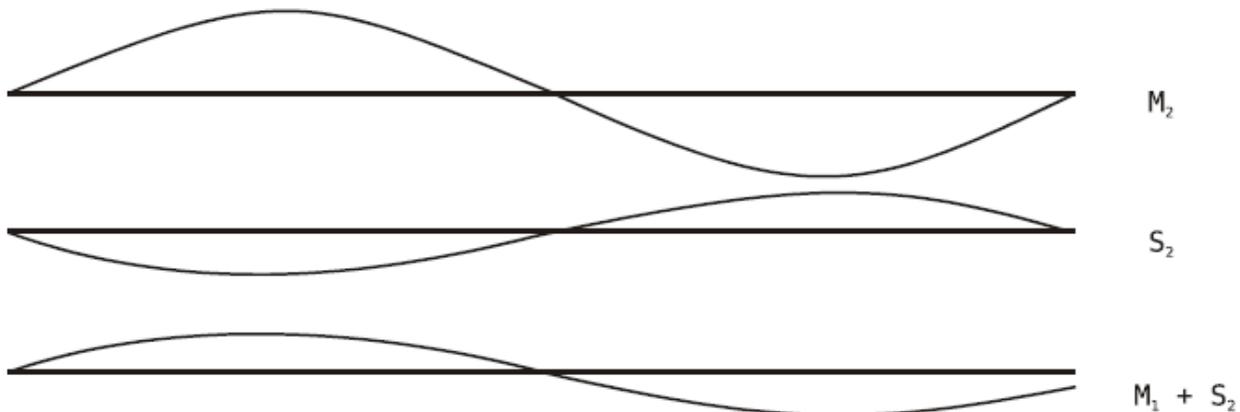
In Phase - Spring Tides



SPRING TIDES

- Lunar semidiurnal
- Solar semidiurnal
- Combined effect

Out of Phase - Neap Tides



NEAP TIDES

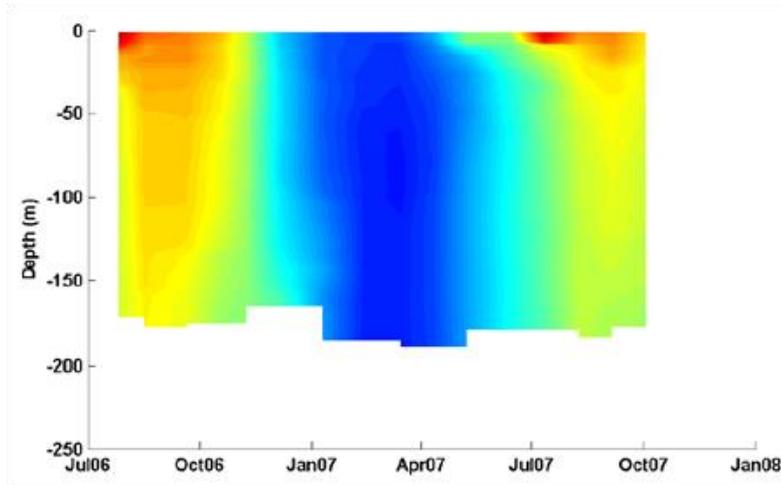
- Lunar semidiurnal
- Solar semidiurnal
- Combined effect

Tidal constituents

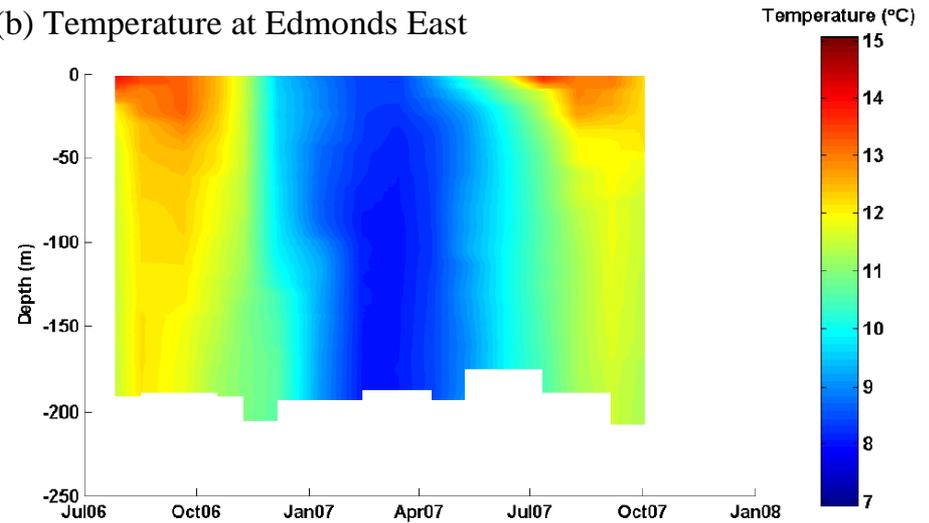
		Amplitude (cm) Phase (degrees)	Budd Inlet	Oakland Bay
M2	Principal lunar semidiurnal	0.0 to 0.2 cm 0.4 to + 0.6 °	10 cm <2 °	9 cm -23 °
S2	Principal solar semidiurnal	0.0 to 0.7 cm 0.7 to + 1.0 °	4 cm <2 °	4 cm -19 °
N2	Major lunar semidiurnal elliptical	0.2 to 0.3 cm -1.1 to -0.3 °	3 cm <2 °	2 cm -21 °
O1	Principal lunar declinational diurnal	0.1 to 0.2 cm -0.5 °	0.6 cm <2 °	0.2 cm -10 °
K1	Luni-solar declinational diurnal	1.8 to 2.2 cm -0.1 to 0.0 °	1 cm <2 °	1 cm -10 °

Northern boundary conditions

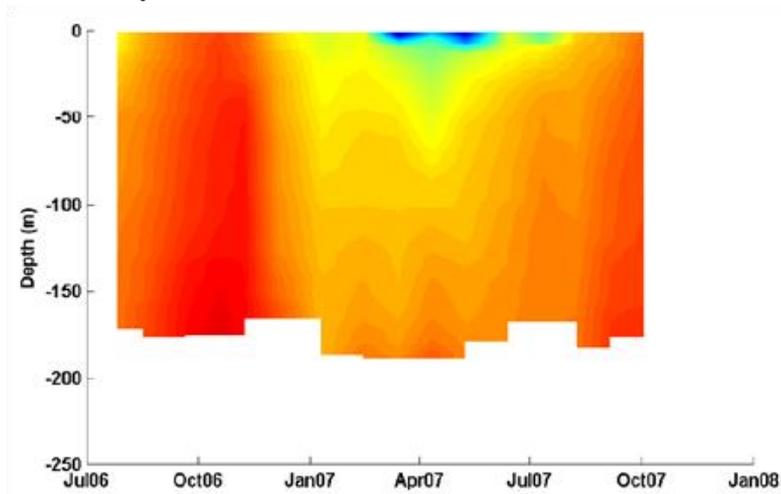
(a) Temperature at Edmonds West



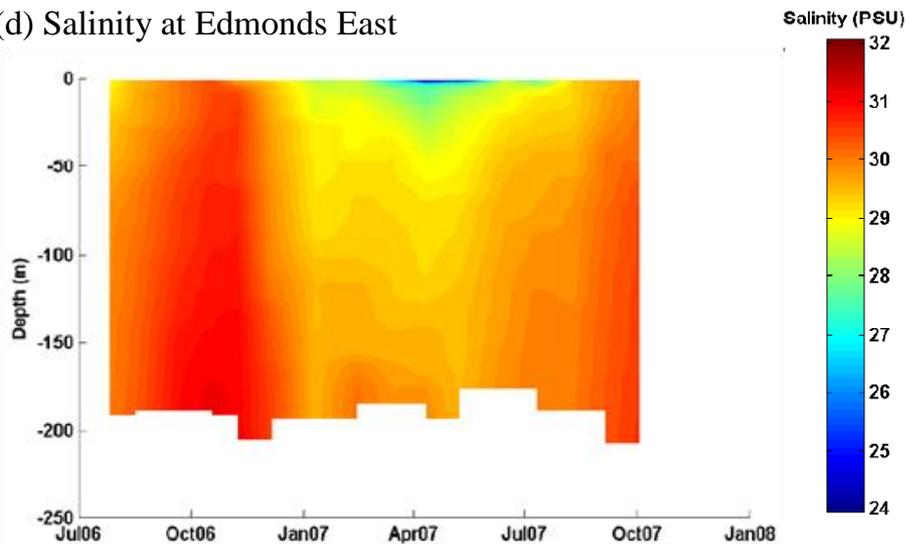
(b) Temperature at Edmonds East



(c) Salinity at Edmonds West

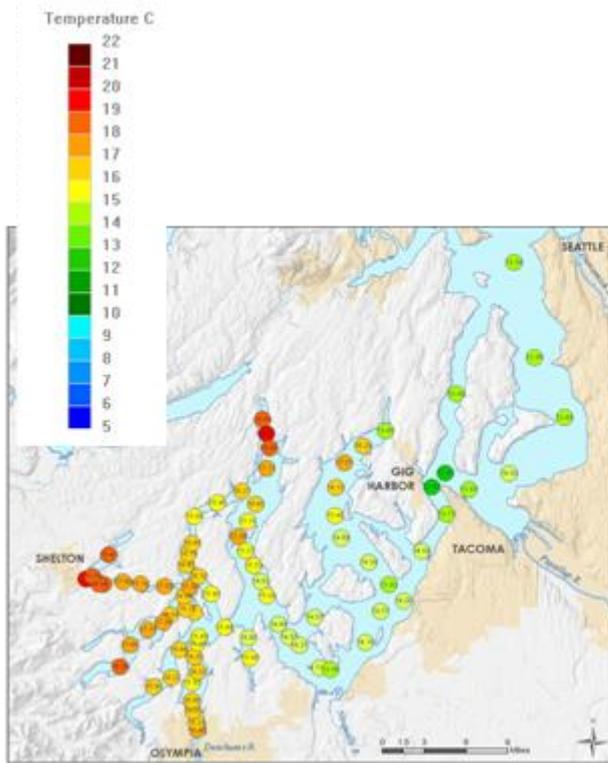


(d) Salinity at Edmonds East



Calibration and confirmation: surface temperature and salinity

- August 2006 data
- August 2006 model

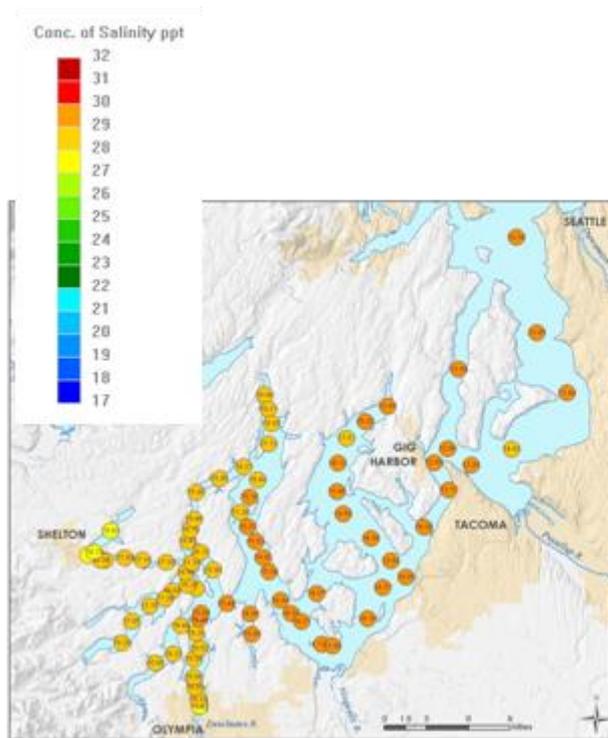


Temperature (°C)

Results are good if the colors are alike

Calibration and confirmation: surface and near-bottom temperature and salinity

- August 2006 data



- August 2006 model

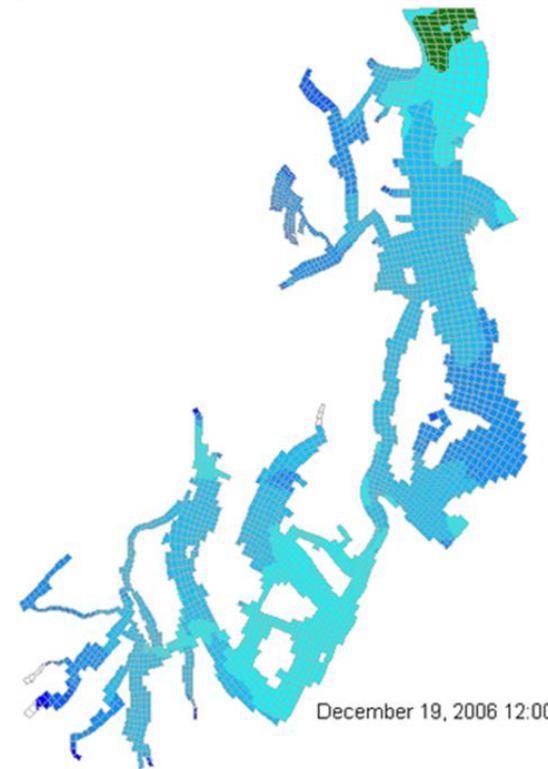
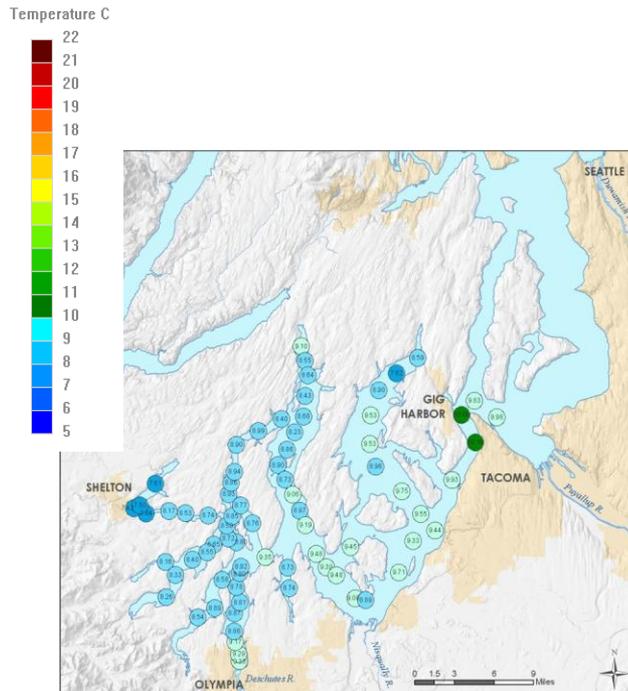


Salinity (psu)

Results are good if the colors are alike

Calibration and confirmation: surface and near-bottom temperature and salinity

- December 2006 data
- December 2006 model



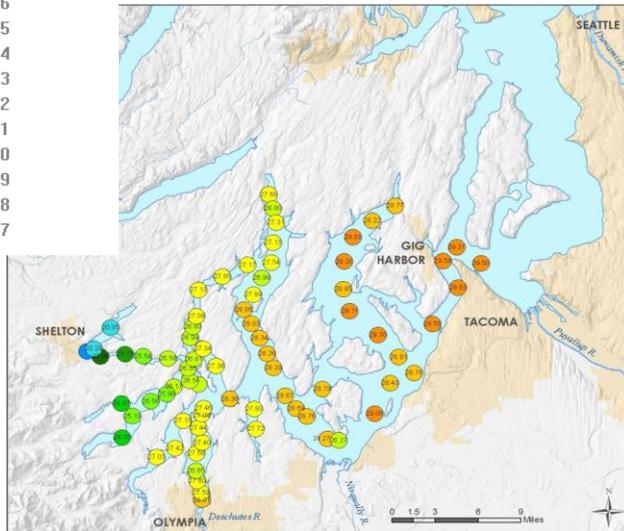
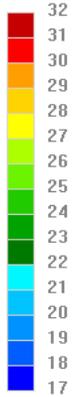
Temperature (°C)

*Results are good if
the colors are alike*

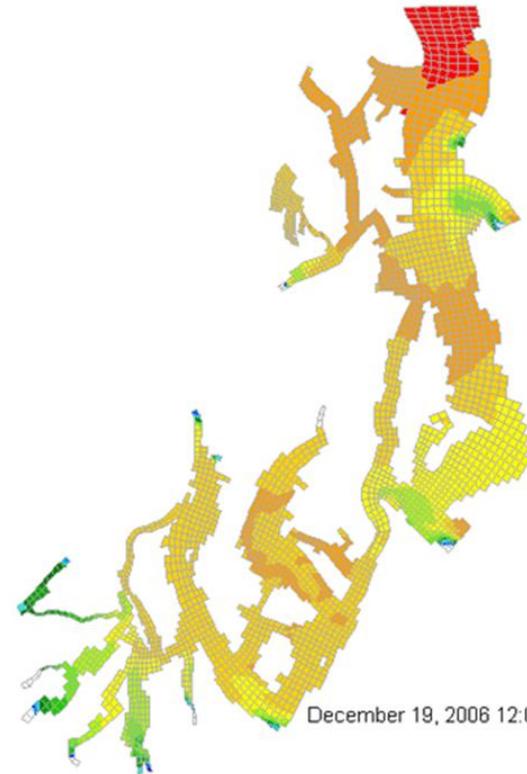
Calibration and confirmation: surface and near-bottom temperature and salinity

- December 2006 data

Conc. of Salinity ppt



- December 2006 model



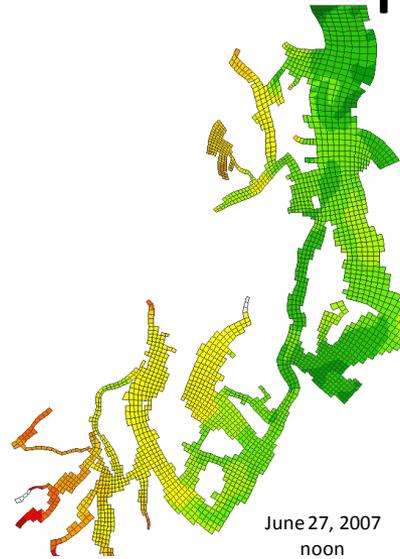
December 19, 2006 12:00

Salinity (psu)

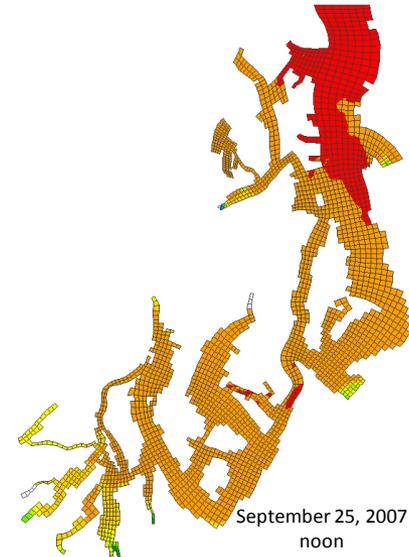
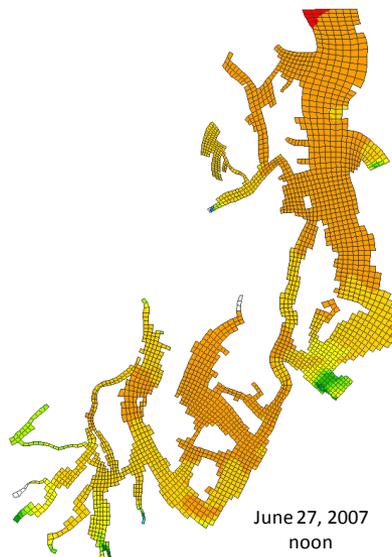
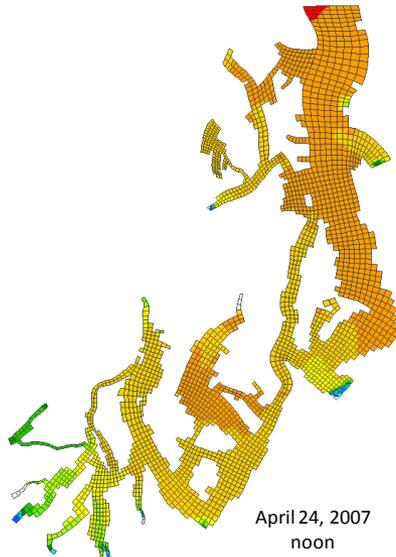
Results are good if the colors are alike

Model predicts surface temperature and salinity temporal and spatial patterns

Temperature

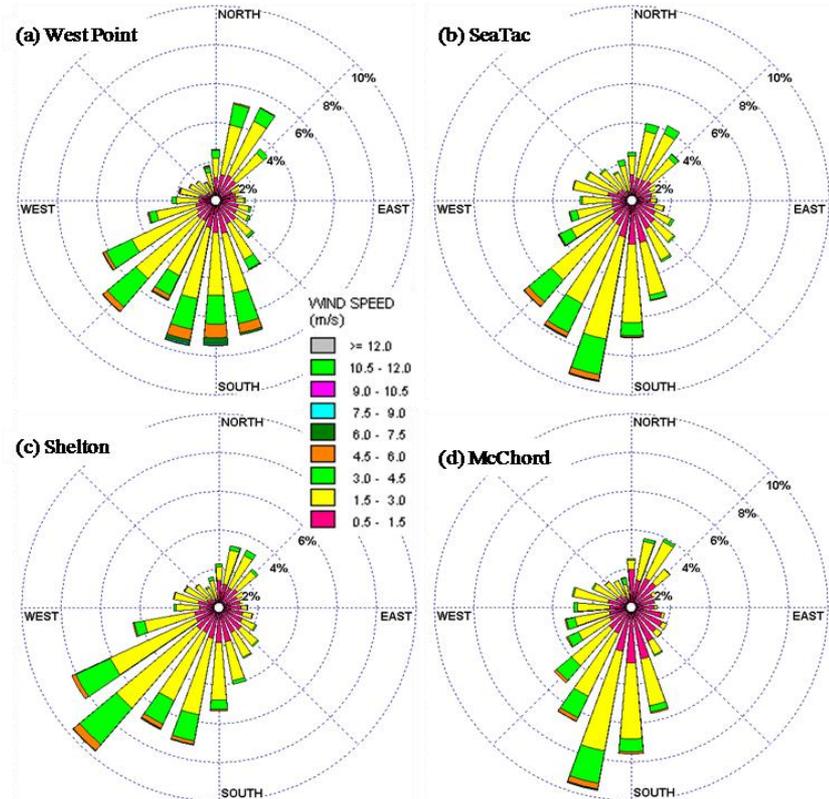
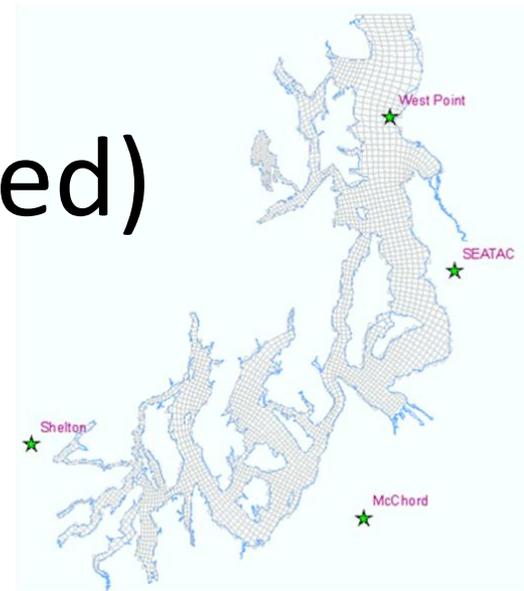


Salinity



Meteorology (updated)

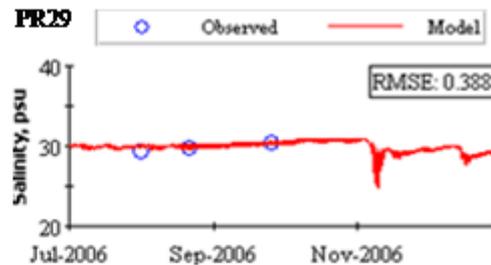
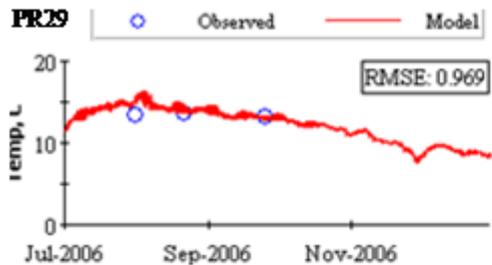
- West Point, SeaTac, and Shelton
 - Wind
 - Precipitation
 - Air temperature
- UW solar radiation data



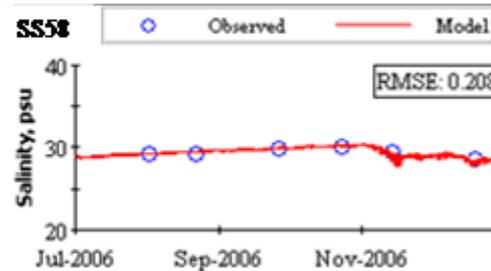
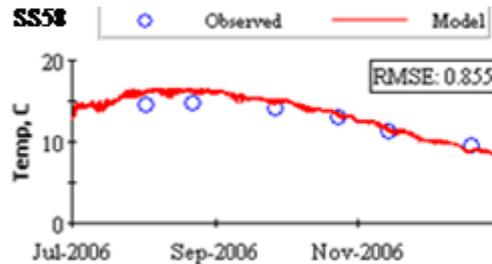
Calibration and confirmation: surface temperature and salinity time series

Temperature (°C)

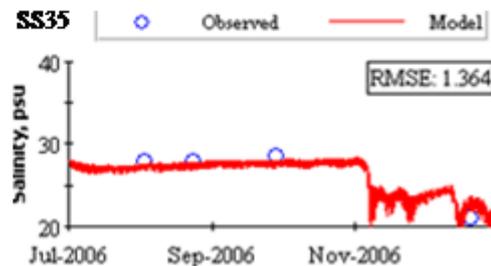
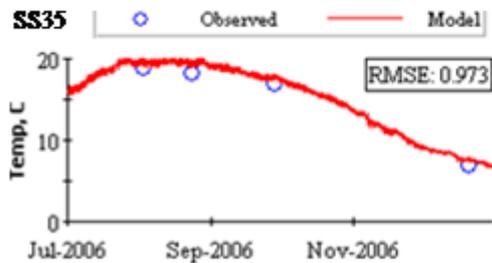
Salinity (psu)



Central Puget Sound



South Puget Sound



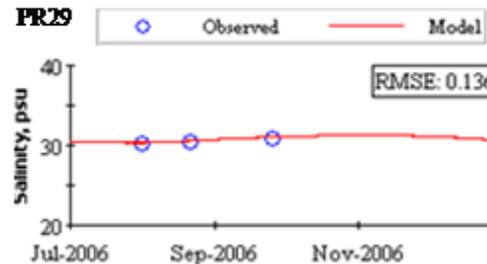
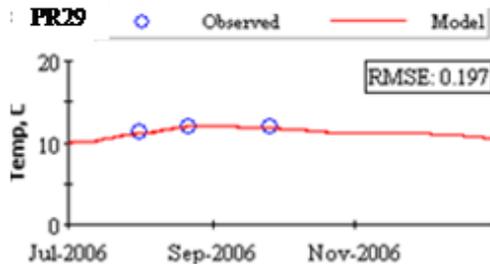
Oakland Bay

Results are good if dots plot on lines

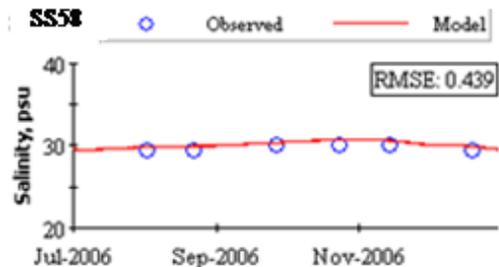
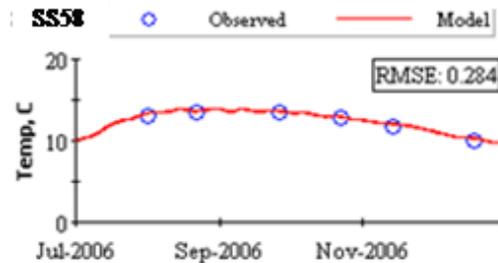
Calibration and confirmation: bottom temperature and salinity time series

Temperature (°C)

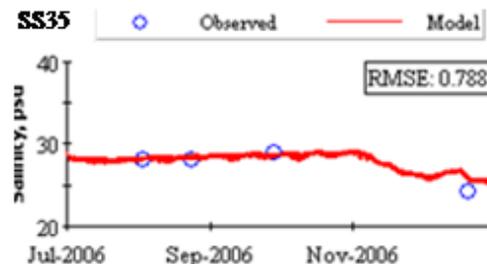
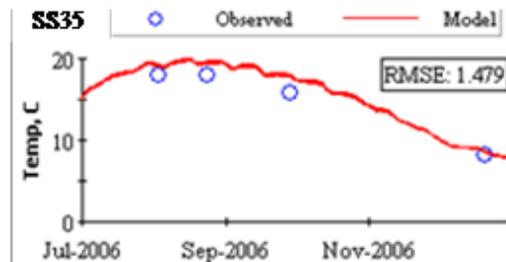
Salinity (psu)



Central Puget Sound



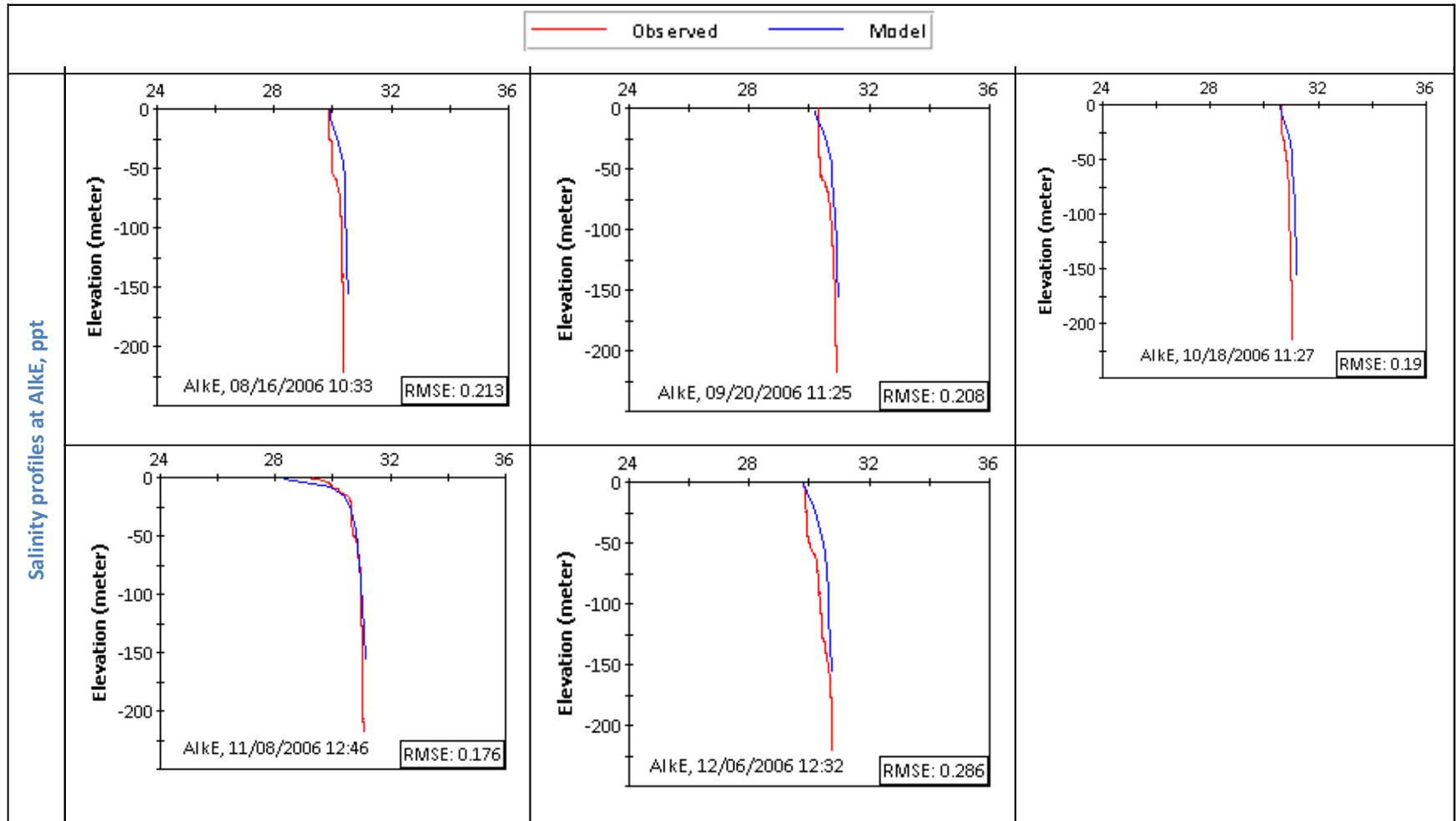
South Puget Sound



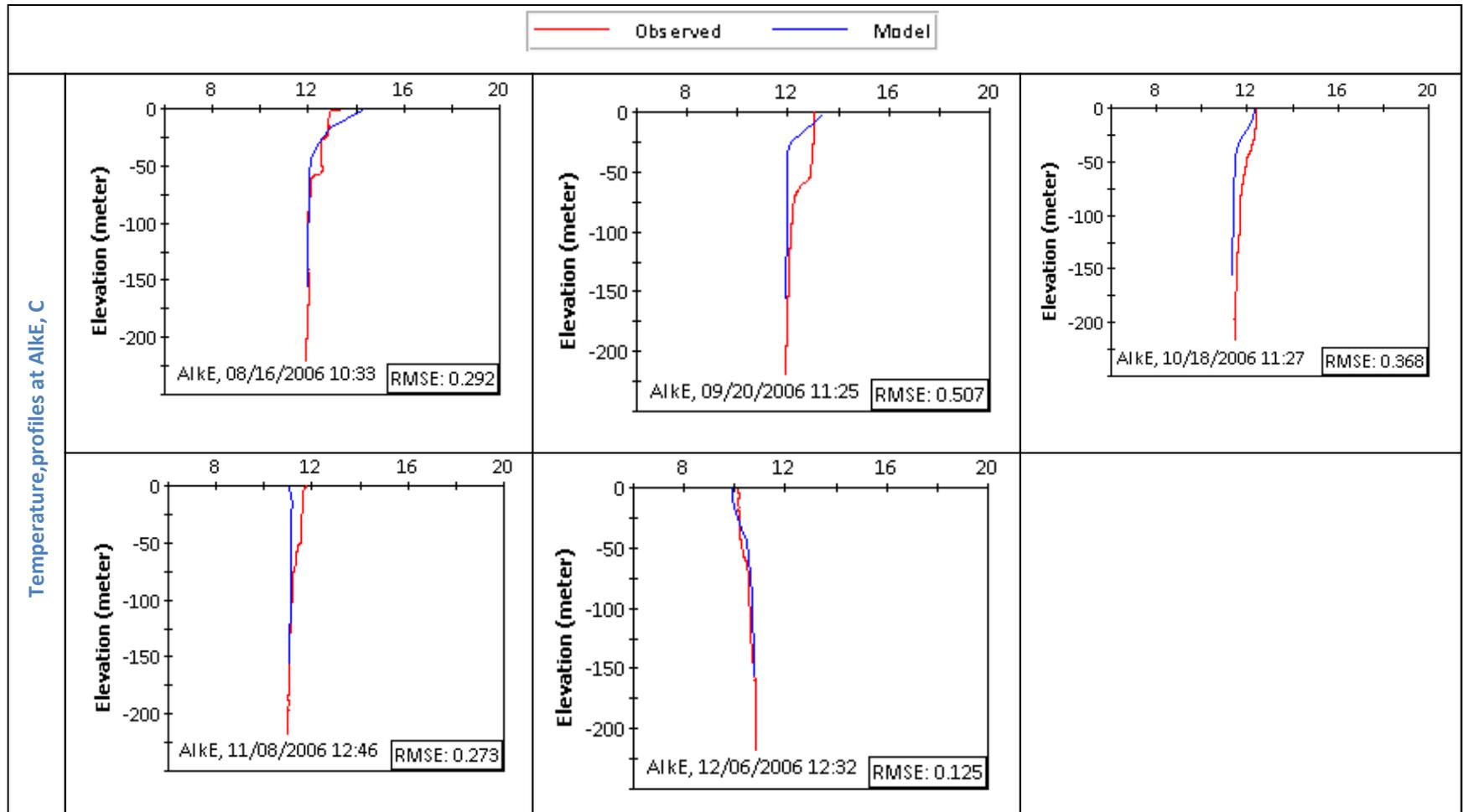
Oakland Bay

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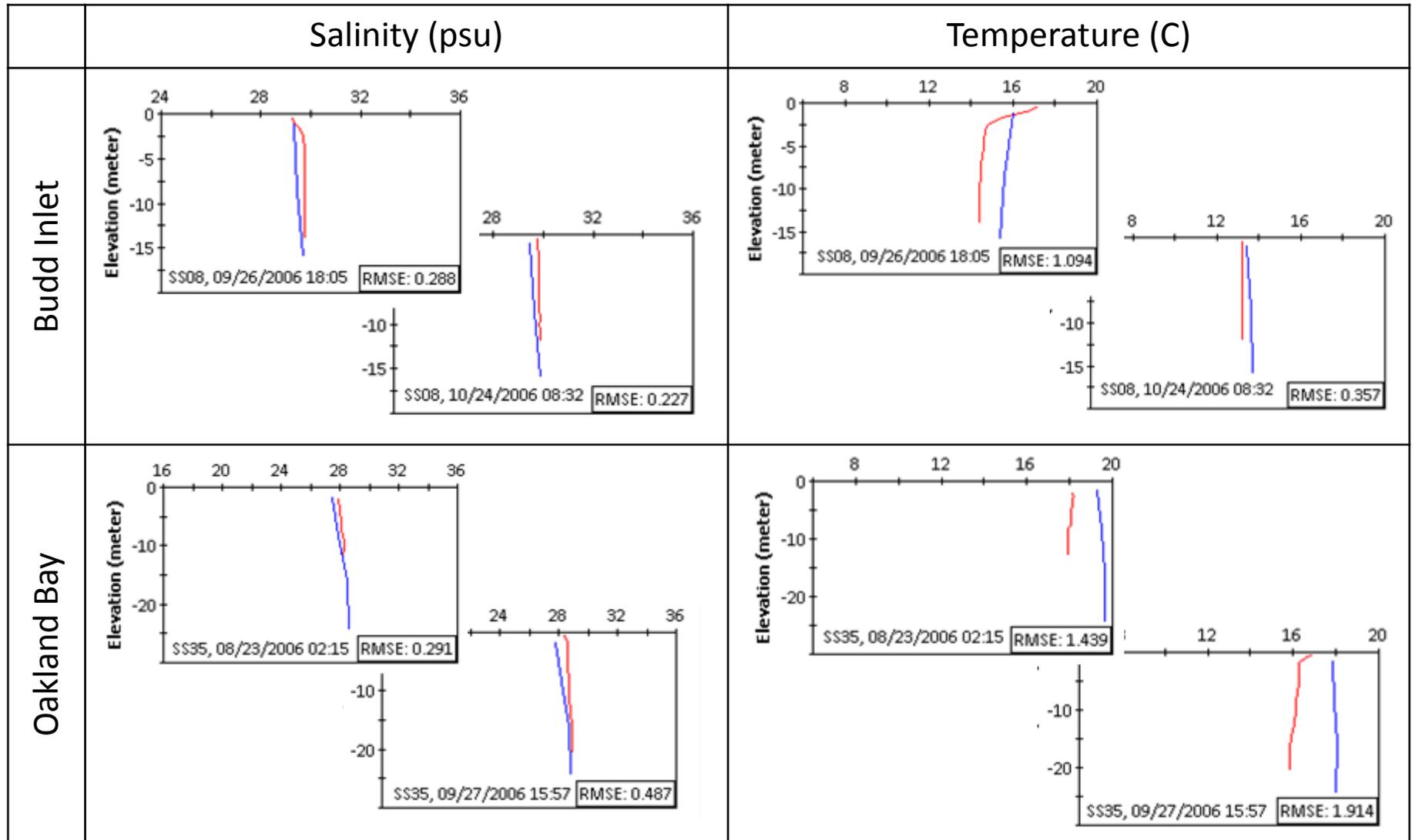
Alki East salinity profiles good



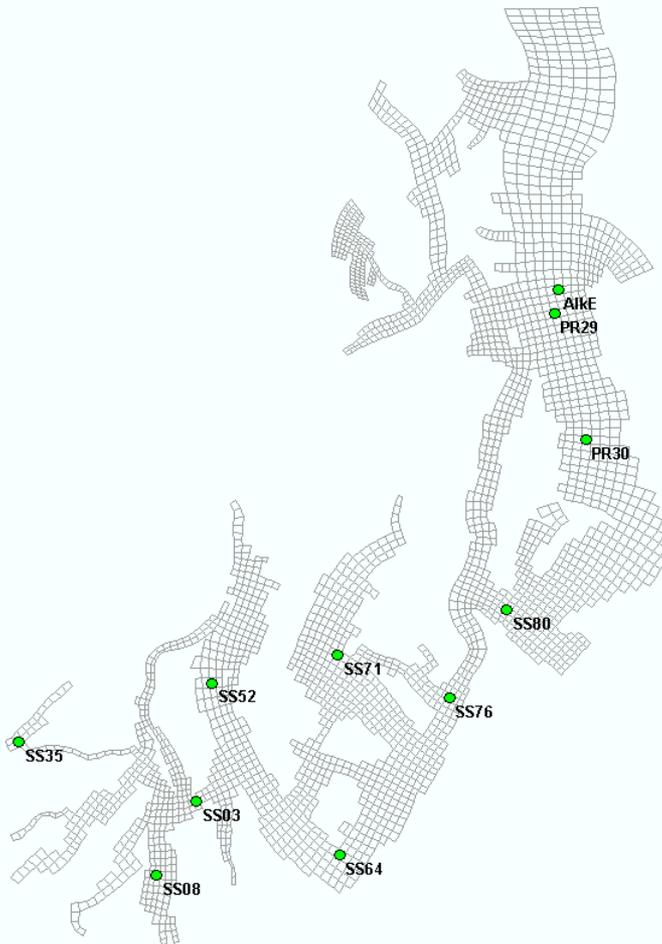
Alki East temperature profiles good



Calibration and confirmation: temperature and salinity profiles



Brunt Väisälä buoyancy frequency



- Requested by Bruce Nairn and Mitsuhiro Kawase
- Related to density stratification and vertical mixing

$$N = \sqrt{-\frac{g}{\rho} \frac{\partial \rho}{\partial z}}$$

- *See report...*

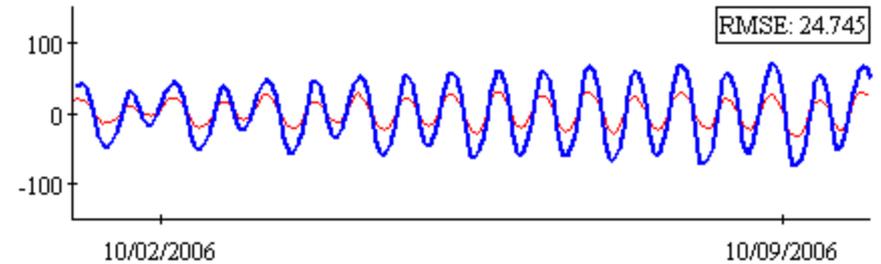
Bottom-mounted ADCPs (14 days)



Dana Passage

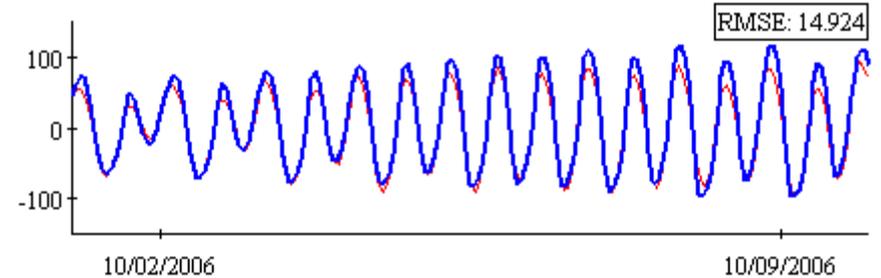
v-velocity cm/sec: Dana (KT)

— Observed — Model



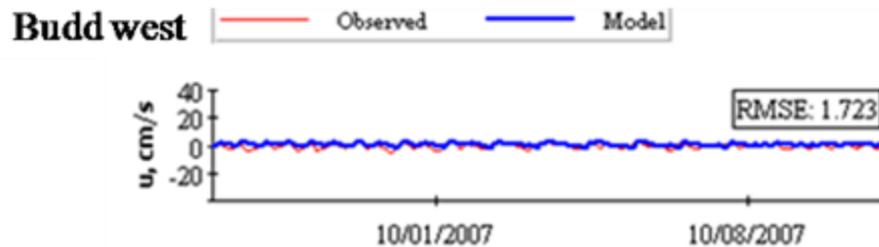
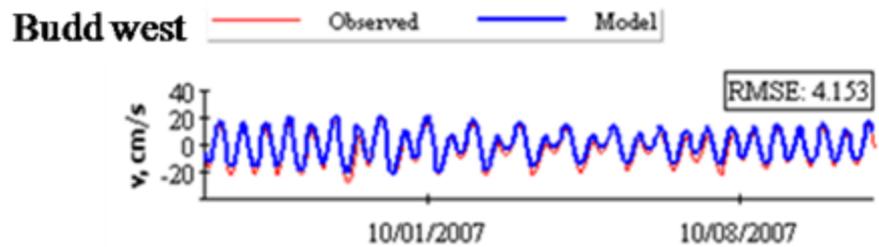
u-velocity cm/sec: Dana (KT)

— Observed — Model

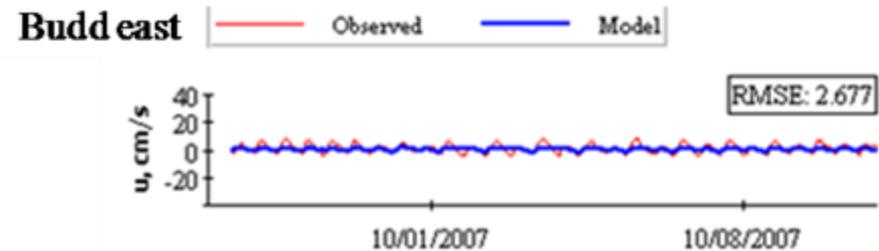
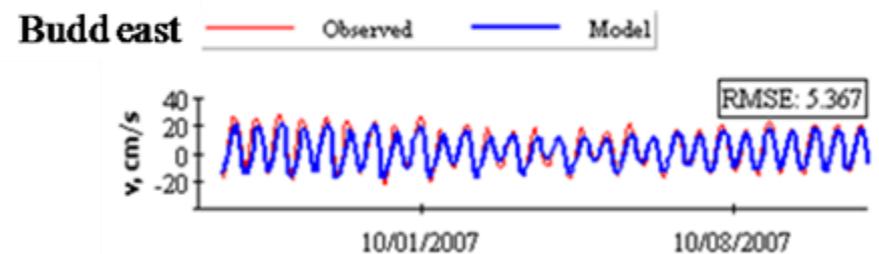


Calibration and confirmation: Budd Inlet current velocities

- West side of inlet



- East side of inlet

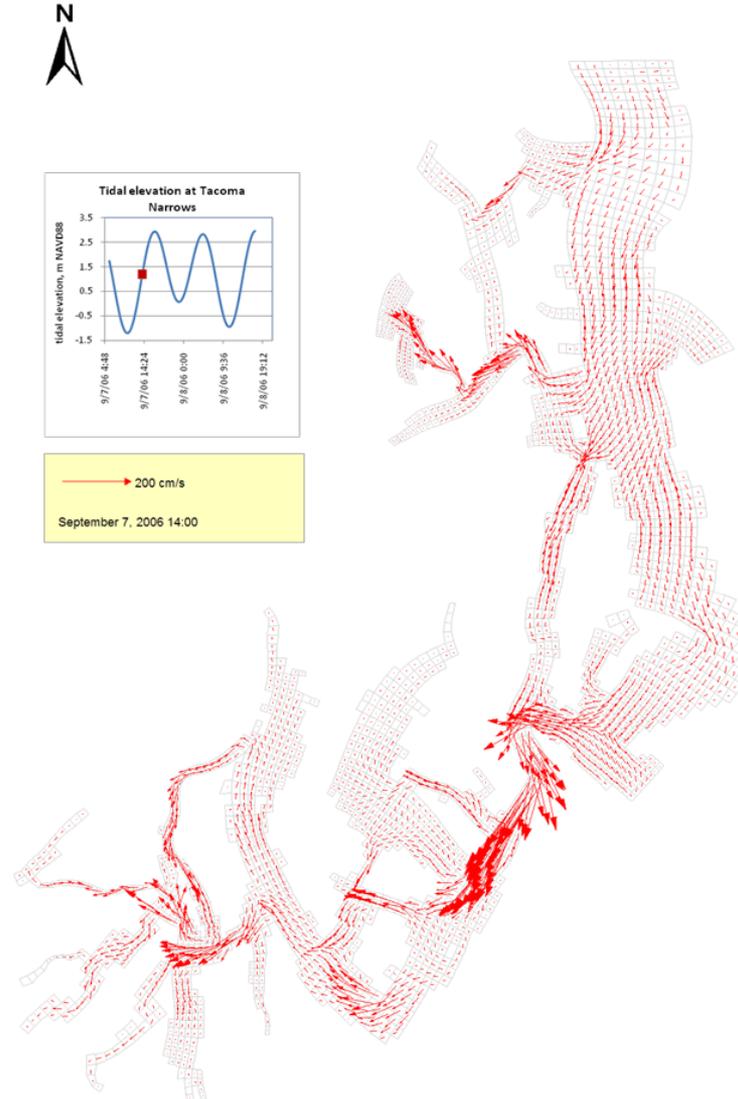
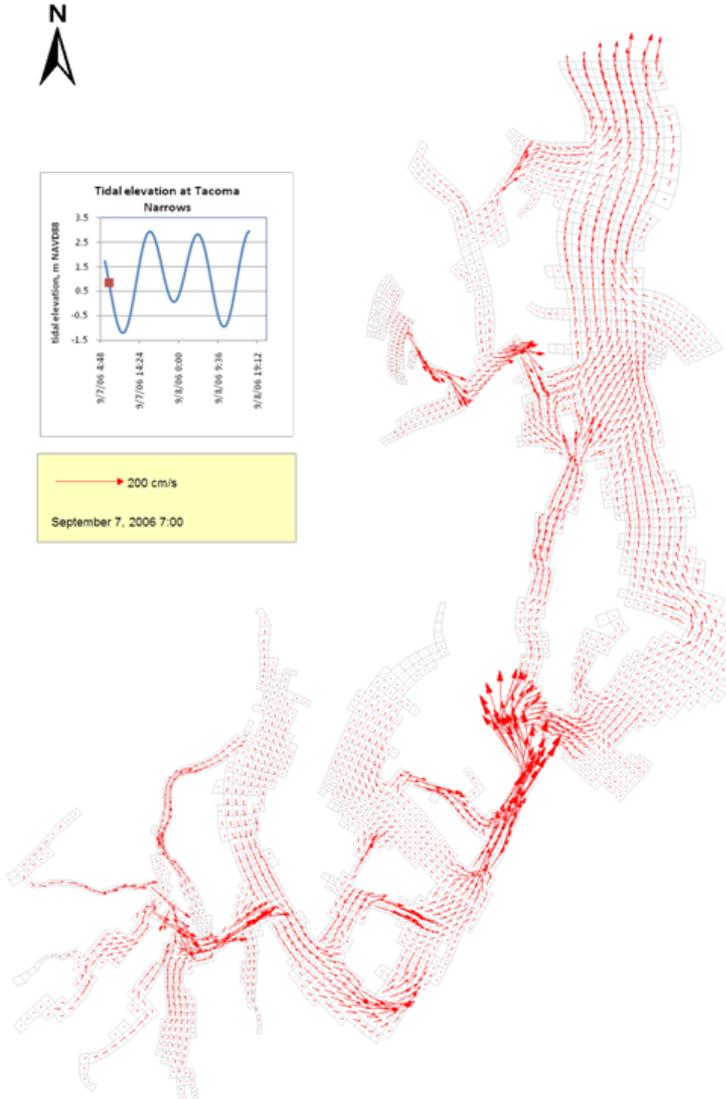


- *Most energy is in the north/south (v) direction*
- *Much less in the east/west (u) direction*

Calibration and confirmation summary

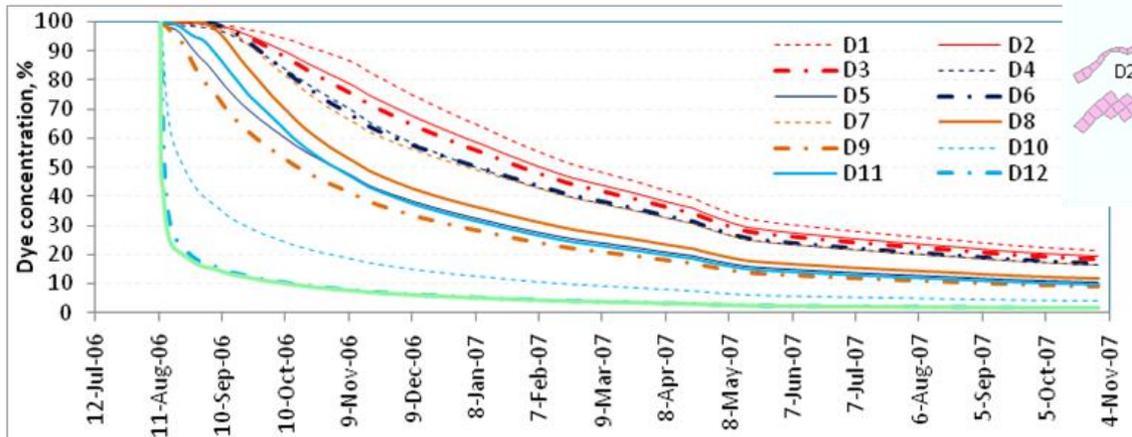
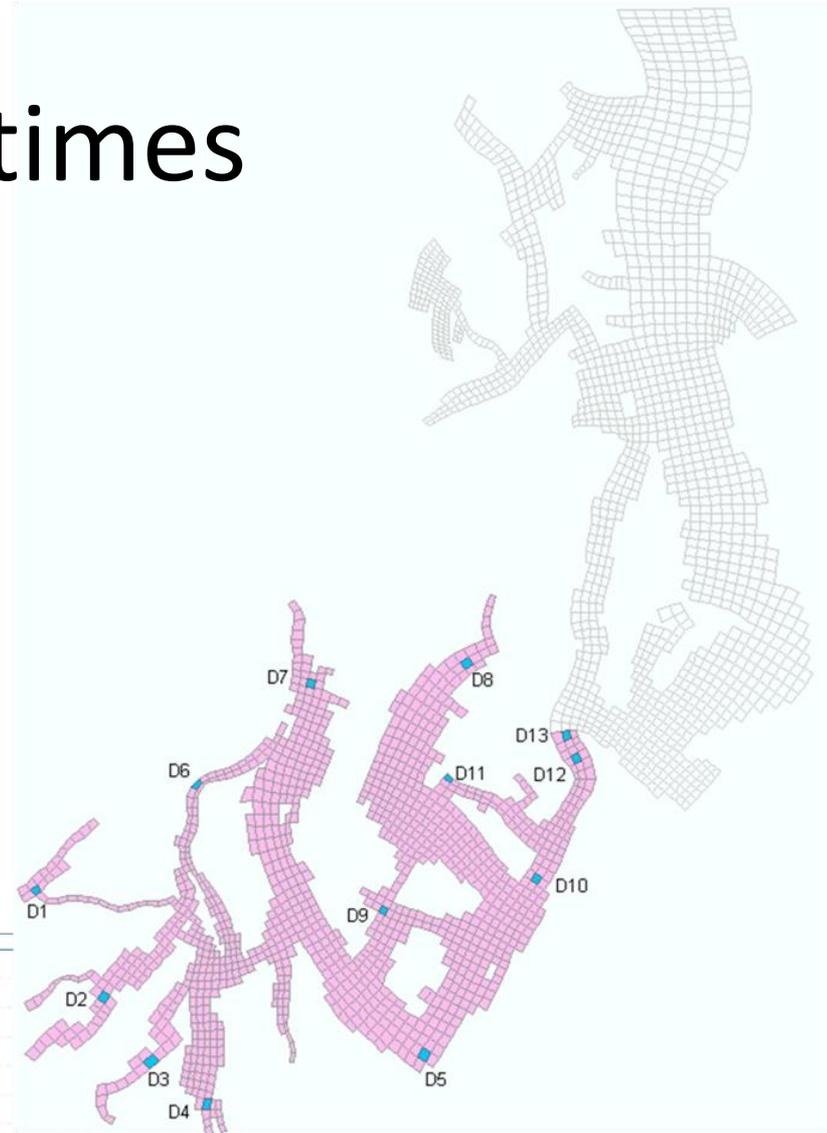
- Water surface elevations well described throughout the model domain
 - Oakland Bay issue
- Surface and near-bottom salinity and temperature capture spatial and temporal patterns
- Profiles capture spatial and temporal patterns
- Current velocities match phasing (timing) and amplitudes

Surface currents

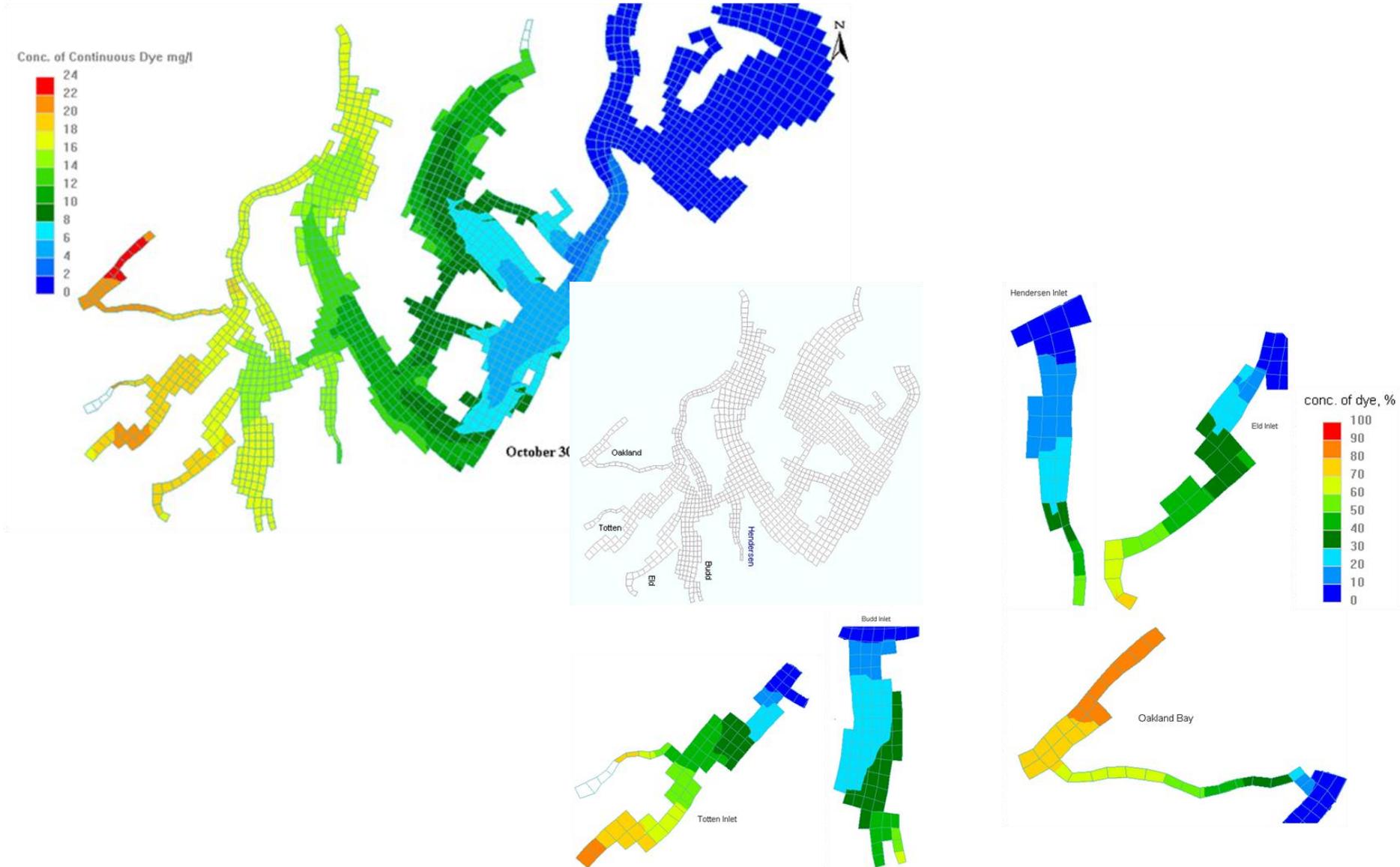


Flushing times

- Simple concept
- Mathematical definition
- Time to reduce to $1/e$ (37%) or 1-log (10%) of initial concentration



Flushing time



Application: Tracer simulations

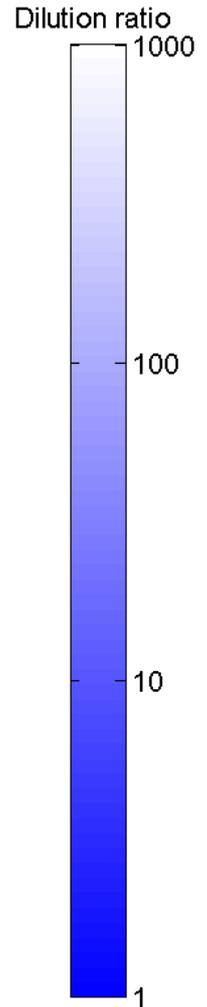
Where does the water go?

- Separate runs

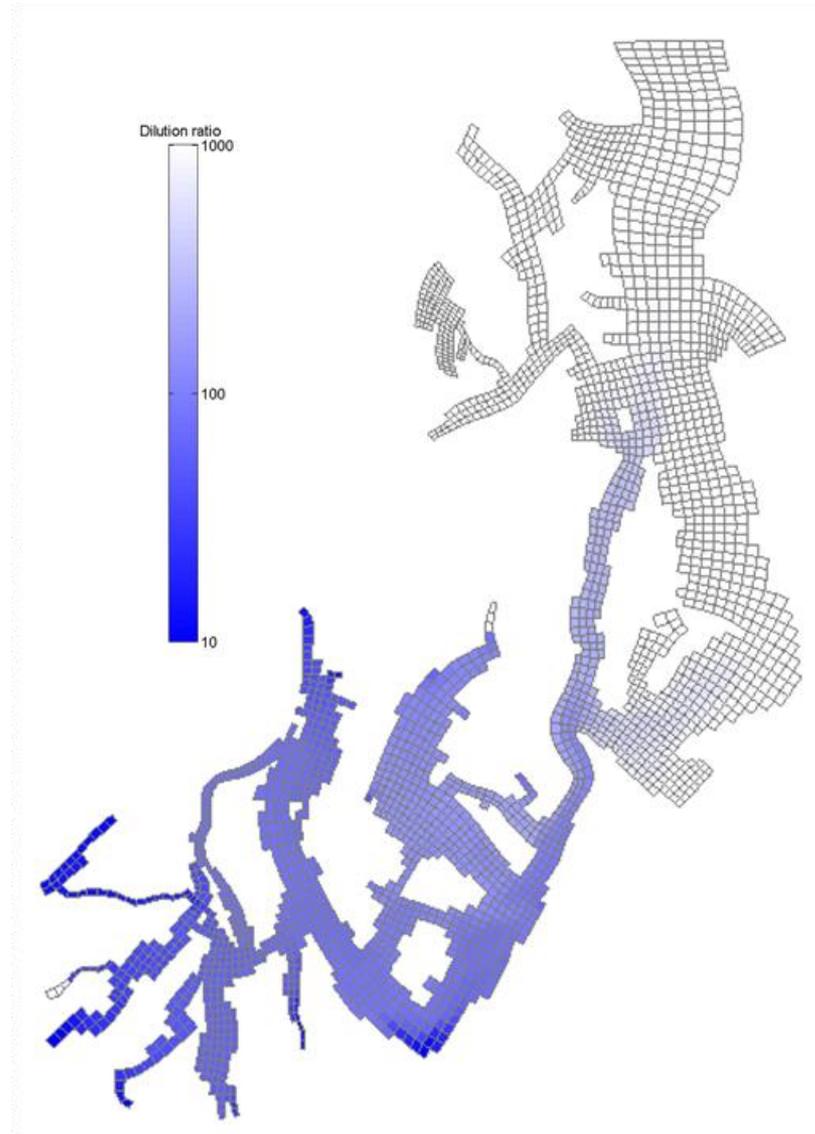
- South Sound rivers
- South Sound WWTPs
- Central Sound rivers
- Central Sound WWTPs

High concentration
=
low dilution ratio

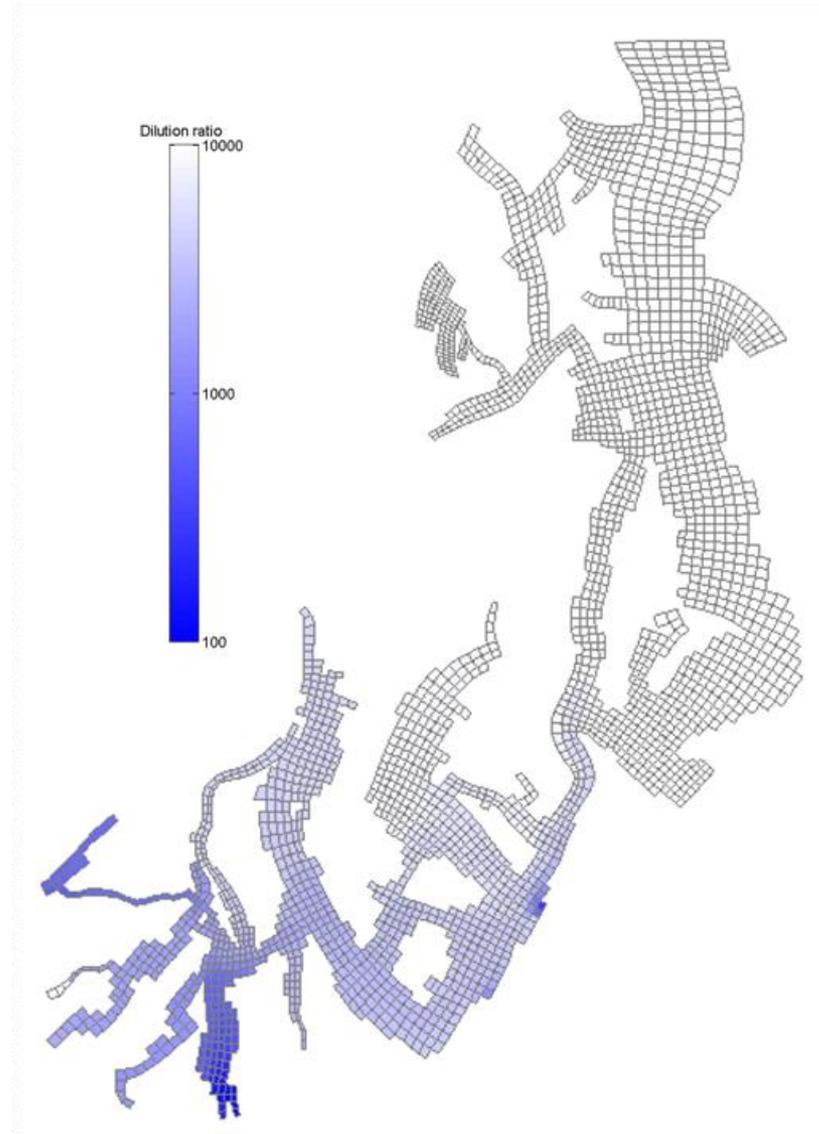
- Maximum tracer concentration that occurs anywhere in the water column



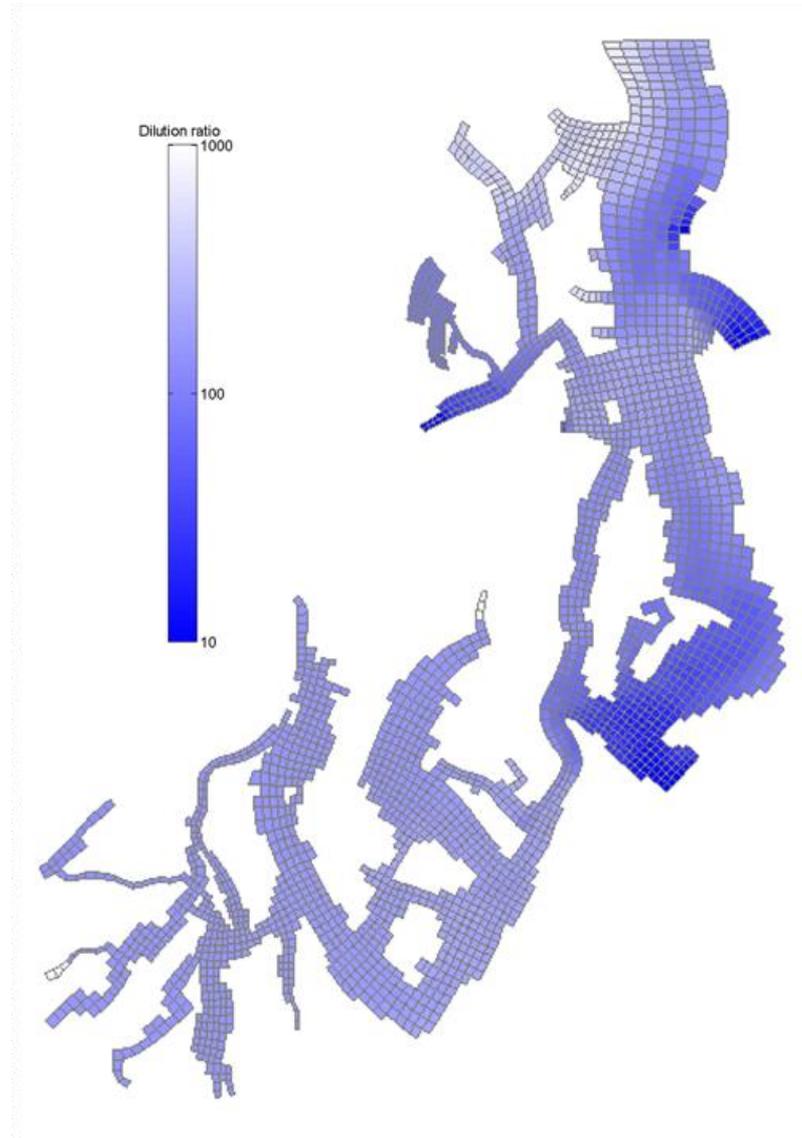
Tracer releases (SPS rivers)



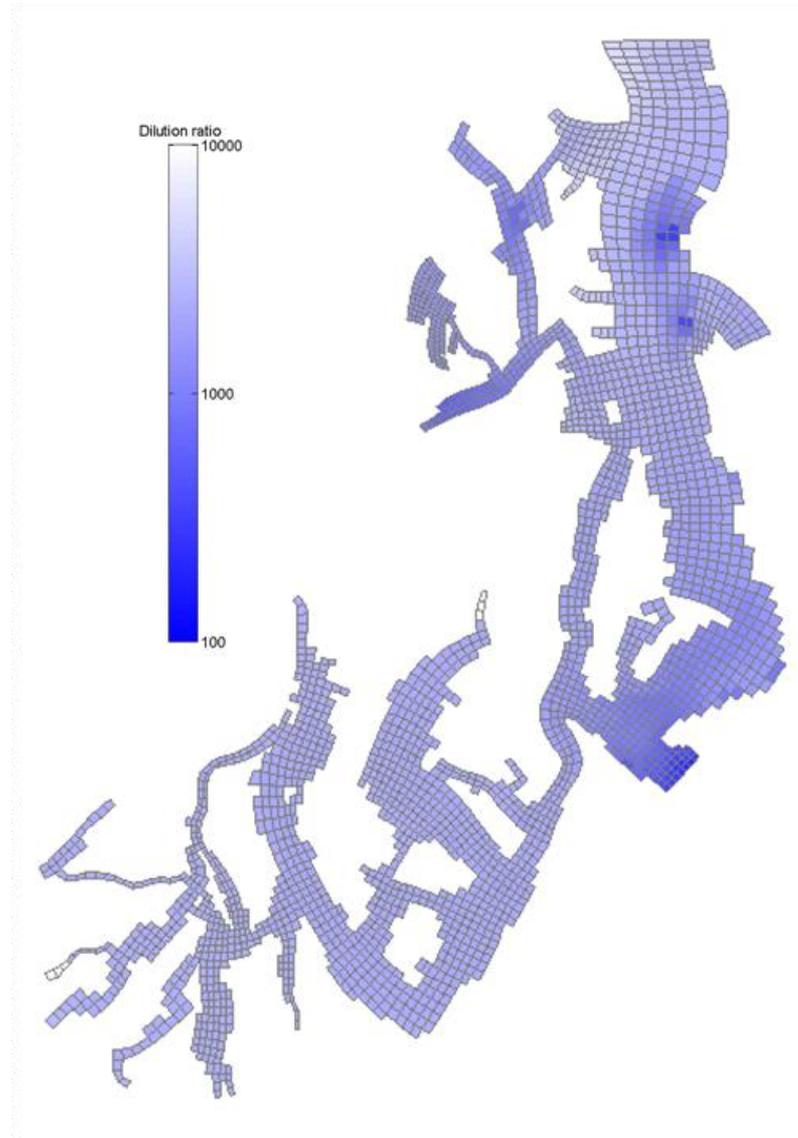
Tracer releases (SPS WWTPs)



Tracer releases (CPS rivers)



Tracer releases (CPS WWTPs)



Tracer conclusions

- Some tracer (water) from Central Puget Sound sources enters South Puget Sound
 - Cannot rule out Central Puget Sound sources
- Dilution and nutrient transformations occur
 - Cannot rule in Central Puget Sound sources without water quality model
- Will need reasonable plume dynamics to get nutrients correct

Next steps

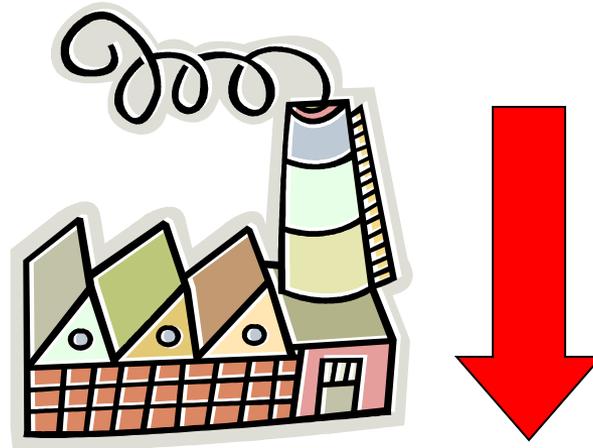
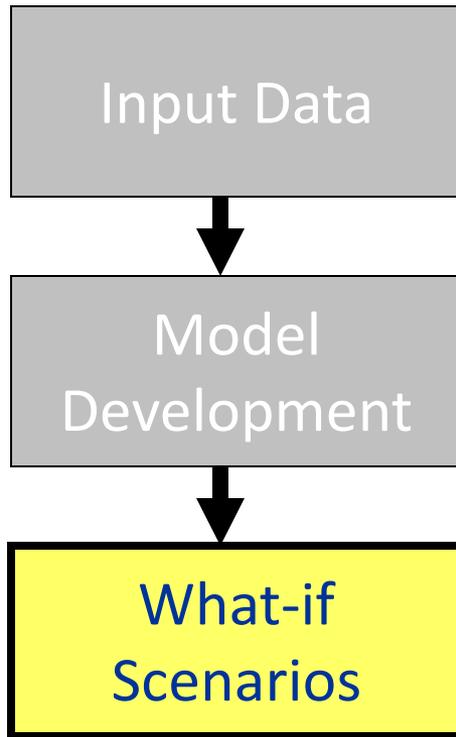
External draft report review

- Please send comments to Andrew Kolosseus by November 12

Water quality model development

- Builds from the circulation model
- Developing boundary conditions
 - Rivers and wastewater treatment plants
 - Northern boundary (nutrient and DO profiles)
- Compare against measured data
 - Calibration and confirmation
- Scenarios

Apply model to various what-if scenarios



*What if
nitrogen loads
decrease?*



*Will South Sound
DO levels...*

*... improve
markedly?*



... remain low?

Questions for model audits

- Are the *boundary conditions* included at the appropriate spatial and temporal scales?
- Are appropriate data sources used to generate the model grid?
- Did the modelers follow an appropriate process for *calibration* (and verification)?
- Are *model kinetics* appropriate and reasonable for this application?
- Are the *scenarios* evaluated appropriately?
- Does the *report* accurately characterize the model results?

Project milestones

- Final circulation model report 2009
- Water quality model development Ongoing
- Water quality model report 2010
- Scenarios Ongoing
- Final project report 2010

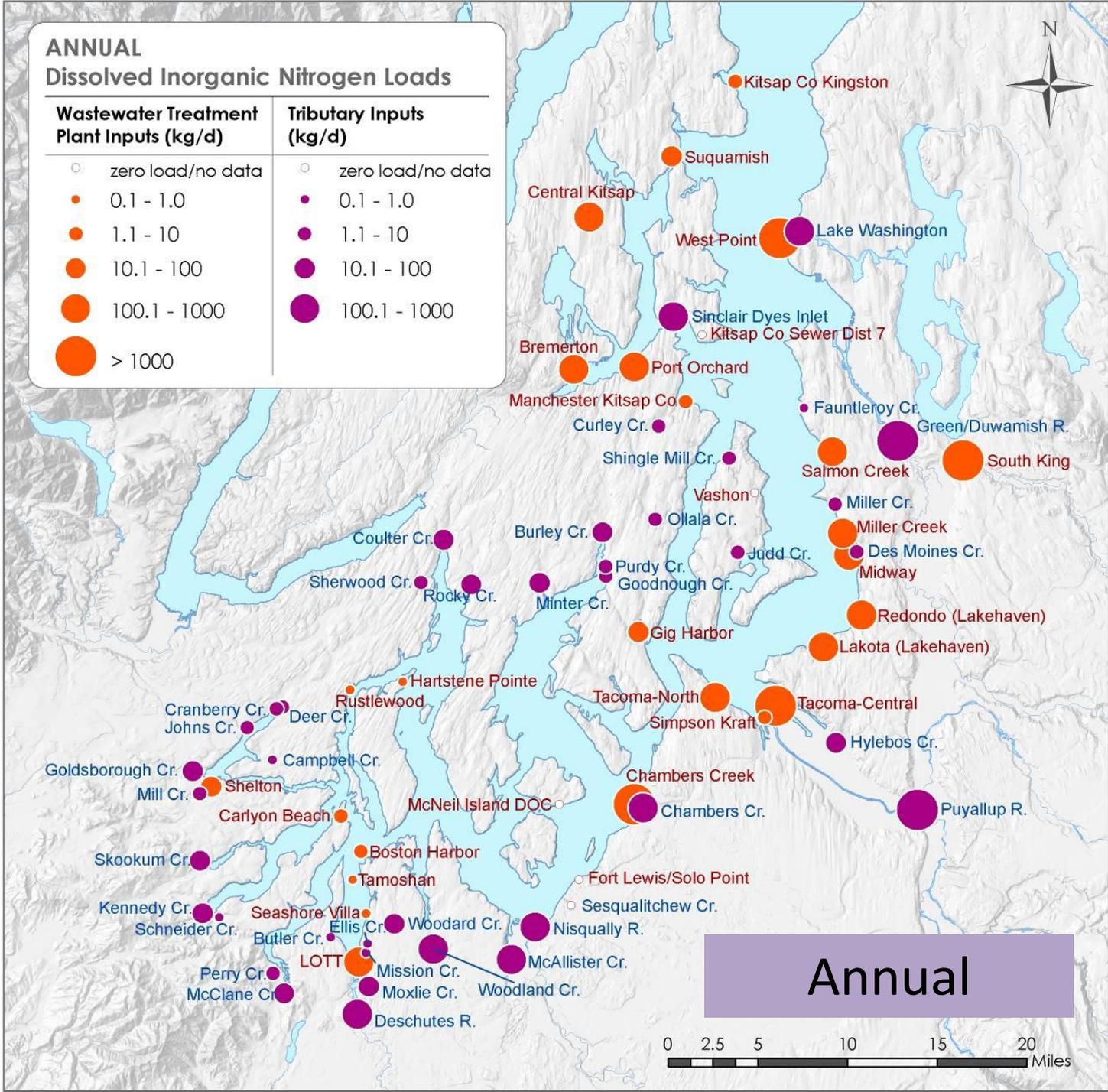
Questions?



If needed for questions

ANNUAL Dissolved Inorganic Nitrogen Loads

Wastewater Treatment Plant Inputs (kg/d)	Tributary Inputs (kg/d)
○ zero load/no data	○ zero load/no data
● 0.1 - 1.0	● 0.1 - 1.0
● 1.1 - 10	● 1.1 - 10
● 10.1 - 100	● 10.1 - 100
● 100.1 - 1000	● 100.1 - 1000
● > 1000	



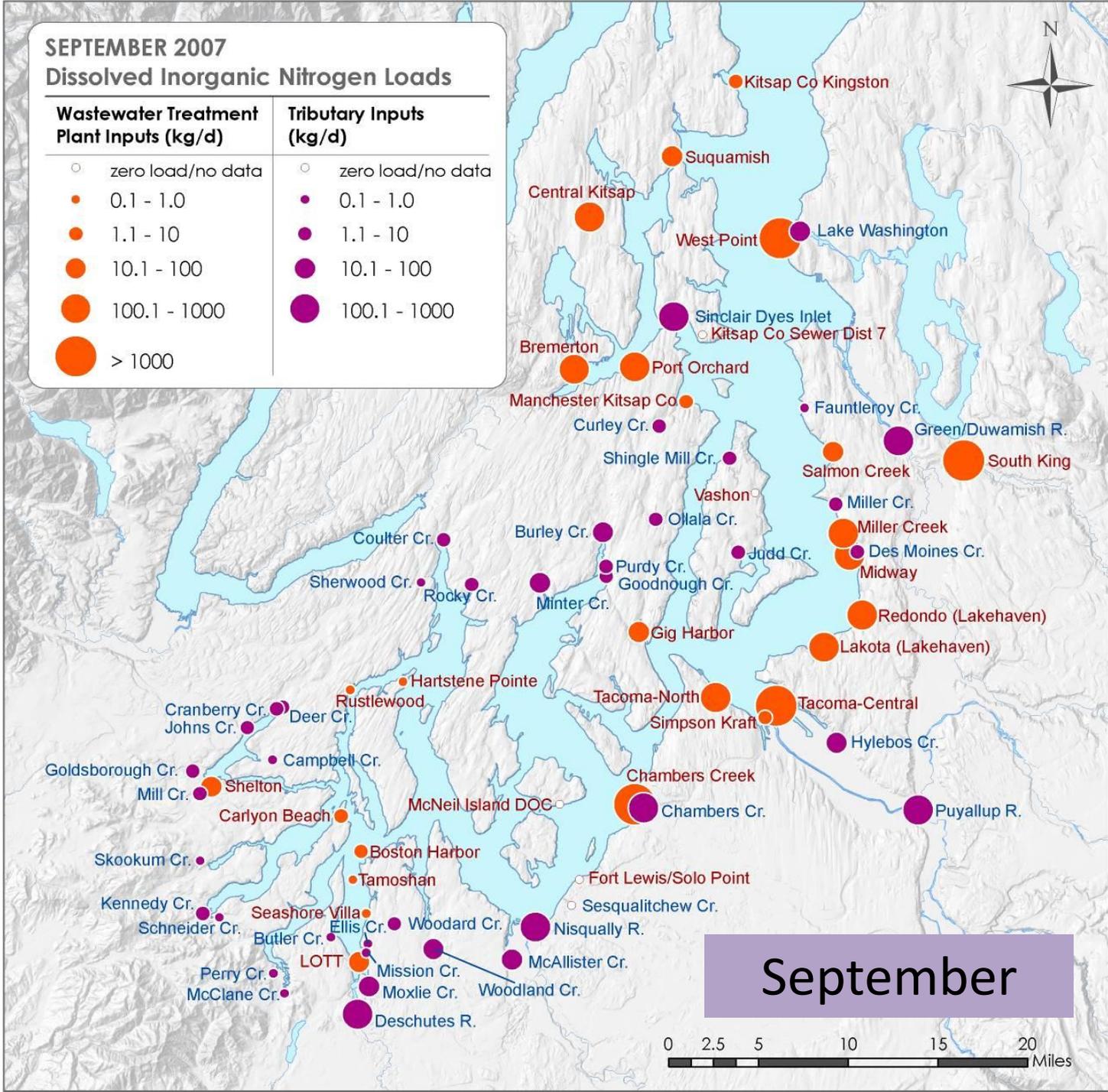
Annual



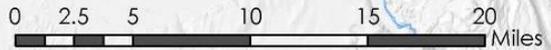
SEPTEMBER 2007

Dissolved Inorganic Nitrogen Loads

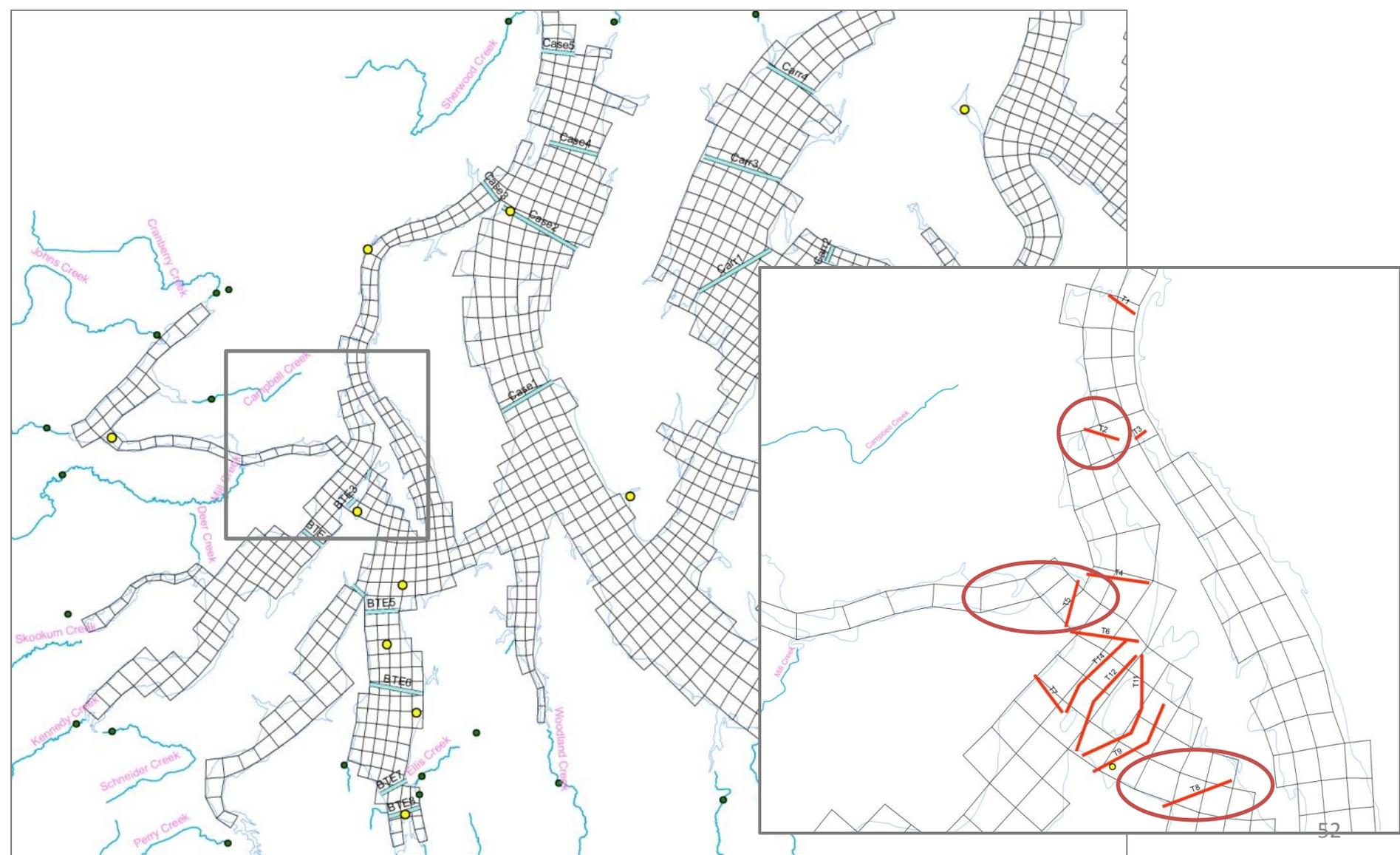
Wastewater Treatment Plant Inputs (kg/d)	Tributary Inputs (kg/d)
○ zero load/no data	○ zero load/no data
● 0.1 - 1.0	● 0.1 - 1.0
● 1.1 - 10	● 1.1 - 10
● 10.1 - 100	● 10.1 - 100
● 100.1 - 1000	● 100.1 - 1000
● > 1000	



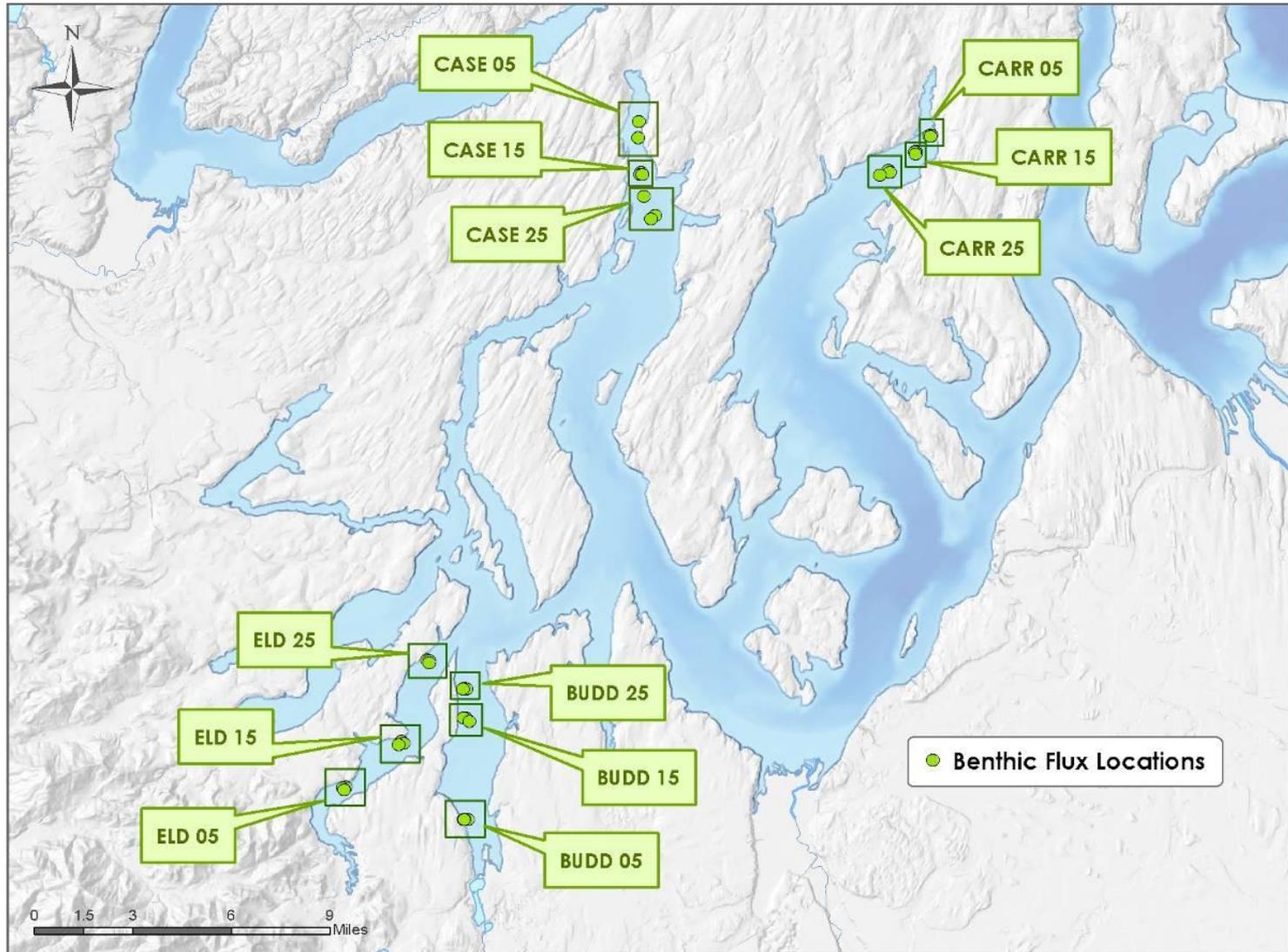
September



Current velocity comparisons



Sediment flux locations



Sediment flux estimates

- Budd Inlet
 - 1998 Budd Inlet Scientific Study (annual and seasonal)
 - Annual: 326 metric tons-N/yr or 890 kg-N/d
 - Late summer: 2400 kg-N/d
 - Present study
 - Late summer: 1100 kg-N/d (Budd Inlet)
 - WWTPs: 2800 kg-N/d (South Sound)
 - Tribs: 2700 kg-N/d (South Sound)
 - *Sediments are an important nutrient reservoir*