Bay Area Clean Water Agencies
A Joint Powers Public Agency
Leading the Way to Protect our Bay

The Utility of Modeling

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HDR | HydroQual

Workshop on Nutrient Science and Management in San Francisco Bay

June 29th, 2011

Focus of Presentation: 3 questions

- How can models be used to understand, manage and regulate water quality?

- What are the key components and data needs of an effective water quality model?

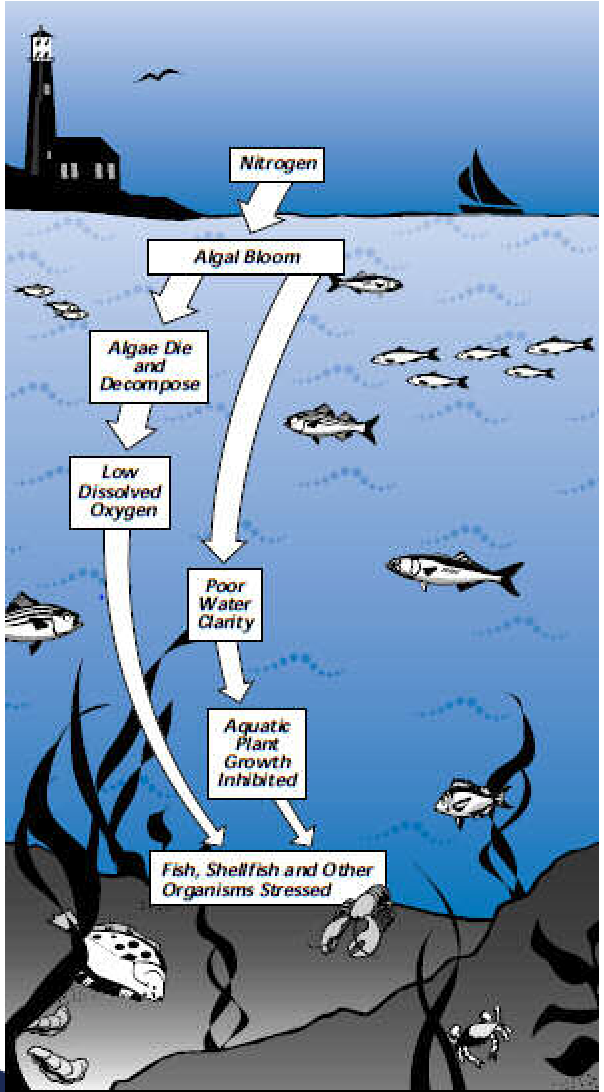
- Based on existing models of San Francisco Bay (SFB), where do we go from here?

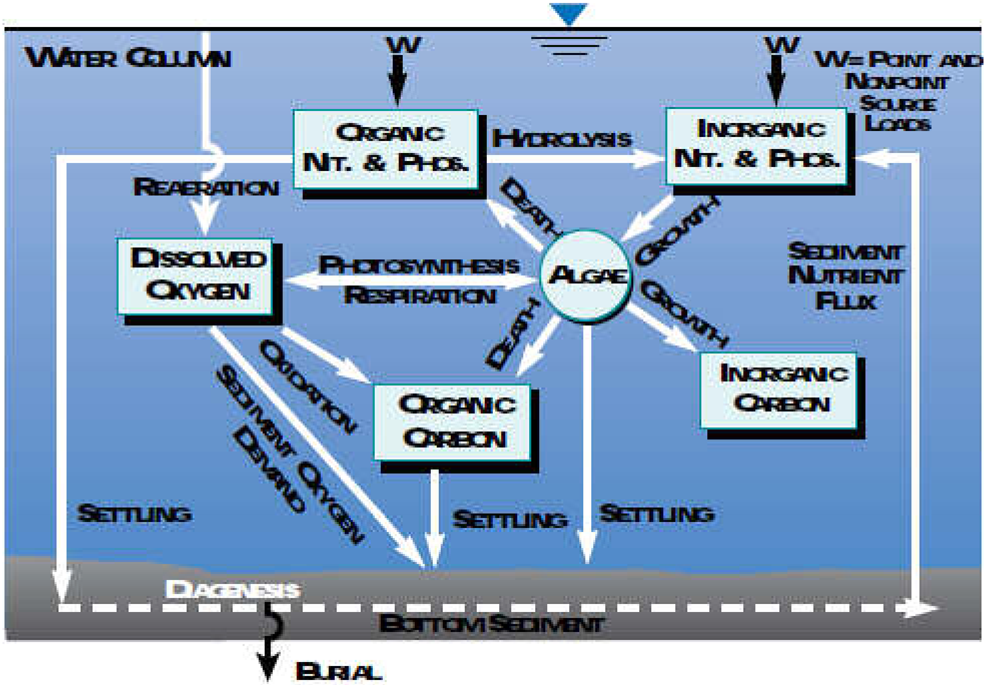
How can models be used to understand, manage and regulate water quality?

How can models be used to understand, manage and regulate water quality?

- **Define Cause and Effect Relationships**
- **Focus Additional Monitoring and Research Needs**
- **Provide a Management Tool to:**
  - Define Impacts of Pollutant Sources
  - Assess Required Levels of Control
  - Evaluate Planning Alternatives for Water Quality Management
  - Assess Future Water Quality Conditions

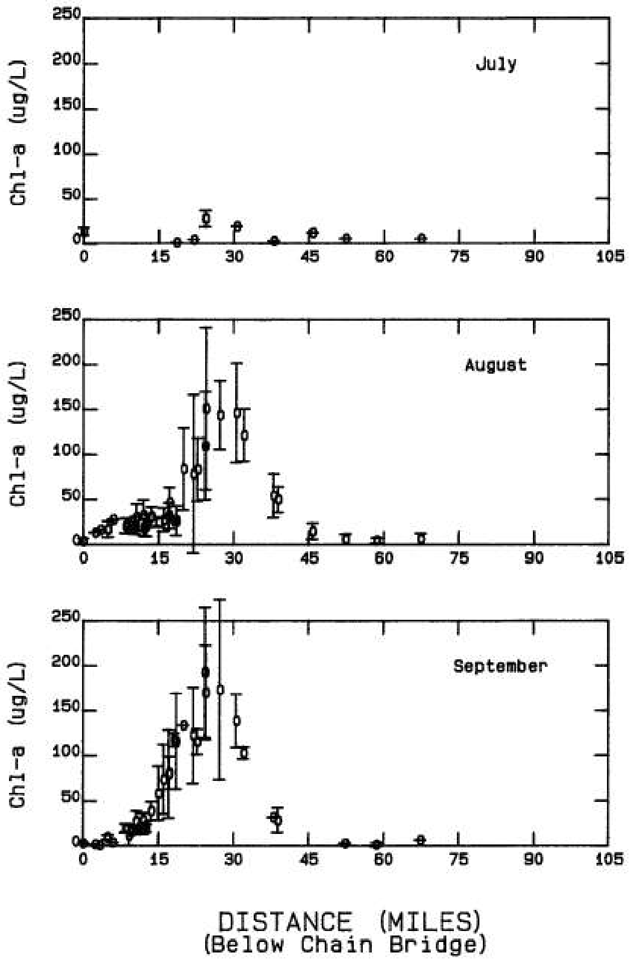
Define Cause and Effect Relationships

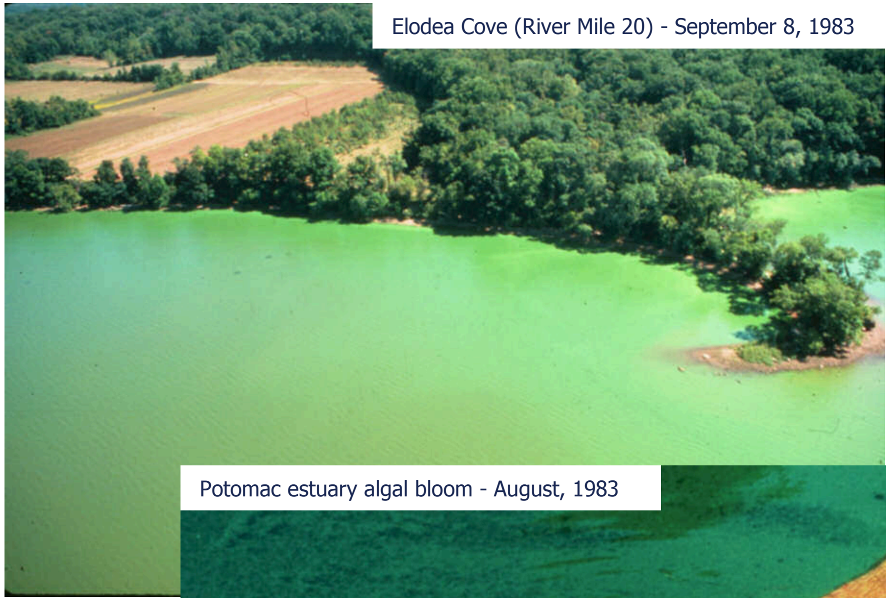




Focus Additional Monitoring and Research Needs

1983 Potomac River algal bloom: chlorophyll-a levels were > 250 µg/L with observations > 600 µg/L in the embayments



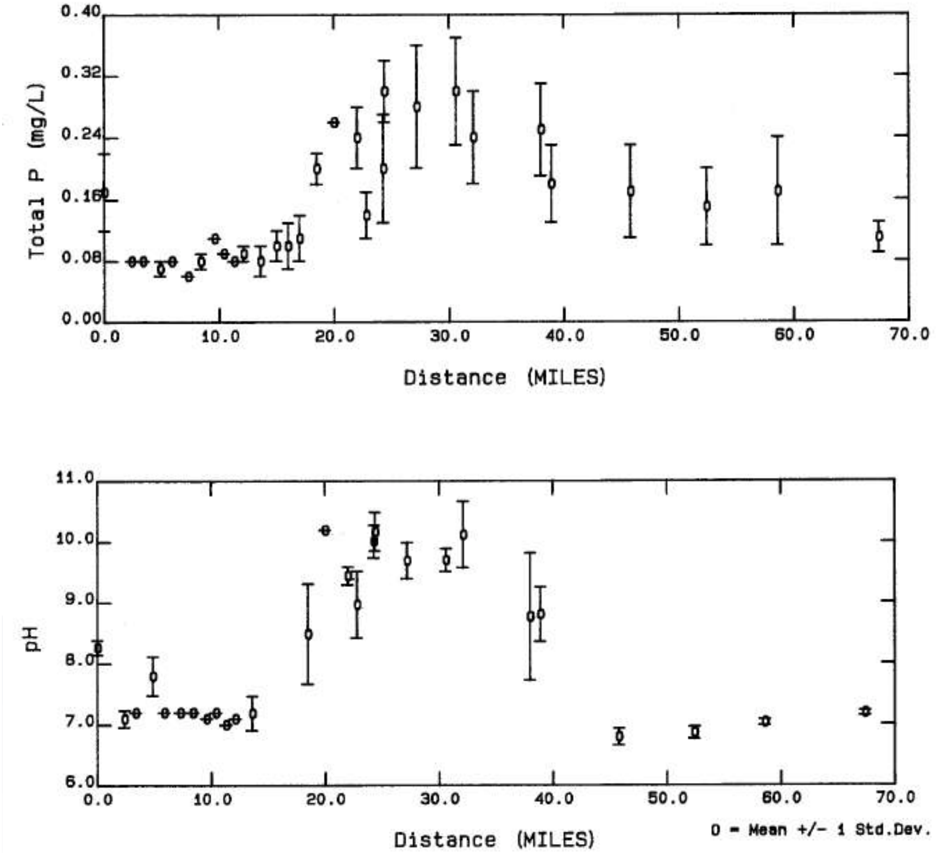


Elodea Cove (River Mile 20) - September 8, 1983

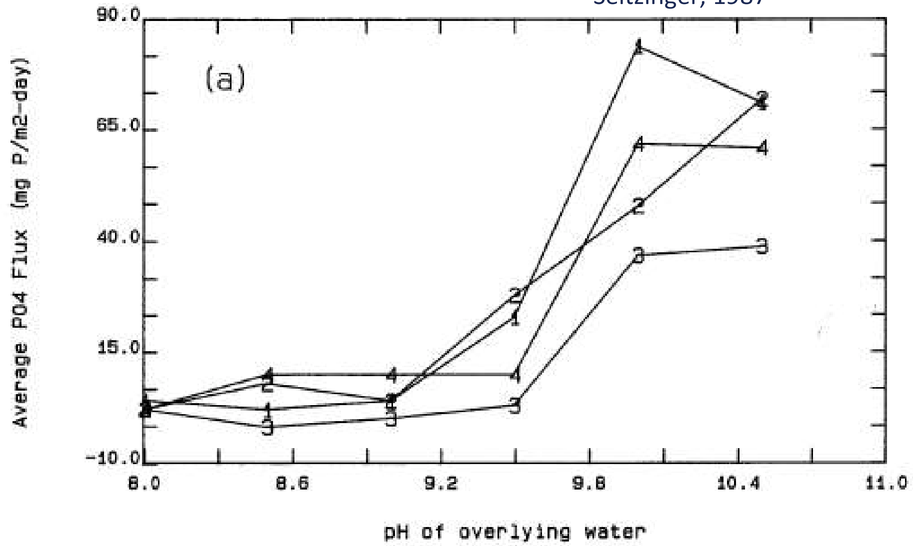
Potomac estuary algal bloom - August, 1983

Focus Additional Monitoring and Research Needs

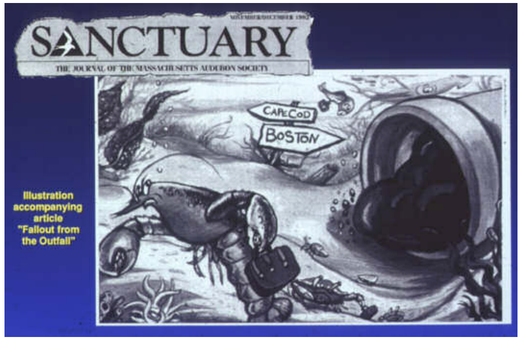
- Total phosphorus higher downstream of the Blue Plains WWTP (located ~ RM 10) and coincided with high pH
- Hypothesis: high pH triggered release of PO_4 from the sediment bed → lab experiments on field cores confirmed the hypothesis



Seitzinger, 1987



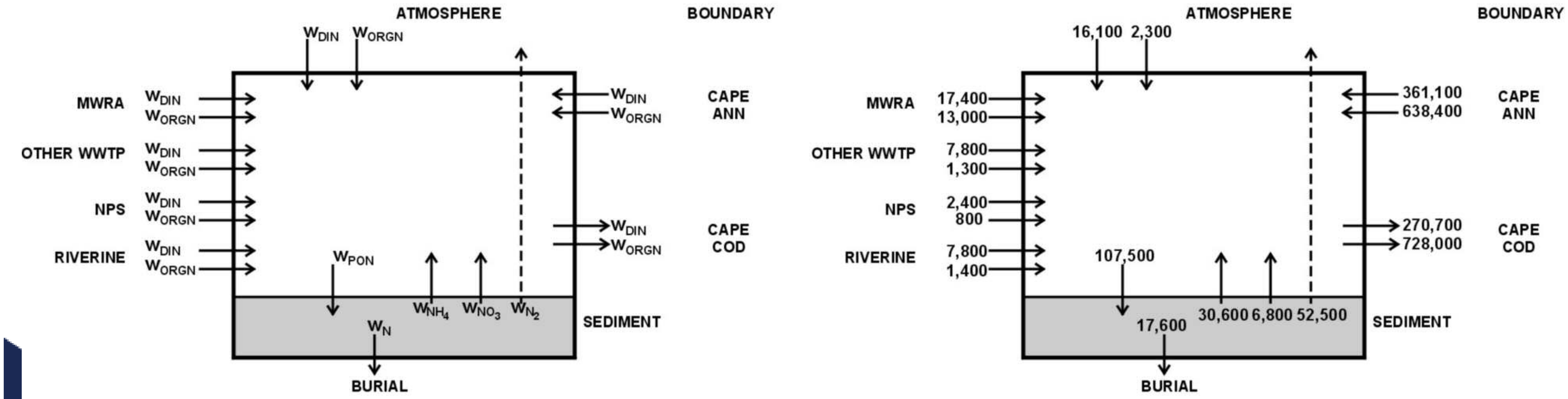
Management Tool (Define, Assess, Evaluate)



Potential impacts of City of Boston’s wastewater effluent on Massachusetts and Cape Cod Bays

Development of Bays Eutrophication Model (BEM) and N-mass balance

MASSACHUSETTS BAYS NITROGEN MASS BALANCE FOR 1992



(All units are kg/day)

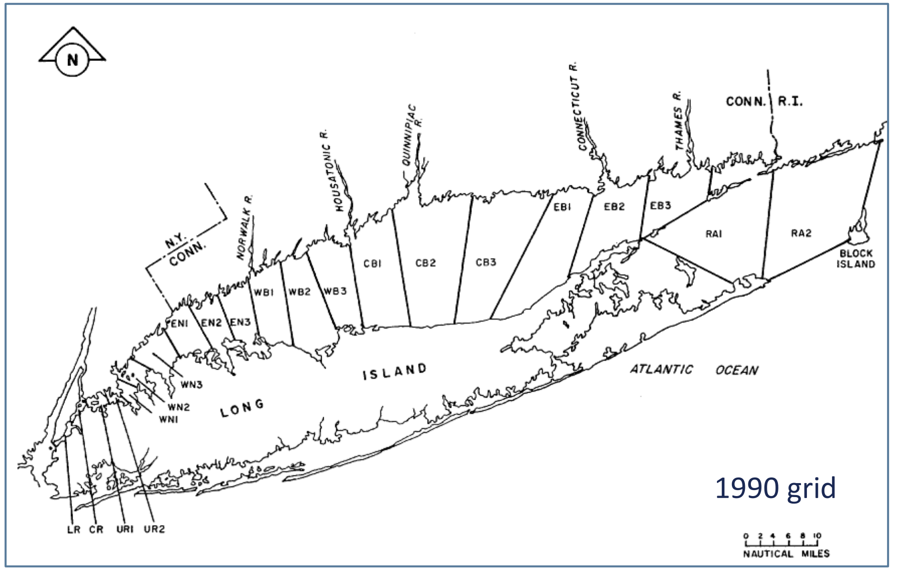
SUMMARY	DIN	ORGN	TN	%TN
MWRA	17,400	13,000	30,400	3
NON-MWRA	34,100	18,800	52,900	5
BOUNDARY	361,100	638,400	999,500	92

Where have models been used successfully?

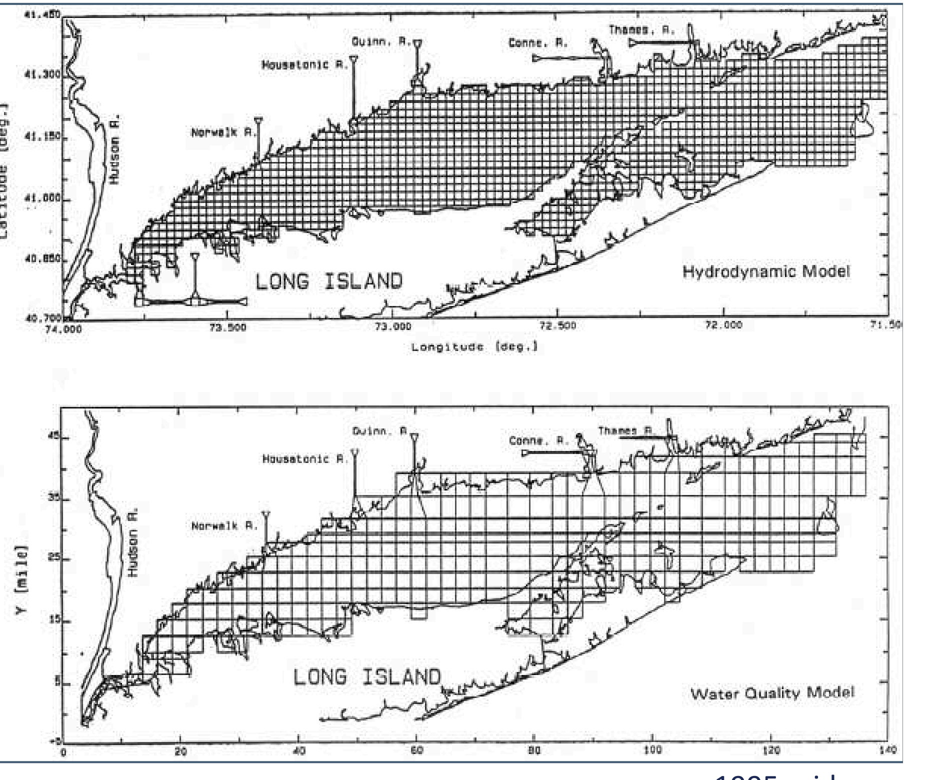
- Suisun Bay – one of earliest eutrophication studies – research driven
- Great Lakes – set TP load reduction to achieve dissolved oxygen goals
- Potomac Estuary – set TP load reduction to achieve chlorophyll-a goals for the estuary
- Chesapeake Bay – TMDL development
- Long Island Sound – TMDL development
- Massachusetts Bays System – understand potential impacts of outfall relocation

What are the key components and data needs of an effective water quality model?

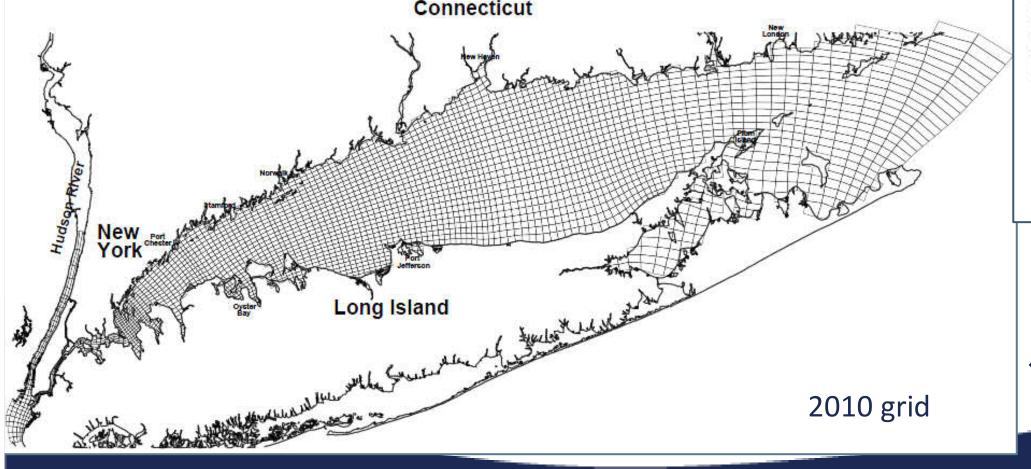
Spatial Evolution of Models



1990 grid

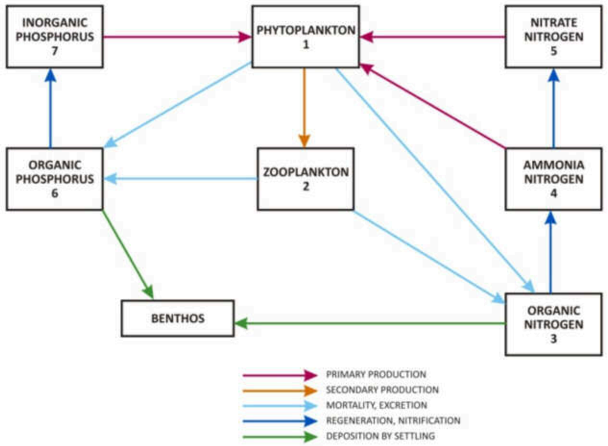


1995 grid

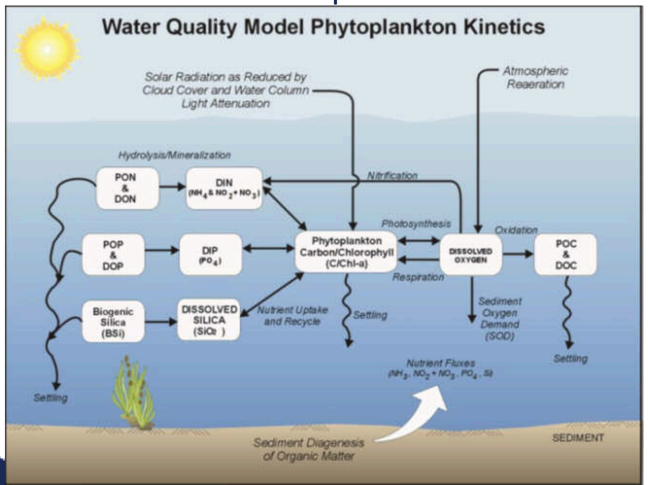


2010 grid

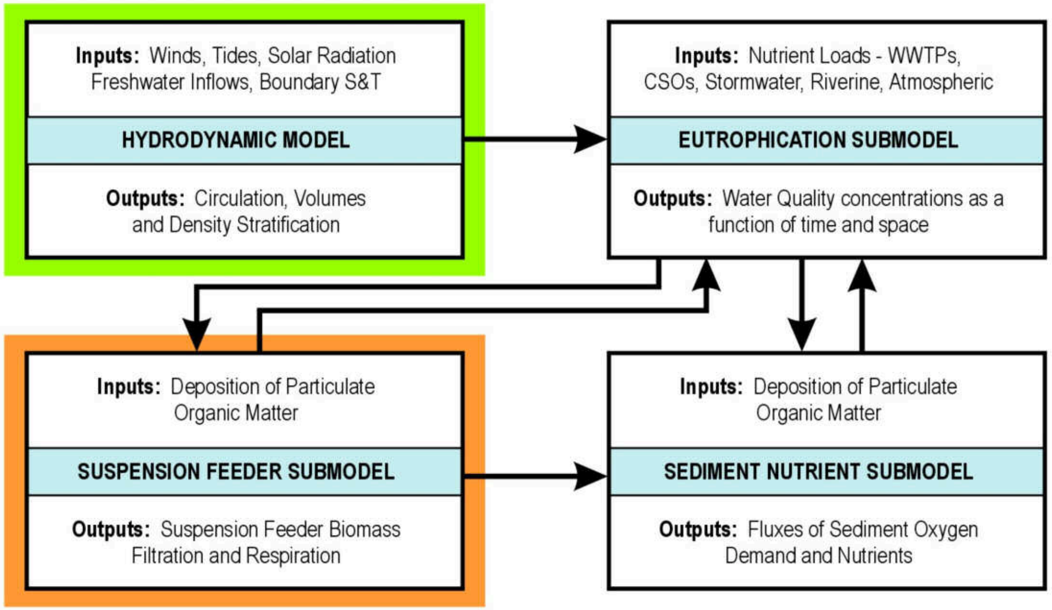
Process Evolution of Eutrophication Models



1970's-1980's box models with "calibrated" transport



1990's coupled hydrodynamic/water quality + sediment flux submodel



2000's suspension feeder submodel

Data Needs for Modern Eutrophication Models

- Water Column Data
  - phytoplankton biomass (chl-a) and species composition, zooplankton/benthic biomass and species composition
  - POM (C,N,P), BSi, DOM (C,N,P)
  - NH_4, NO_3, PO_4, DSi, BOD_5, DO
  - T, S, SS, turbidity/light attenuation
  - Primary production
- Sediment Data
  - fluxes of SOD, $J_{NH4,}$, $J_{NO3,}$, $J_{PO4,}$, $J_{Si,}$ denitrification rates
  - sediment composition POC, POP, PON, TPO_4, ^{210}Pb dating

Data Needs for Modern Eutrophication Models

- Loading Estimates
  - point source, nonpoint (stormwater and ag), atmospheric, boundary inputs (Delta and ocean exchange)
  - freshwater inflows and precipitation
  - nutrient forms – particulate and dissolved organic forms (C, N, P), inorganic forms and suspended solids
  - frequency considerations – weekly to monthly

Example Monitoring Programs and Costs

Chesapeake Bay

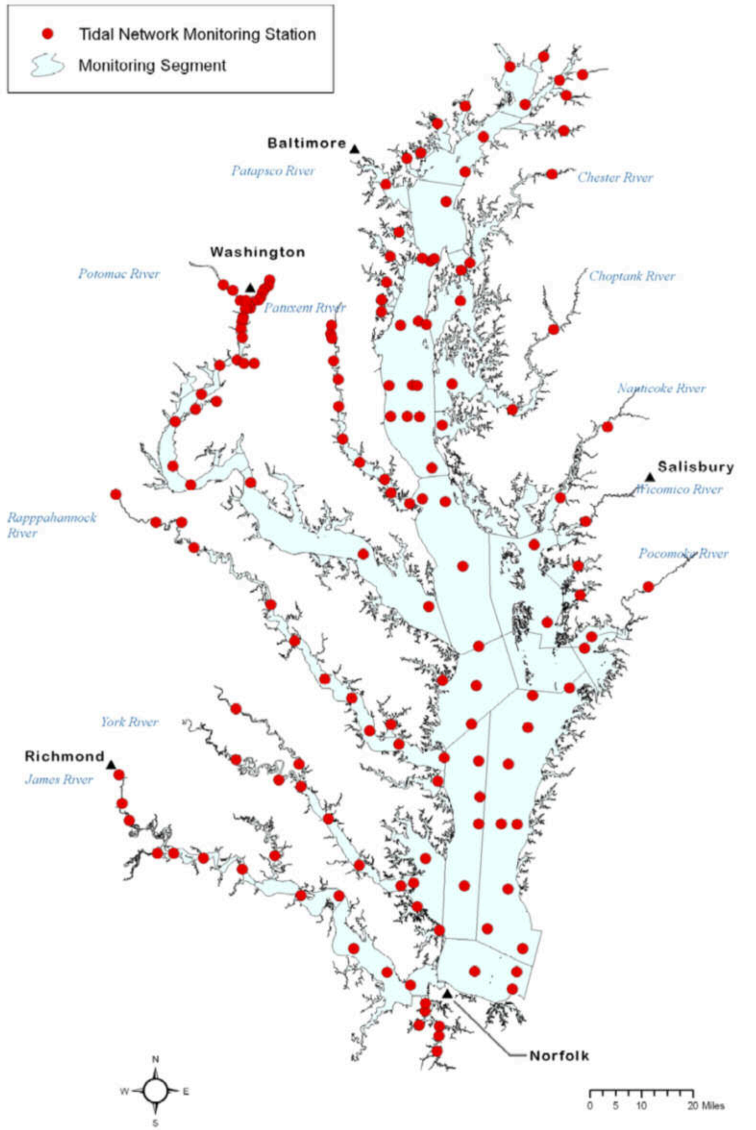
~150 sampling stations; 14 annual cruises

SAV, phytoplankton, benthic invertebrates and water chemistry (top/bottom +CTD)

~$3.8 M/year budget (50- 50 split Fed/ states;

~$100k/year special studies, e.g. sediment nutrient flux and SOD

Begun in 1985



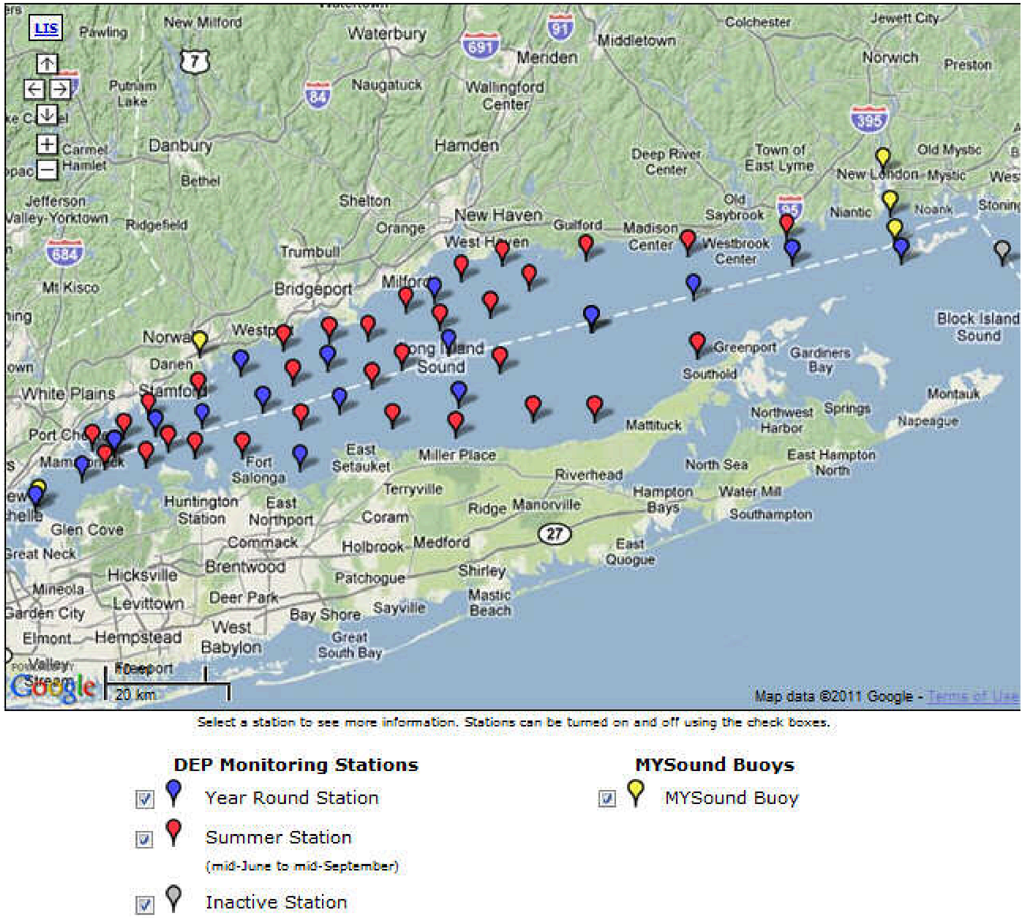
Long Island Sound

47 active stations

Sampling includes phytoplankton, zooplankton and water chemistry (top/bottom + CTD)

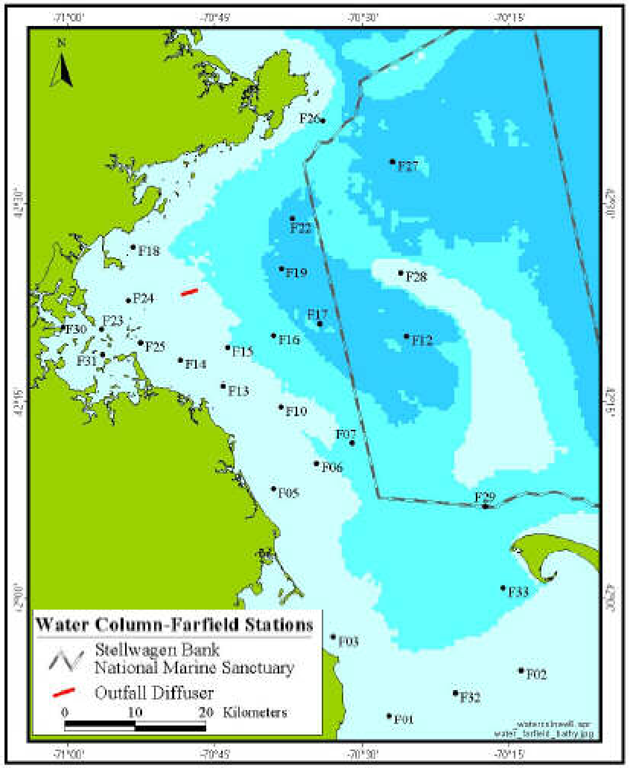
$850k /year Federal budget with some cost sharing from CTDEP

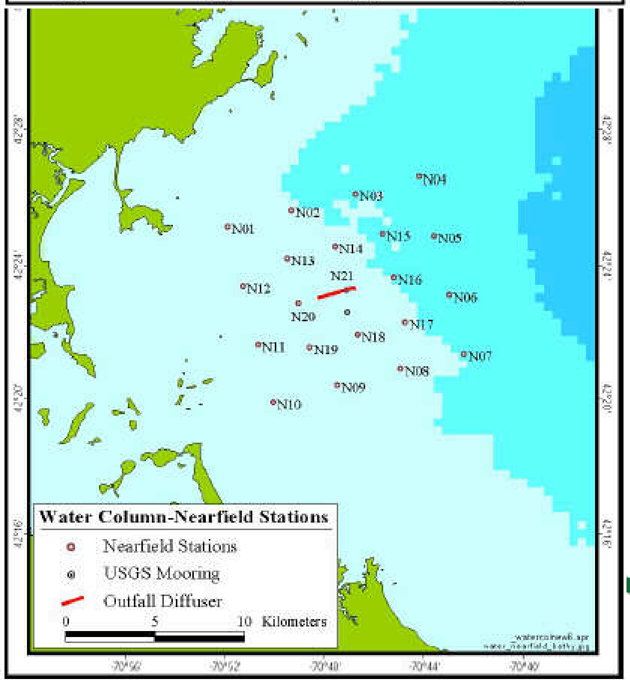
Begun in 1991



Massachusetts Bays System

- 21 near-field (outfall) and 22 far-field stations
- Sampling includes phytoplankton and zooplankton biomass + species composition, water chemistry (up to 5 depths + CTD) and some primary production
- Sediment nutrient flux and SOD
- $2.5-$3.5M/year MWRA budget
- Projected future costs of $1.5M/year (reduced monitoring plan -14 stations and 9 times/year)
- Begun in 1992



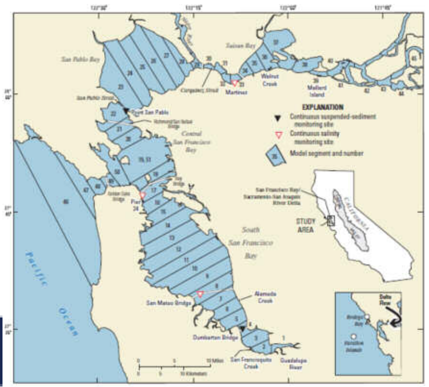


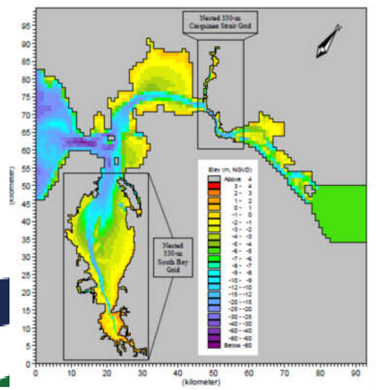
Based on existing models of SFB, where do we go from here?

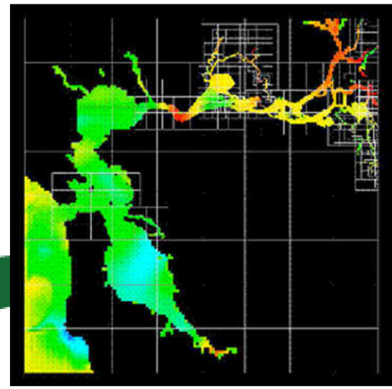
Hydrodynamic Models of San Francisco Bay

A number of hydrodynamic models exist for SFB

- 1-D: DSM (DWR) – well calibrated/no vertical structure - Delta
- 2-D: UP (Uncles-Peterson) model (USGS) - well calibrated
- 2-D: RMA2 (RMA) - finite element grid
- 2-D: MIKE-21(DHI) – proprietary, used to look at fate and transport of brake shoe copper
- 2-D: REALM (DWR/UCal-Berkeley, LBNL) - adaptive mesh/no vertical structure/work in progress

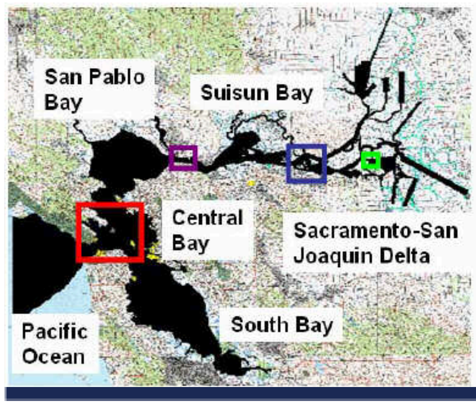


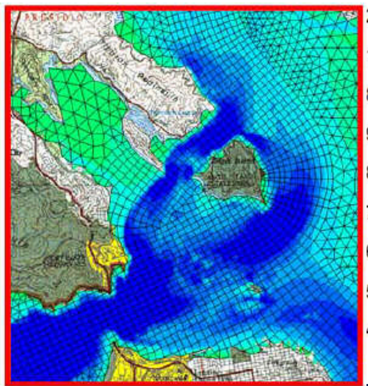


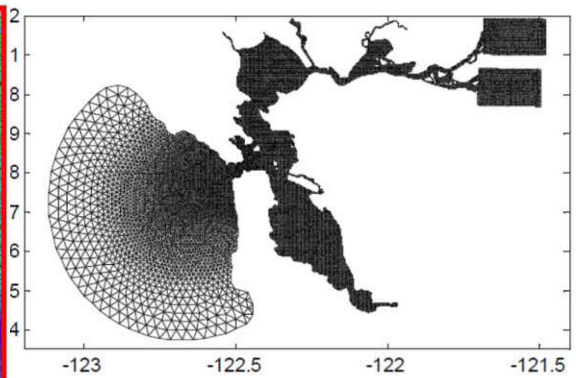


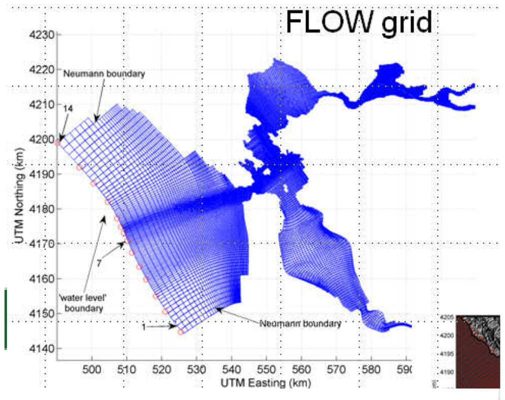
Hydrodynamic Models of San Francisco Bay

– 3-D: TRIM/TRIM3D (USGS) - proprietary, z-level, well calibrated
– 3-D: UnTrim (River Modeling) – proprietary, unstructured, well calibrated
– 3-D: SUNTANS (Sanford University) – open-source, unstructured, partial calibration
– 3-D: Deltf3D (Deltares) - open-source, structured, partial calibration









Water Quality Models of San Francisco Bay

- 1-D: DSM2-QUAL (DWR) – tracers, 1970's eutrophication kinetics
- 1-D: Various statistical, analytical and finite volume models
  - used to look at processes affecting phytoplankton in the SFB system
- 2-D: Lisa Lucas (USGS) – Pseudo-2-D hydrodynamic and phytoplankton model (no nutrients)

- However, no nutrient-based phytoplankton/dissolved oxygen model of the Bay exists
- Recent WQ data suggest increasing phytoplankton biomass – hence it may be time to consider the development of a modern eutrophication model

Recommended Initial SFB Modeling Steps

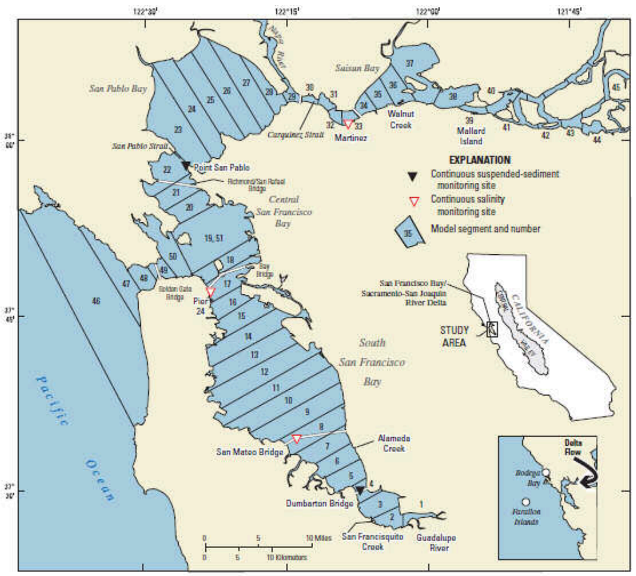
- 1st Step – develop Conceptual Site Model of SFB
  - Identify spatial resolution and processes to include in the model – will help focus data/research needs
- 2nd Step – develop monitoring/field data collection plans
  - Identify spatial and temporal resolution for data collection efforts and special studies/research efforts
- 3rd Step – begin preliminary modeling efforts
  - Develop initial assessment of the system
  - Identify research/monitoring/field data needs

Long-term Phased Modeling Approach is Recommended

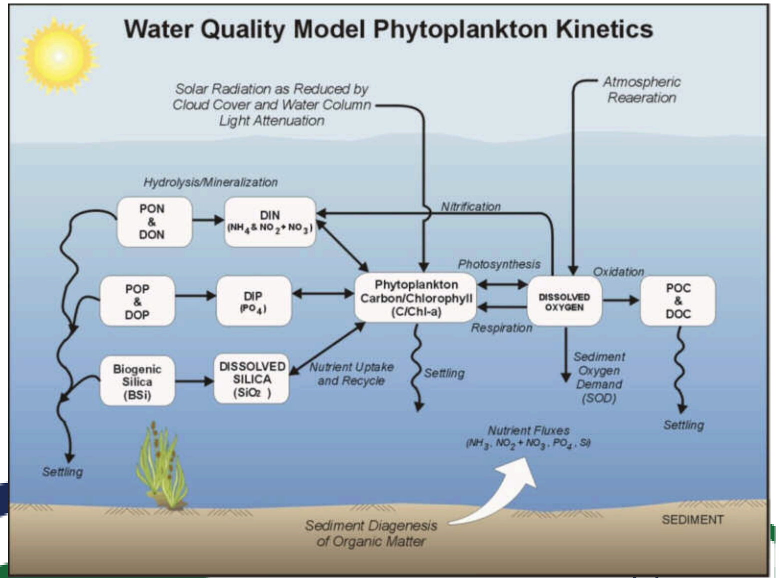
- Start simple and buildup
- Consider a series of continually refined (both spatially and process-driven) models - developed over time
- Build on previous 1-D process models
- Initial focus on developing nutrient mass balances
- Test "What If?" scenarios
- Processes could be expanded to consider effects of other co-factors influencing phytoplankton growth

Recommended Modeling Approach – 1st Step

- Time-variable “box” model approach, perhaps driven by information from 3-D hydrodynamic models of the Bay



- Modern eutrophication kinetics with “parameterized” zooplankton and suspension feeder grazing, but including sediment flux model



Applications for Initial Model

- Develop initial mass balance for nutrients
- Confirm or refine previous 1-D process models, but on a baywide basis
- Decadal changes? - can the model confirm that recent increases in light availability and reductions in benthic grazers explain the changes in phytoplankton biomass?

Questions