Science to Support Nutrient Management in San Francisco Bay

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Outline

- Background: nutrients in SFB

- SFEI Nutrient Initiatives

  - *Science synthesis to inform management decisions*

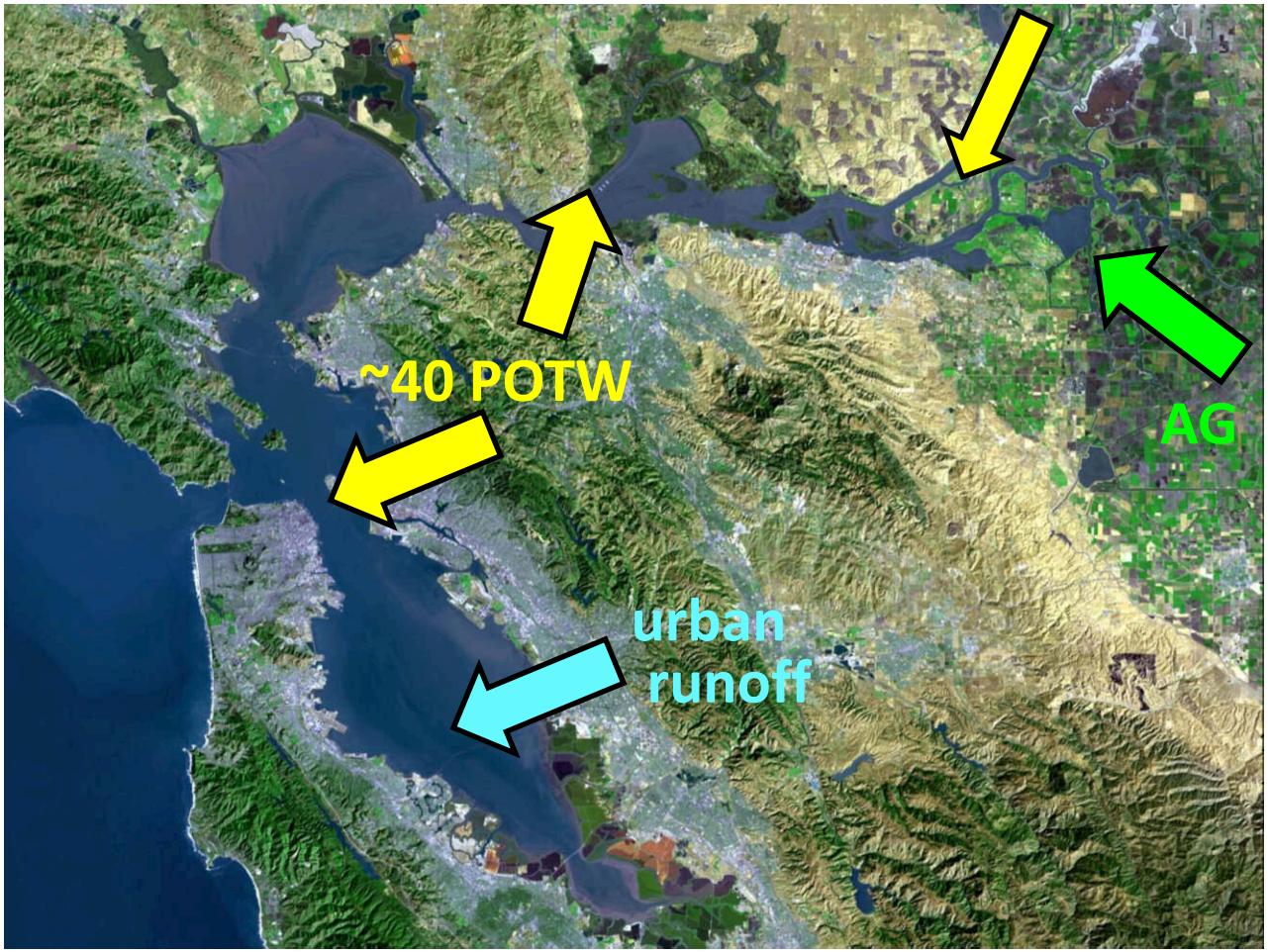
  - *Monitoring*

  - *Quantifying nutrient loads*

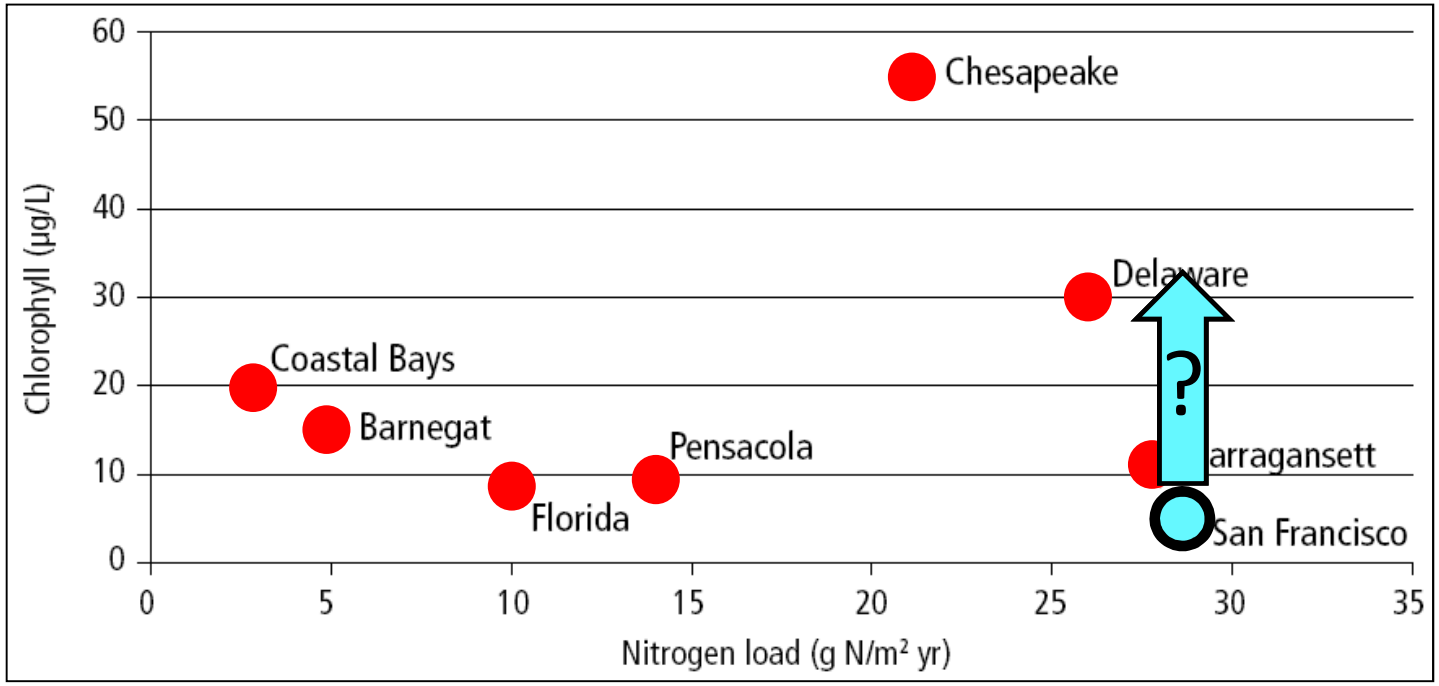
  - *Load-response modeling*

- SFEI and SCCWRP collaboration

San Francisco Bay - Large nutrient loads…



San Francisco Bay Paradox



National Estuarine Experts Workgroup (2010)

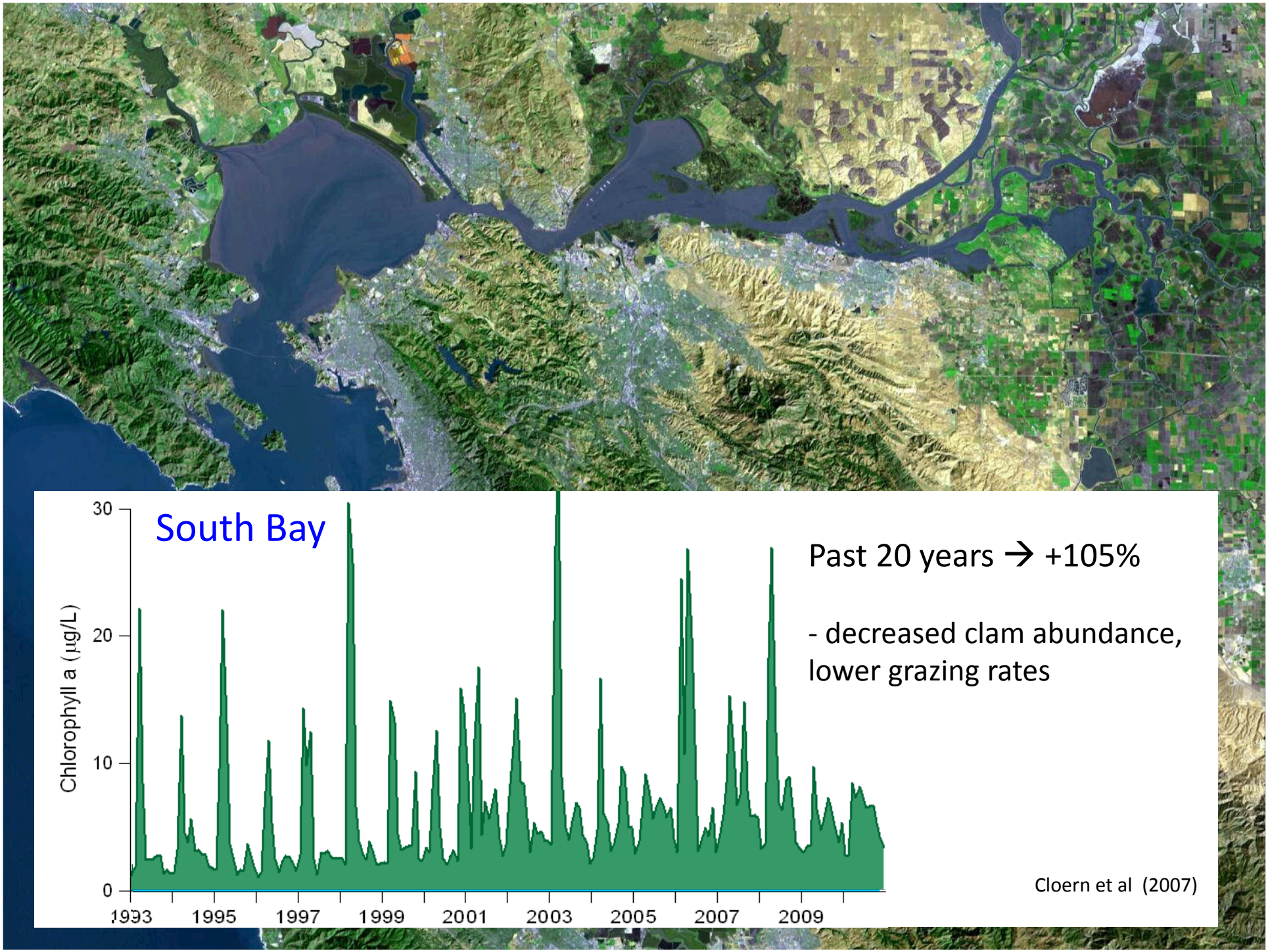
Resilience of San Francisco Bay

1) High turbidity

2) Strong tidal mixing

3) Filter-feeding clams

} Subject to change?

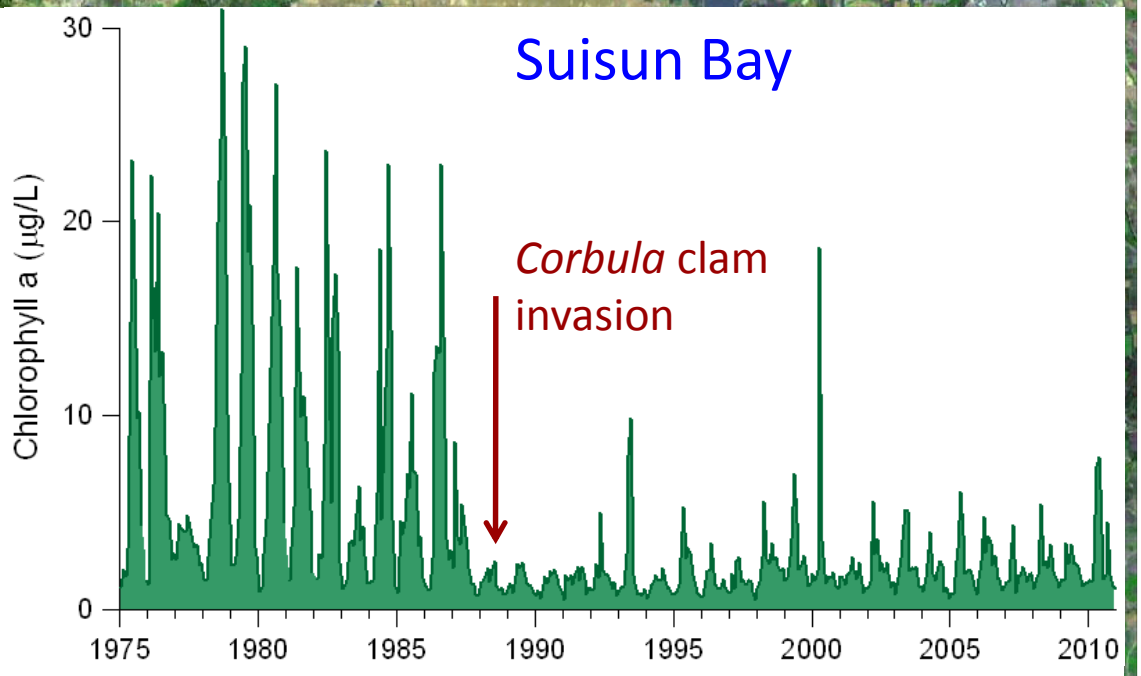

South Bay
Chlorophyll a (µg/L)
30
20
10
0
1993
1995
1997
1999
2001
2003
2005
2007
2009
Past 20 years → +105%
- decreased clam abundance, lower grazing rates
Cloern et al (2007)

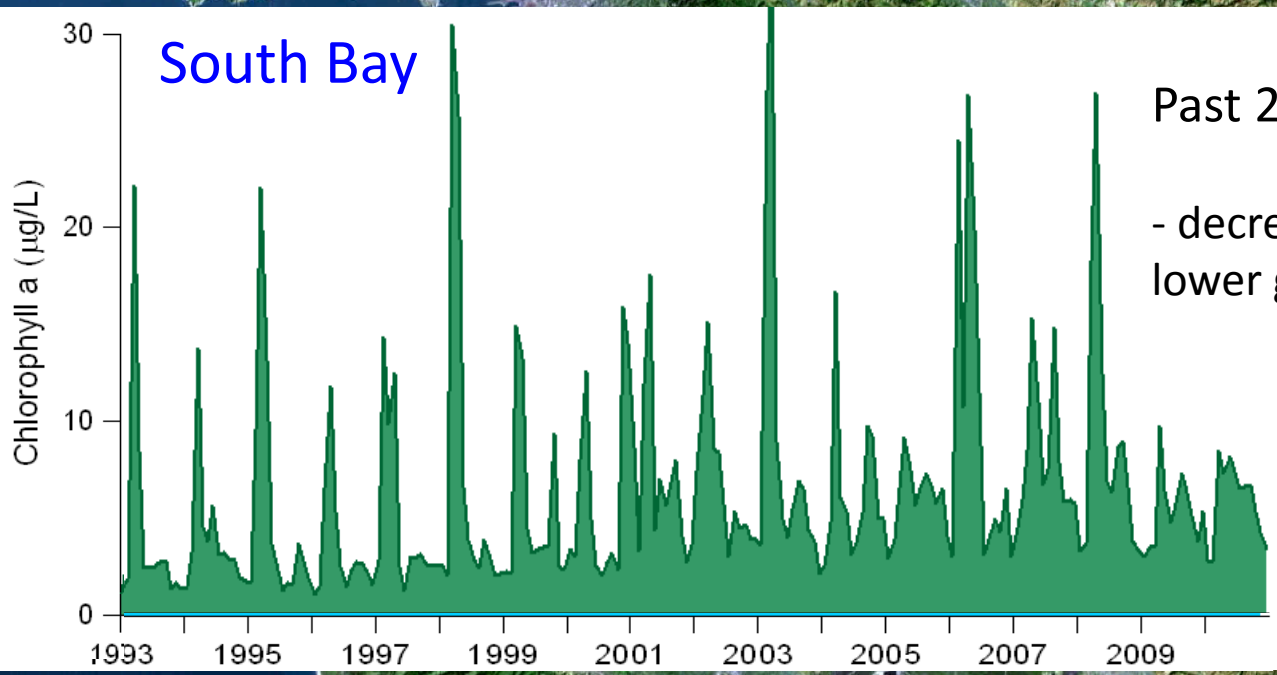
- low Chl-a → food limitation

- Past 20 yrs → +32%

Source: J. Cloern, USGS

- NH_4^+ impacts
  - impairing primary production?
  - toxicity to copepods?





Past 20 years → +105%

- decreased clam abundance, lower grazing rates

Cloern et al (2007)

Need for a Bay-Wide Nutrient Strategy

- Nutrient objectives on the horizon: Nutrient Numeric Endpoint (NNE)

- Consensus among scientific community: Bay conditions are changing
  - increasing chl-a, harmful algal blooms, other roles of NH_4^+ (?)

- No regionally-administered water quality monitoring program
  - uncertain future for USGS research program (40 yr record)

- Lot of nutrient-related work being done with limited coordination

SFEI Nutrients - Science to Support Management Decisions

- ***Synthesis to inform management decisions***

- ***Monitoring Program Development***

- ***Quantifying loads***

- ***Load-response modeling***

SFEI Nutrients - Science to Support Management Decisions

- ***Synthesis to inform management decisions***
  - Bay nutrient strategy
  - Conceptual models, problem definition
  - Objectives and assessment framework: phytoplankton, D.O., NH_4^+

- ***Monitoring Program Development***

- ***Quantifying loads***

- ***Load-response modeling***

Key Management Questions

Is there a nutrient problem, and how is it defined?

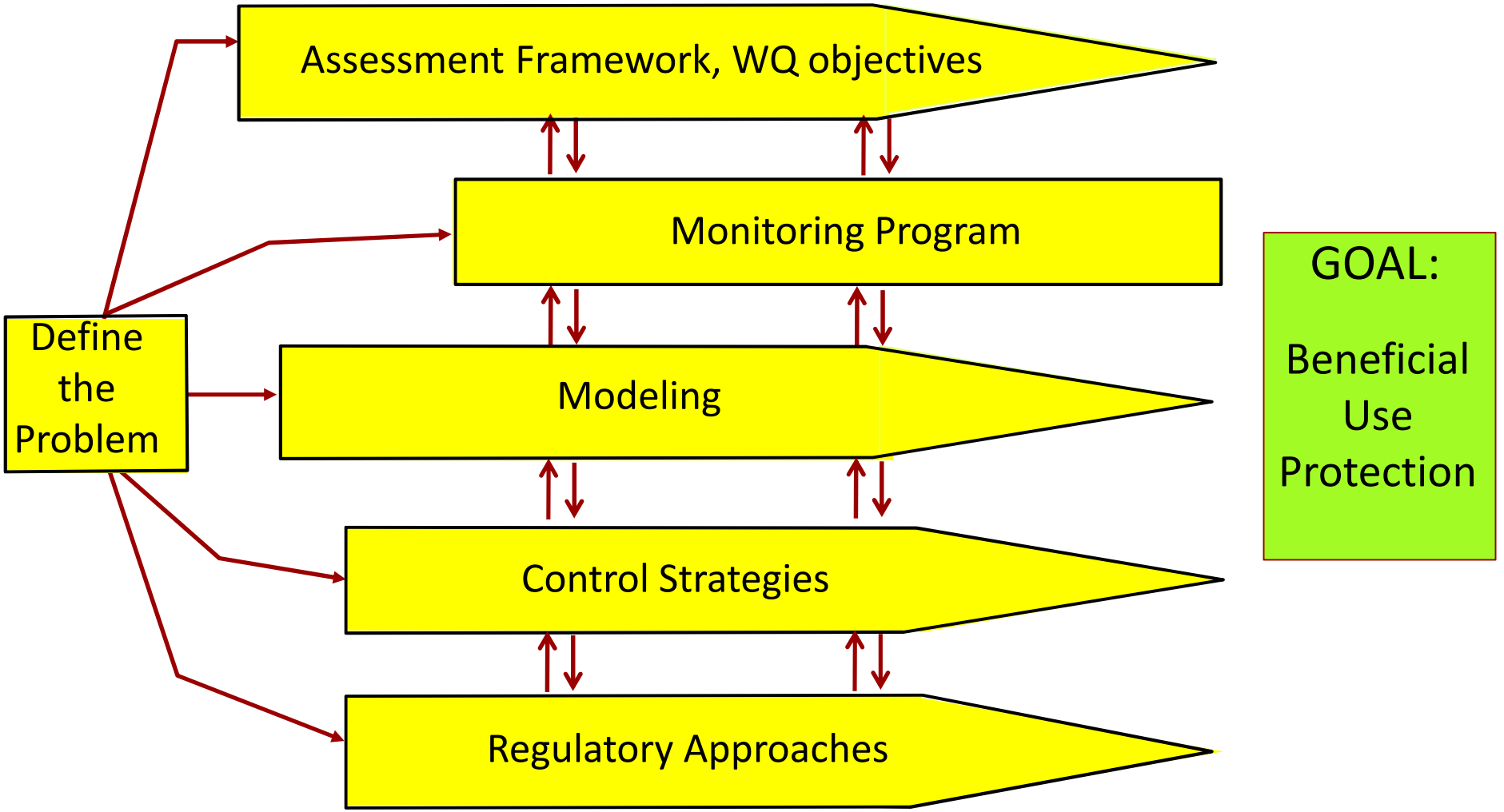
- *Now? Future? Under what scenarios?*
- *In which Bay segments/habitats?*

Most important sources, pathways, and processes?

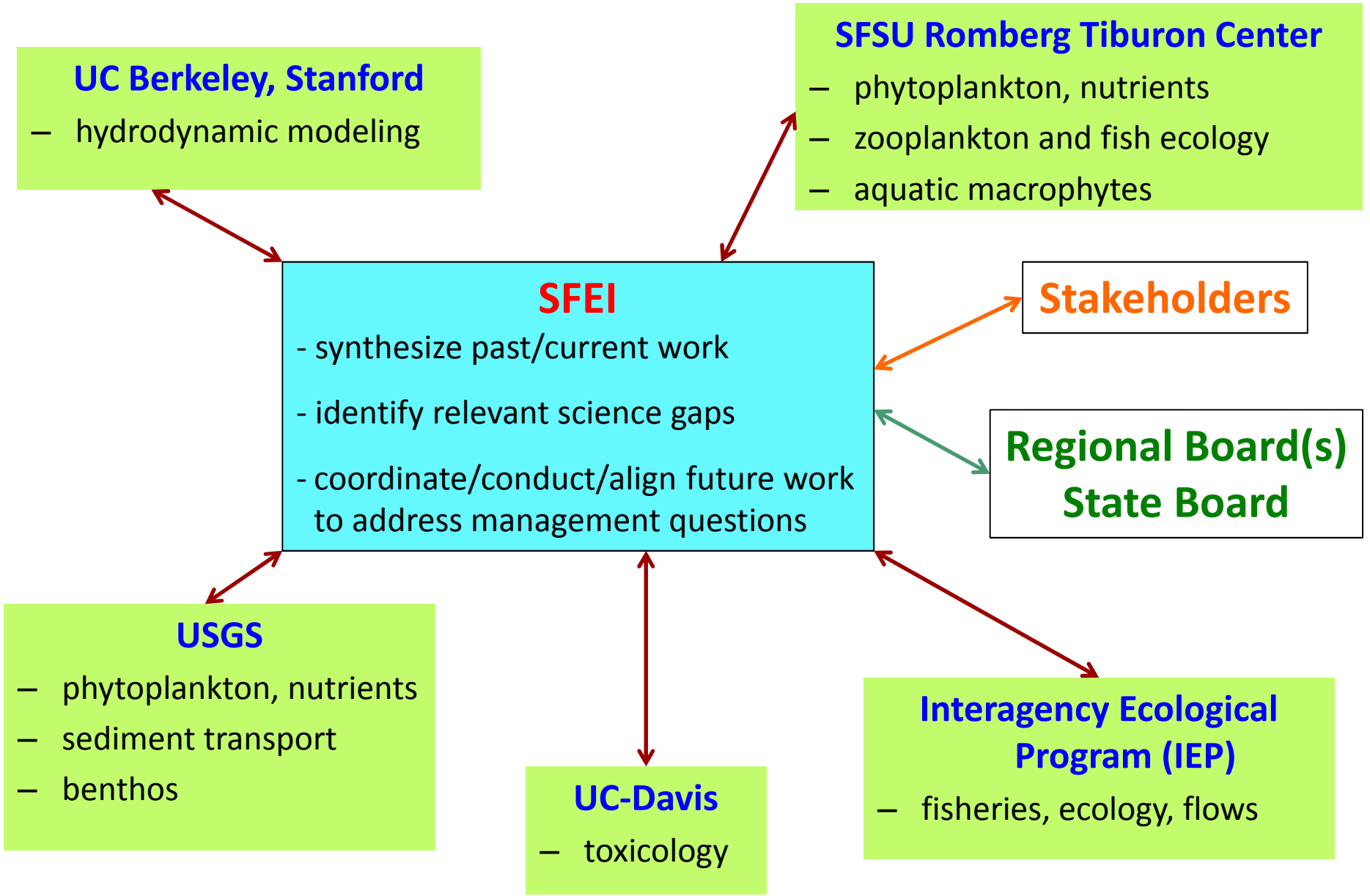
What loads can be assimilated without impairing beneficial uses?

What are appropriate guidelines for identifying a problem?

Draft Nutrient Strategy



Strong Bay/Delta Research Community



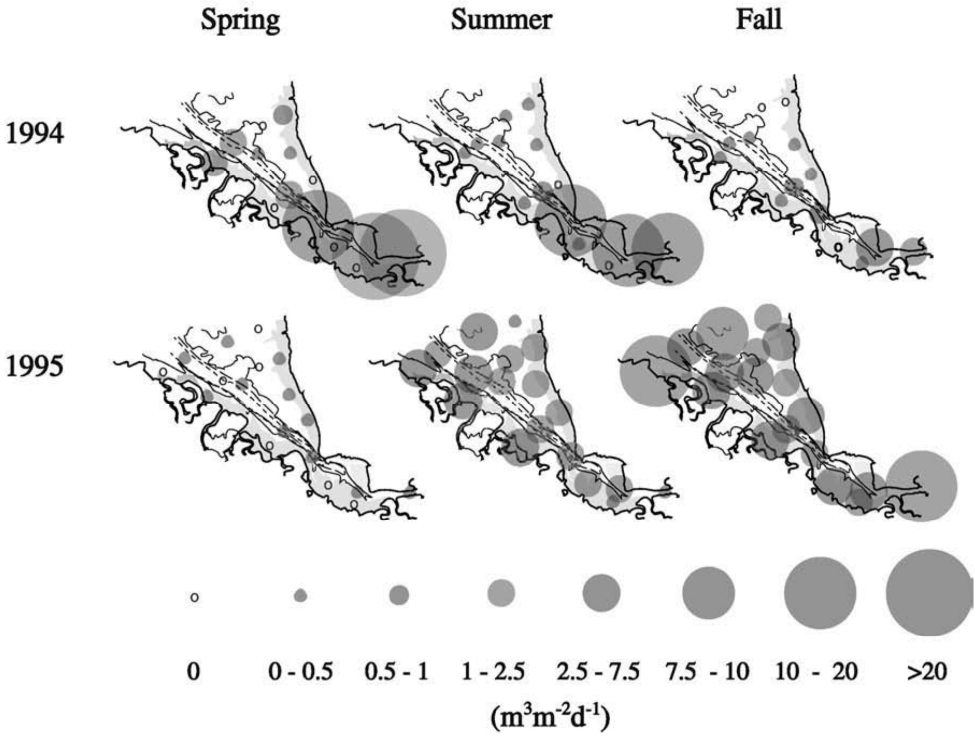
Bloom formation: South Bay

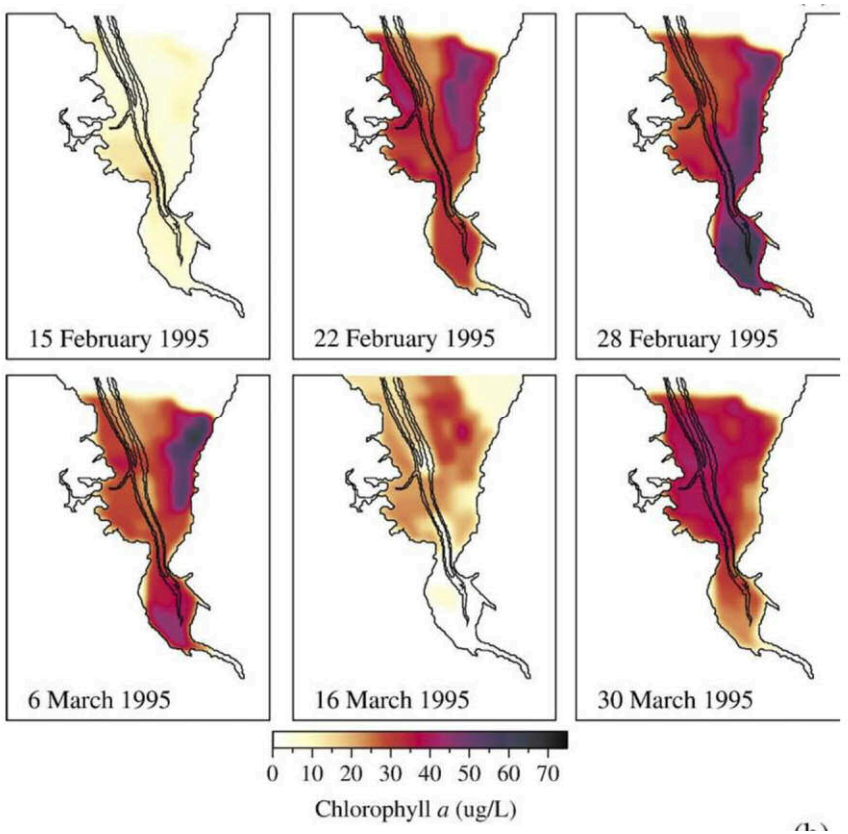
Physics and Benthos

- light limitation

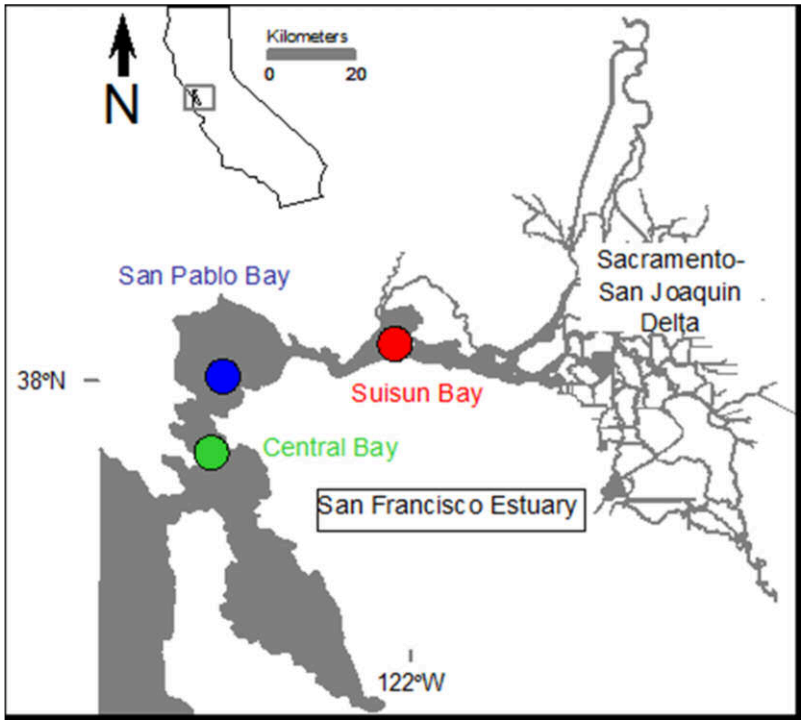
- lateral exchange
  - light-rich shoals
  - light-poor deep subtidal

- seasonal/interannual variations in clam abundance

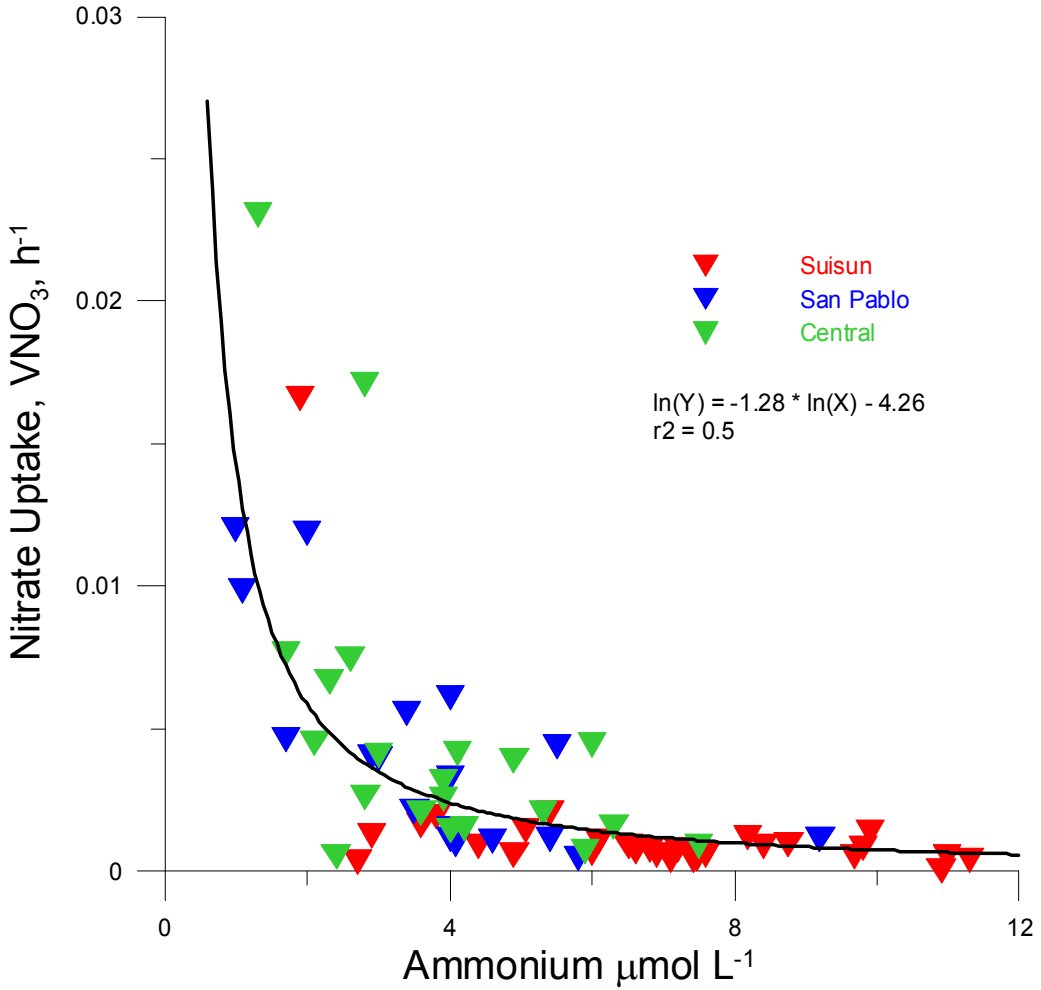




Thompson et al. 2008
Lucas et al., 2008



Evidence of NH4 inhibiting NO3 uptake



Dugdale et al., 2007

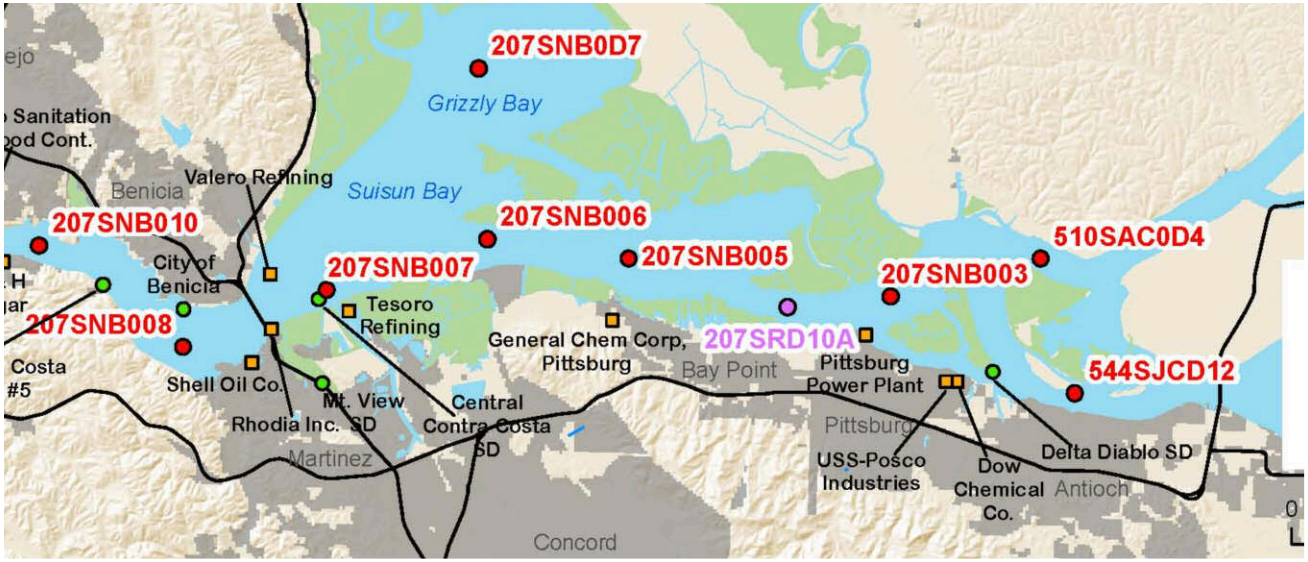
Suisun Bay Study (2010-2012)

Objectives:

- Determine if NH4, copper and/or pesticides cause inhibition of primary production (laboratory study – TIE)

- Determine if NH4 conc, specific nutrient ratios, or nitrogen uptake rates are related to a lower rate of primary production (field study)

Researchers/Funding: Region 2, SFSU-RTC, SWAMP, Water Contractors, Central Contra Costa Sanitation District



Interagency Ecological Program – Delta and Suisun Bay

- Emphasis on underlying causes of Pelagic Organism Decline (POD)
  - *~$25mill/yr*

- Highly altered ecosystem: withdrawals, altered habitat, contaminants
  - *multiple factors likely contribute to POD*

Baxter et al. 2010

- Major changes in lower food web of Delta and Suisun Bay
  - *phytoplankton biomass*
  - *zooplankton: biomass, community composition, size*

Jassby 2008
Winder and Jassby 2011

- *Microcystis* blooms with increasing frequency in the Delta

Lehman et al. 2005, 2008

Other Suisun/Delta Nutrient Studies

Microcystis in the Delta (2011-2014; Parker et al., SFSU-RTC)

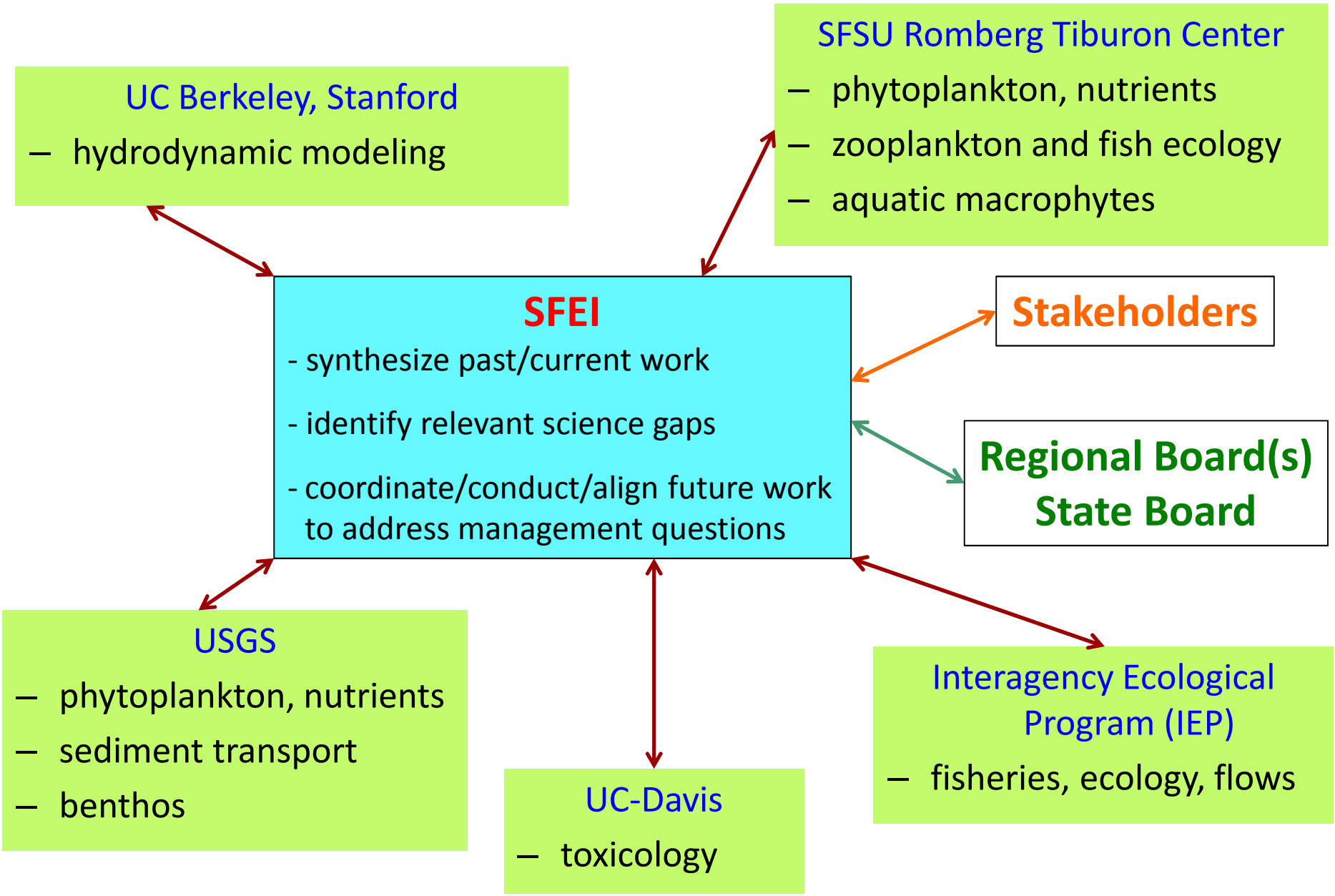
Goal: Determine environmental conditions leading to Microcystis blooms, their toxicity, and their impact on the pelagic food web

Effect of nutrient forms/ratios and light availability on Delta lower food web (2011-2014; Glibert et al. U-Maryland)

Goal: Test the relationship between phytoplankton community composition/production and N and P ratios and chemical form, and light availability

Sediment flux study (2011-2014; Glibert and Cornwell, U-Maryland)

Strong Bay/Delta Research Community



Problem Definition: Conceptual Models, Scenarios

(2012) RMP

What current problems, or future scenarios, are most concerning?

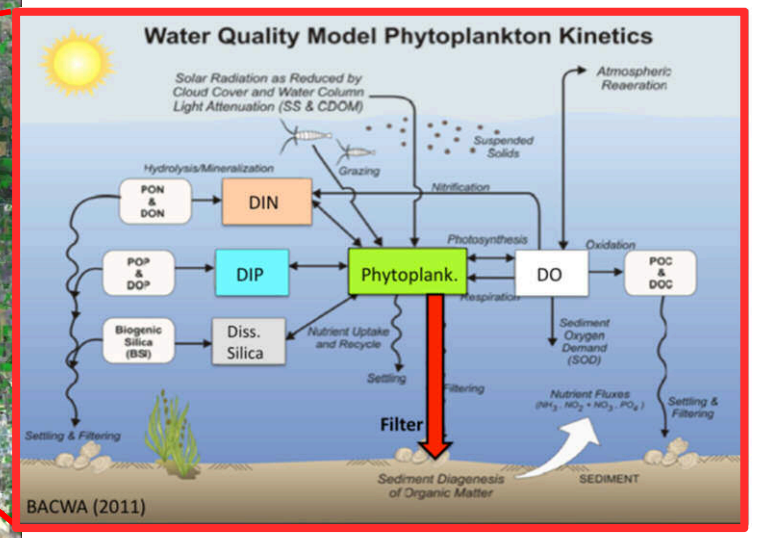
What information do we need to evaluate these problems/scenarios?

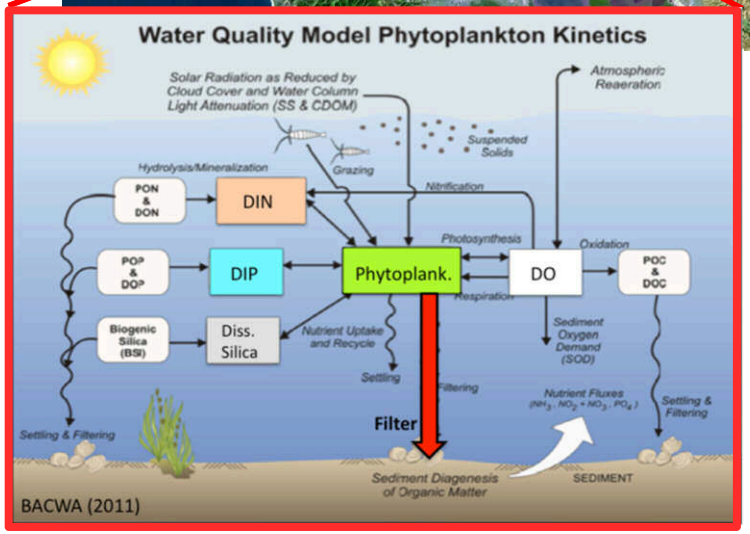
How do we detect current problems or the onset of future problems?

Problem Definition: Conceptual Models, Scenarios

Example Scenarios

- 1% per year decrease in sediment load
- decreased clam abundance
- changing nutrient loads, NH4:NO3, N:P:Si
- drought conditions
- climate change effects





Outcomes

- 'Consensus' statement on nutrient outlook for the Bay
- Critical knowledge gaps and science plan
- Feedback to assessment framework
- Monitoring/Modeling recommendations

Phytoplankton Assessment Framework

SWRCB

(2012-2013)

Phytoplankton: leading candidate indicator for assessment of Bay eutrophication

What are the precise measures of phytoplankton that we need to assess ? Biomass ? Assemblage? Harmful algal species?

What are the appropriate thresholds for regulatory action?

What kind of monitoring data are needed to make an assessment?

Phytoplankton Assessment Framework

SWRCB

(2012-2013)

Phytoplankton: leading candidate indicator for assessment of Bay eutrophication

<u>Outcomes</u>

- Transparent decision framework to determine whether regulatory action is required
- Numeric targets that can be used to inform decisions on load allocations

Suisun Bay: evaluating potential impacts of nutrients and NH_4^+

(2012-2015)

Complex management questions

- Pelagic Organism Decline (POD)
- Phytoplankton and zooplankton
  - Decreased abundance
  - Different community composition
- Potential links to nutrients, with specific focus on NH_4^+

Suisun Bay: evaluating potential impacts of nutrients and NH_4^+

(2012-2015)

Outcomes

- Synthesis – Nutrient/NH_4^+ role in…
  - *altered phytoplankton community composition?*
  - *low primary production rates?*
  - *copepod toxicity*
- Data gaps and future studies

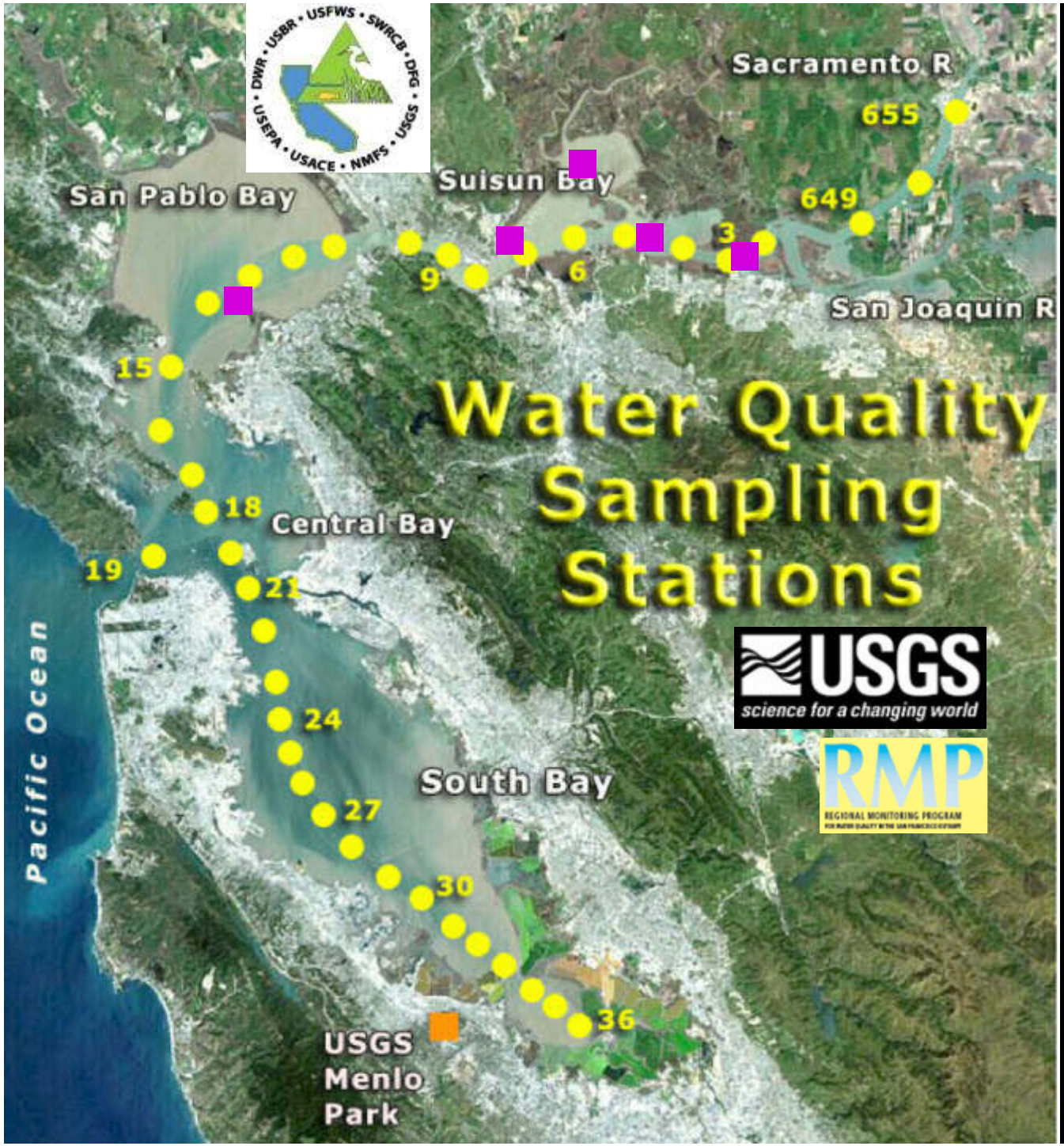
SFEI Nutrients - Science to Support Management Decisions

- *Synthesis to inform management decisions*

- ***Monitoring Program Development***
  - Nutrient/water quality monitoring program development
  - Special Studies

- *Quantifying loads*

- *Load-response modeling*



1969-present

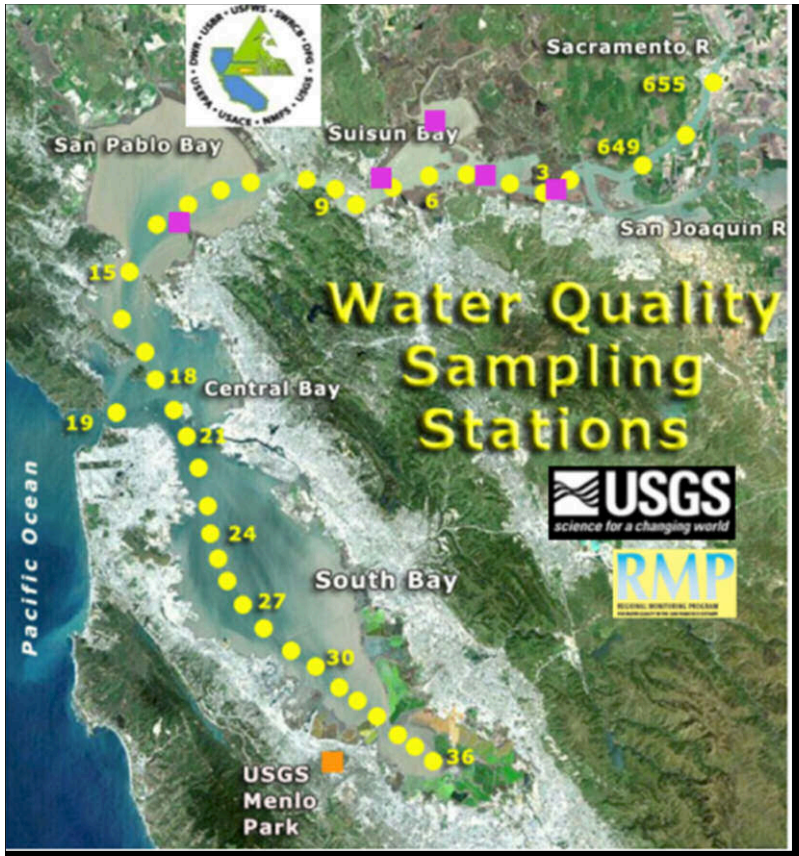
- monthly sampling

- research studies

- RMP support
  -1993-present

● USGS

■ IEP

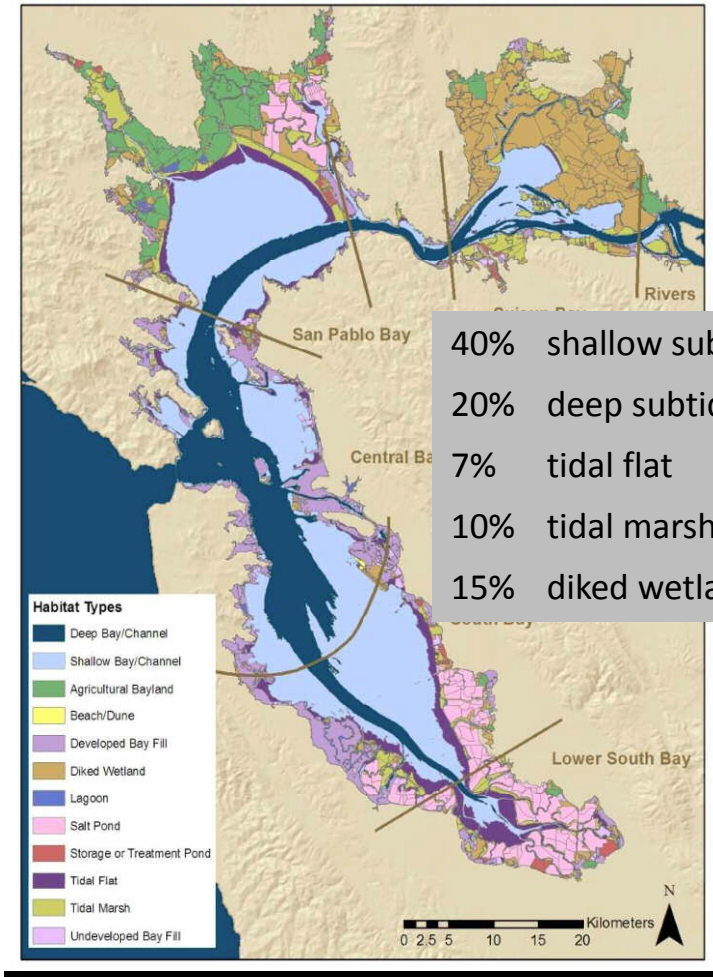


Next Generation…

"Regular" Monitoring

- identify optimal spacing along spine

- complement with moored sensors



40%	shallow subtidal
20%	deep subtidal
7%	tidal flat
10%	tidal marsh
15%	diked wetland

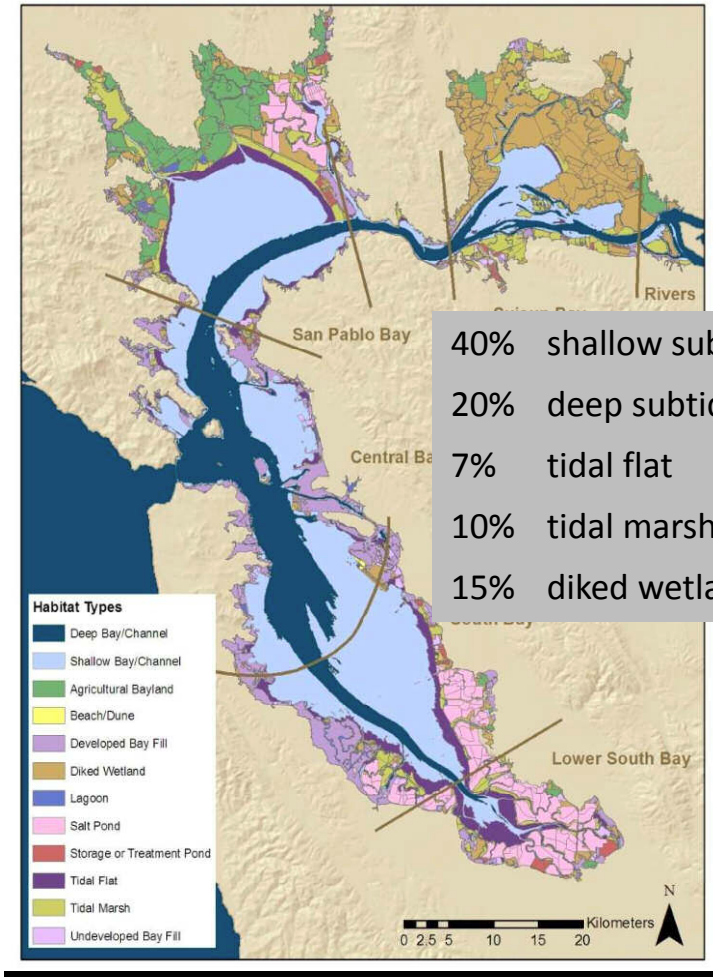
Next Generation…

"Regular" Monitoring

- identify optimal spacing along spine
- complement with moored sensors
- lateral transects

Special studies

- processes, internal cycling
- focus sites/habitats
- exchange across Golden Gate



40%	shallow subtidal
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Parameters

- *Chemical/biological*
  - salinity, T, PAR, nutrients, DO
  - chl-a, phytotoxins
  - phytoplankton composition
  - zooplankton abundance/composition
  - benthos
- *Processes*
  - growth/uptake kinetics
  - denitr., nitrif., oxygen demand
- *Physical*
  - velocities/exchange (ADVs)

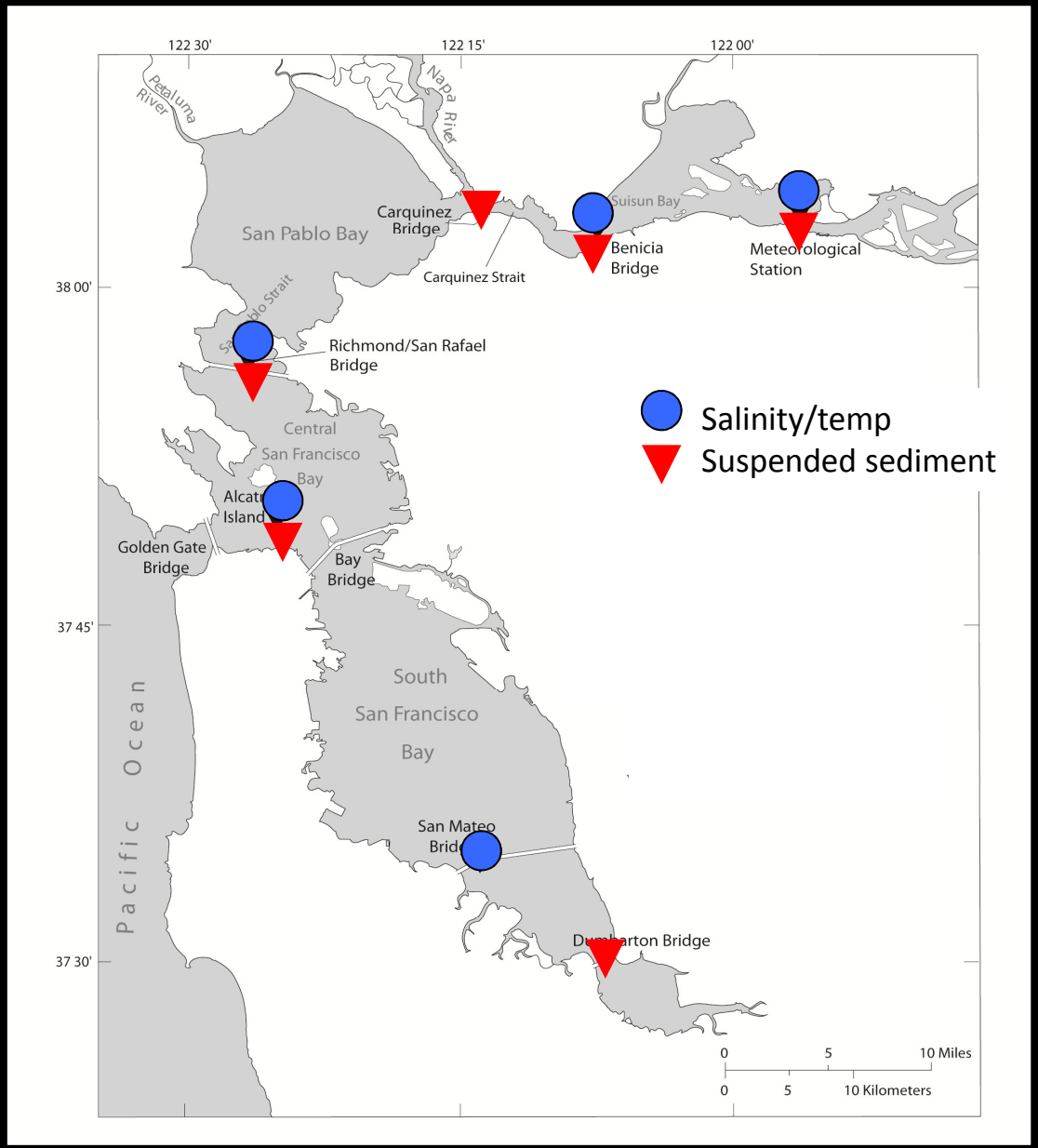
Continuous monitoring

<u>Suspended sediment</u>

- 15 minute interval
- 1991-present
- Funding: RMP & USACE

<u>Salinity/T:</u>

- 15 minute interval
- 1989-present
- Funding: IEP & DWR, USGS



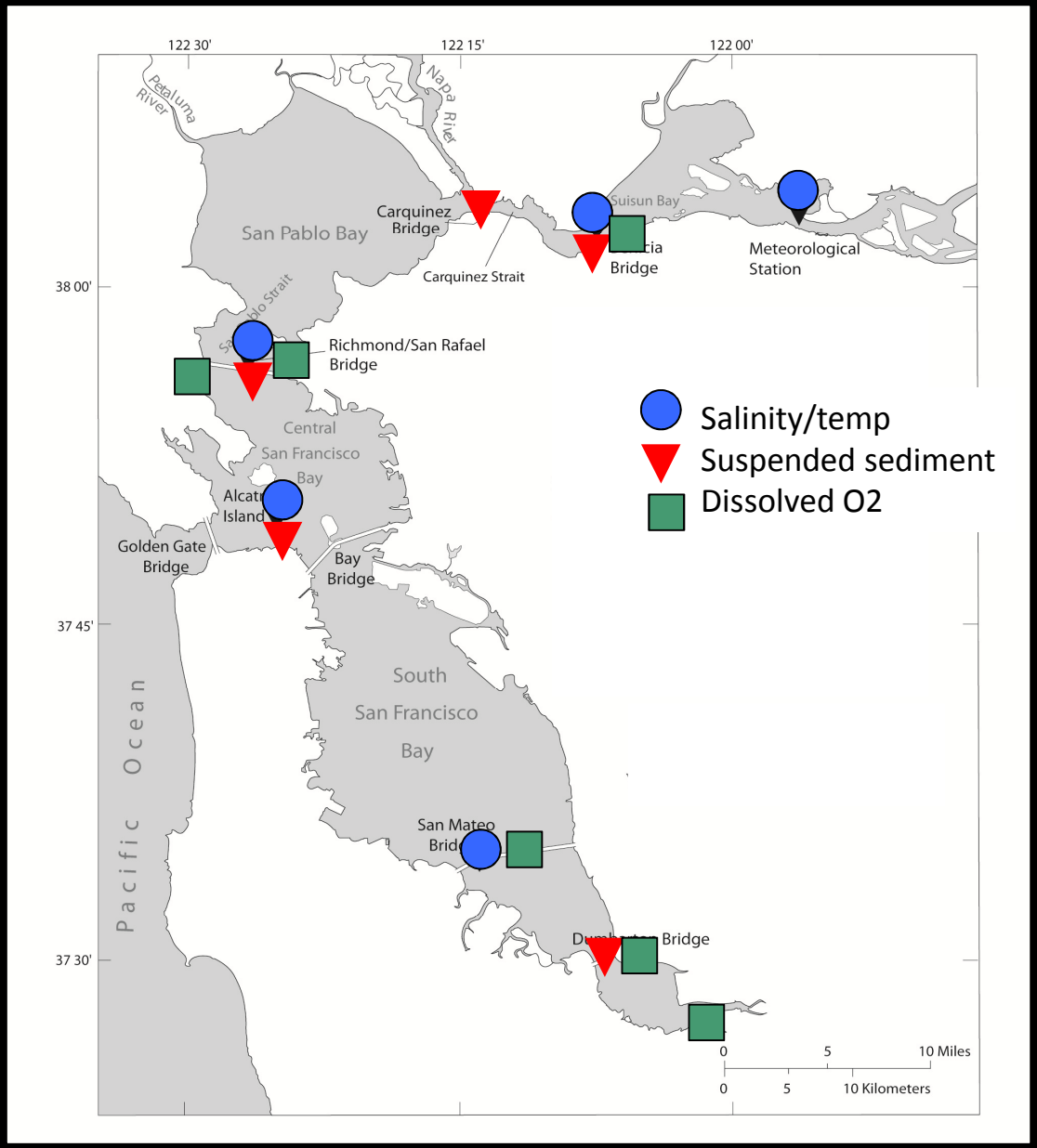
Continuous monitoring

Dissolved Oxygen

- on the horizon…

What else??

- chl-a ?
- nutrients ?
- flow cytometry ?



SFEI Nutrients - Science to Support Management Decisions

- *Synthesis to inform management decisions*

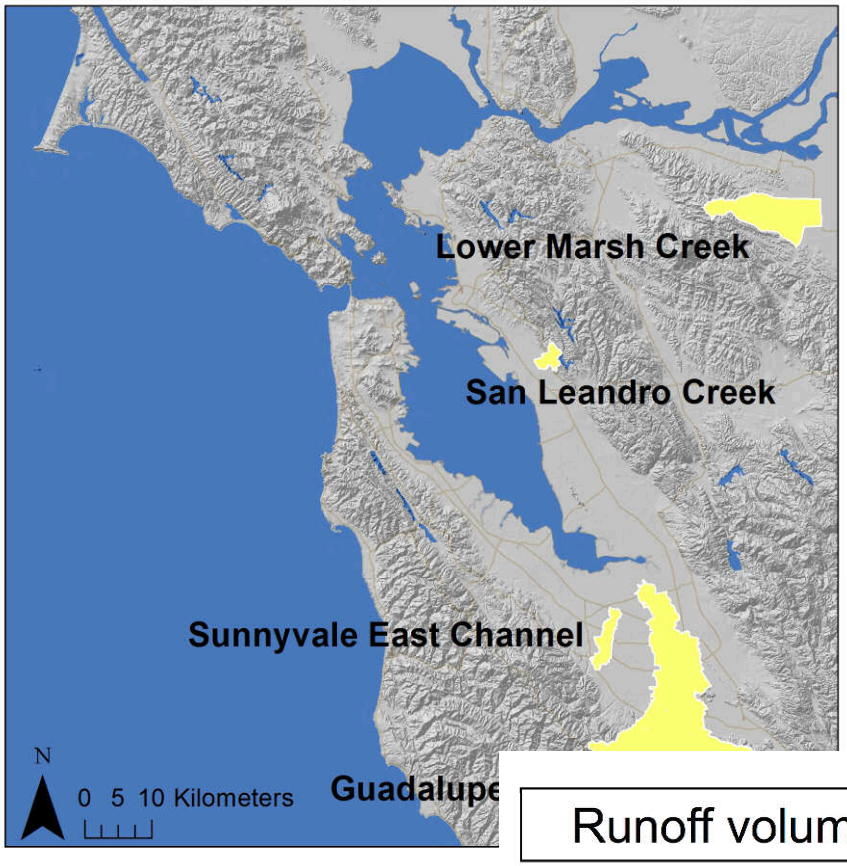
- *Monitoring Program Development*

- ***Quantifying loads***
  - On-going watershed loading studies
  - Effluent characterization and Bay segment load estimates

- *Load-response modeling*

Contaminant export from urban watersheds

- 10 year SFEI history of characterizing contaminant export from Bay-area watersheds
  - Stormwater sampling program
  - 20+ watersheds characterized to different degrees
  - Focus: Hg, PCBs, dioxin, other organics, suspended sediments
  - Limited focus thus far on nutrients

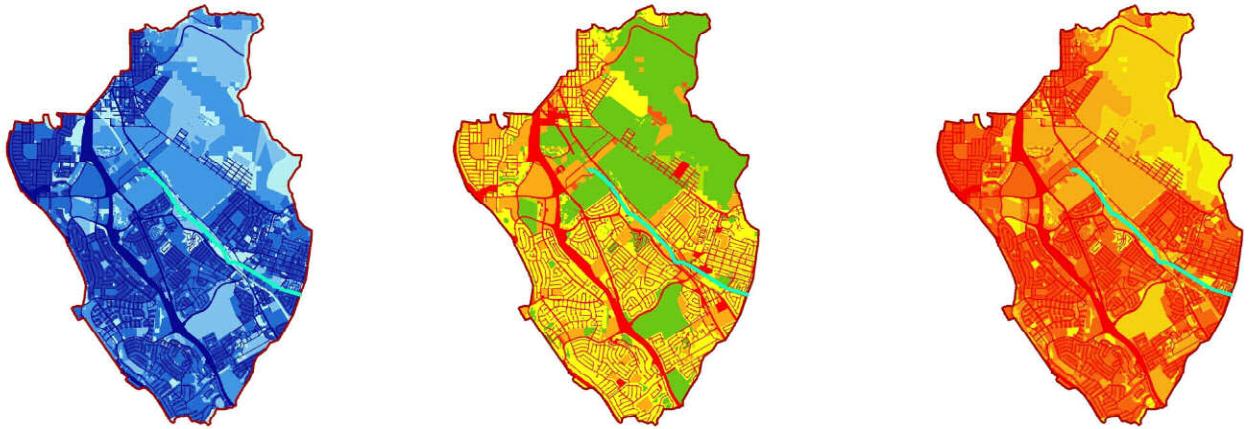


Current Studies: nutrients

- 4 watersheds in 2012, 4 storms
- 4-6 watersheds in 2013-2014
- contaminants, flow, turbidity
- Added:
  - -NO3, NO2, NH4, PO4, TN, TP

Runoff volume* x Concentration = Load

Developing GIS-based "spreadsheet" Regional model

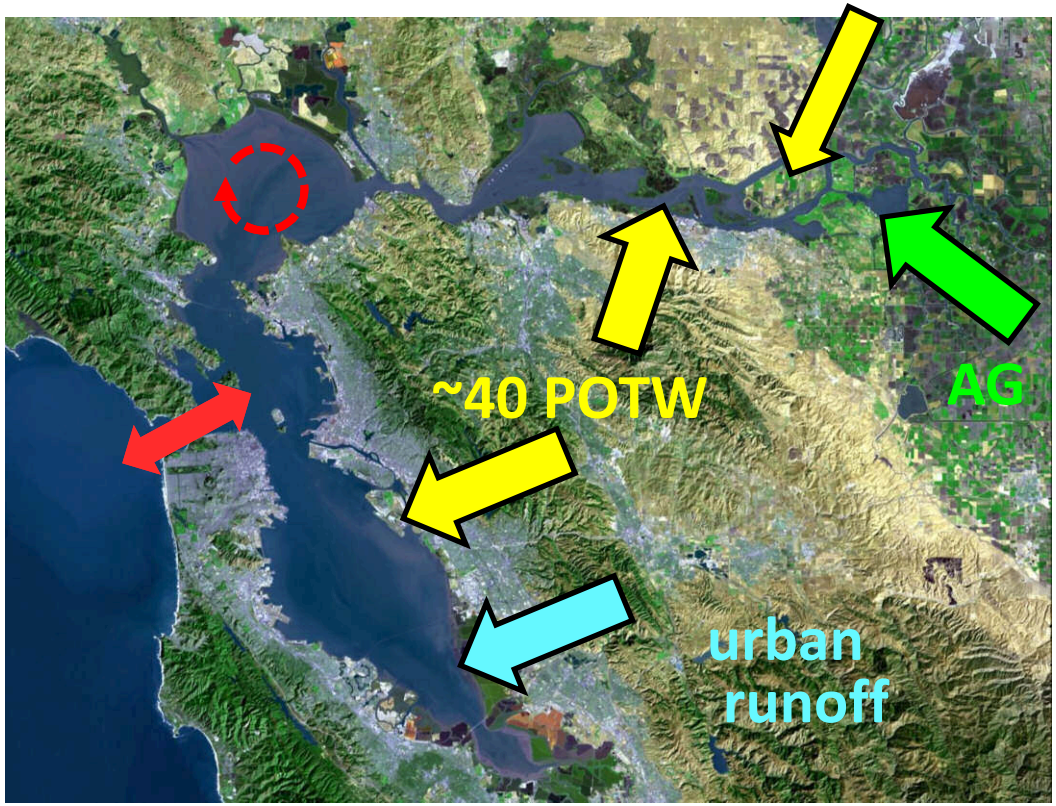


Lent and McKee (2011)

Funding: RMP and BASMAA

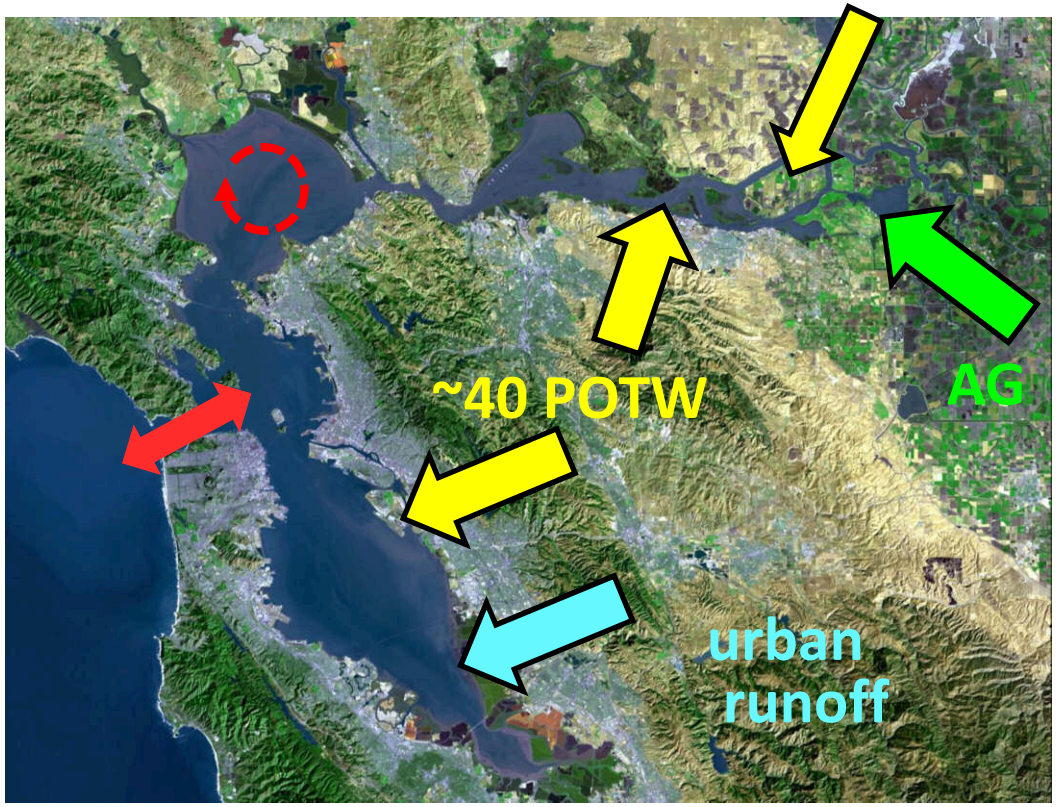
Assess Nutrient Loads to the Bay

(2012-2013) RMP



- Assess major nutrient loads (and composition)
- Characterize variations in space and time
- Identify major uncertainties and data gaps, future work

Assess Nutrient Loads to the Bay



Very Rough Numbers

	Tons DIN/yr
Bay POTWs	18,000
SacRegional	5,000
Sac+SJ Rivers (Agriculture*)	5,000
Urban runoff**	1,000

- *Space/time will be important (Bay segments)*
- *POTW effluent characterization*
- *Urban runoff contribution, and Delta inflow*

*Kratzer et al. (2011)

**Gluchowski and McKee (2011)

SFEI Nutrients - Science to Support Management Decisions

- *Synthesis to inform management decisions*

- *Monitoring Program Development*

- *Quantifying loads*

- ***Load-response modeling***

    - Modeling program development (hydrodynamics, nutrients/contaminants)

Bay/Delta Modeling

- Engaged and top-notch Bay/Delta modeling community

- Multiple platforms, multiple actors, and multiple funders
    - 1D, 2D, 3D
    - Delft3D, UnTRIM, SUNTANS, EFDC
    - limited agreement on “the best model”

- *Strengths*: hydrodynamics and sediment transport

- *Weaknesses*: water quality (nutrients, phytoplankton, D.O.) and contaminant models

Modeling Needs for Nutrient Management

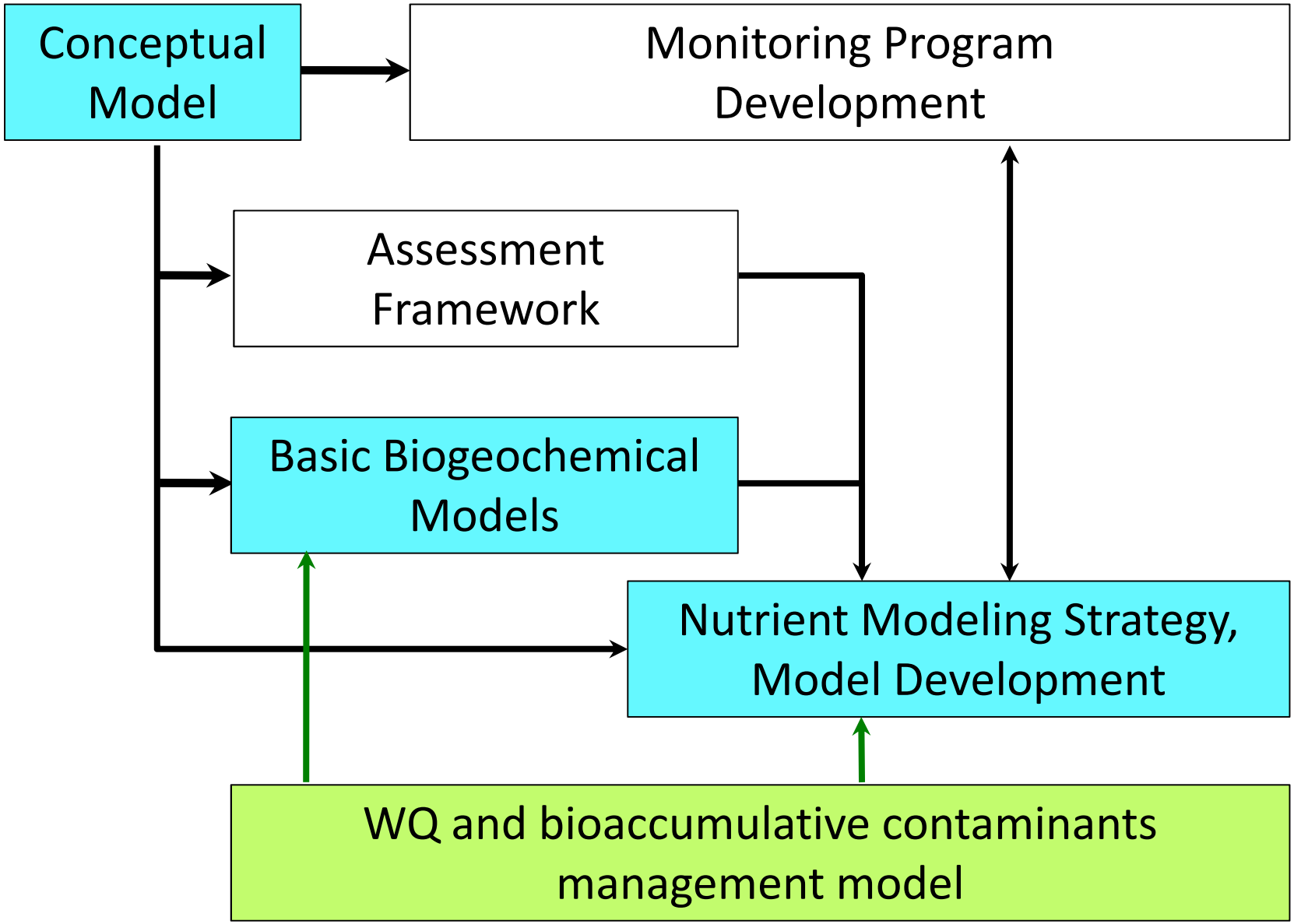
- Goldilocks hydrodynamic model
    - *sufficiently complex, but useable by non-developers*
    - *open-source*

- Development of a WQ/phytoplankton model

- Coupling with coastal ocean model (ROMS)
    - *upwelling and exchange across Golden Gate*

- Compatible (to extent possible) with needs for other contaminants

Staged Approach:



Numeric Models: Suisun Bay, South Bay

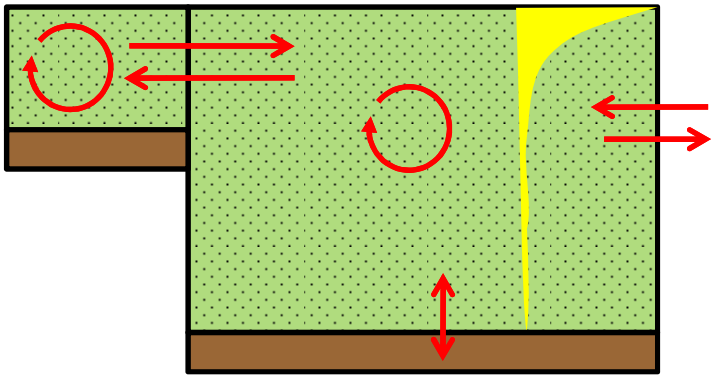
BACWA

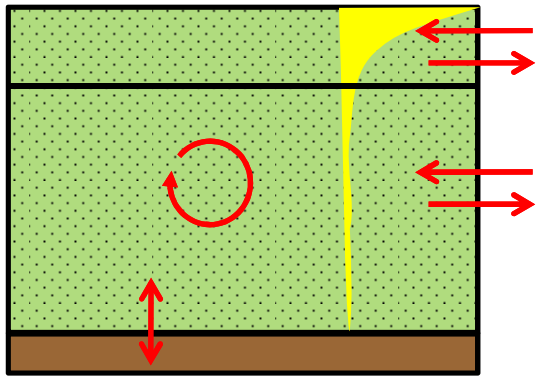
(2012-2014)

- Quantitative data synthesis and nutrient budgets
- Assess relative importance of key processes/drivers
- Sensitivity analysis, identify critical uncertainties and data gaps
- Characterize system response (e.g., chl, O_2) under future scenarios

Numeric Models: Suisun Bay, South Bay

BACWA

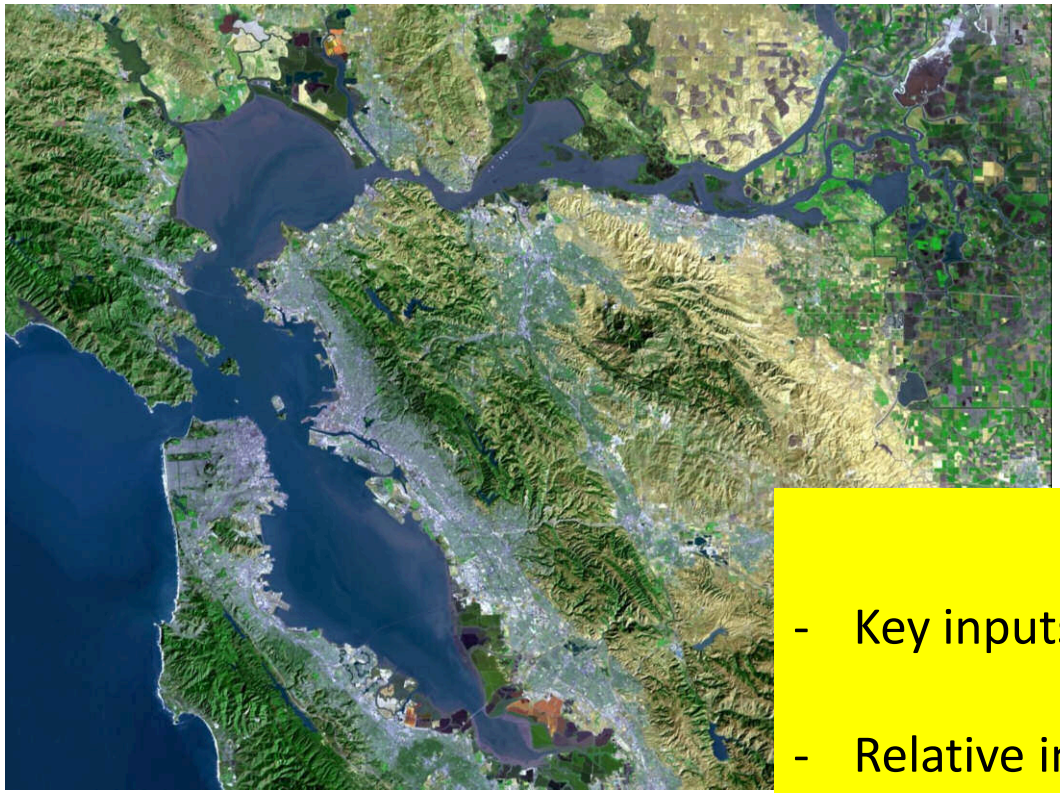


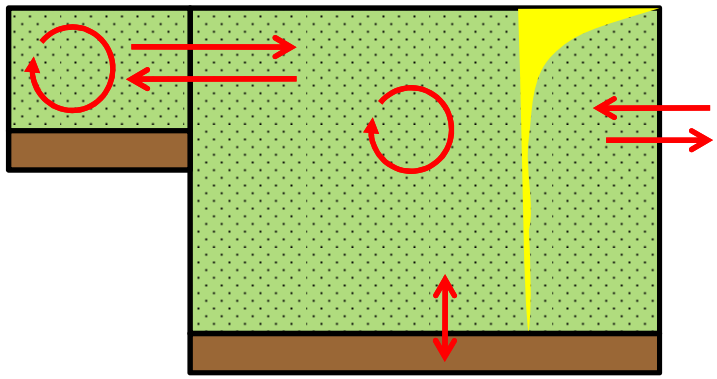


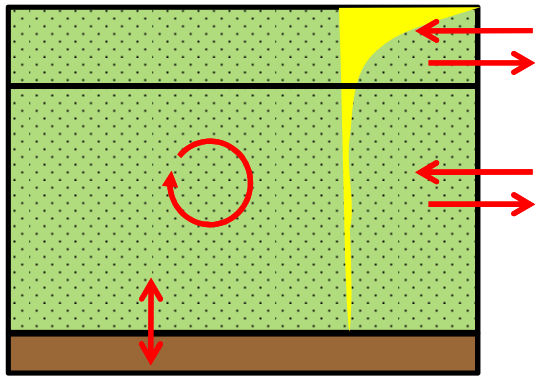
- flow, tidal exchange (t_{res})
- light limitation
- benthic grazing
- potential inhibition of PP by NH_4^+
- budgets: transformations, sources, and sinks

Numeric Models: Suisun Bay, South Bay

BACWA







Outcomes

- Key inputs to advanced modeling
- Relative importance of processes
- Uncertainty/sensitivity analysis
- Knowledge/data gaps
  → field studies, monitoring
- Narrowing scenarios of concern

SF Bay Regional Strengths/Resources for Nutrient Research

- Strong engagement of stakeholders and Regional Board
- Established university & agency nutrient research programs
  - *Mechanistic understanding of controls on load-response*
  - *Understanding of how to use phytoplankton as an indicator*
- Long-standing ambient water quality monitoring program
  - *Key in development of models*
  - *Status and trends*
- Significant data collection on some nutrient sources
  - *stormwater loading studies*
  - *POTW effluent characterization*
- Considerable modeling work (hydrodynamic) to build upon

Overview of Joint SCCWRP-SFEI Presentation

- **Comparative presentation on research on common program elements**
  - SCCWRP
  - SFEI
- **Opportunities for leveraging and enhancing collaboration**
  - Roundtable discussion

Potential Areas of Collaboration

Strong collaboration already exists because of NNE

- ✓ Guidelines
  - Phytoplankton NNE Assessment Framework
  - Application of dissolved oxygen to habitats with "natural hypoxia"
- Load-response models:
  - Hydrodynamic and water quality
  - Watershed and airshed
- Drivers for cyanobacteria and other harmful algal blooms
- Monitoring

Load-Response Models

Hydrodynamic and water quality models:

- Collaboration in development of nearshore models (ROMS, SUNTANS) - biogeochemical & phytoplankton dynamics
- Simple box models
- Mechanistic studies (benthic flux, denitrification/ nitrification)

Watershed and airshed loading models

- Applications of spreadsheet versus calibrated numeric models
- Additional investments in land-use specific runoff data
- Methods for direct estimates of atmospheric deposition

Guidelines

- ✓ Phytoplankton NNE Assessment Framework
  - Will be developed for SF Bay
  - Potentially adapted to other State enclosed bays (including ports and harbor)
- Dissolved oxygen objectives
  - Application of dissolved oxygen to habitats with "natural hypoxia"
  - Common issue to So Cal, SF Bay and Delta

Cyanobacteria et al. Harmful Algal Blooms

- Improved/standardized monitoring methods and networks
  - Passive sampling techniques
  - Development of rapid molecular methods-
  - Monitoring coordination through HABMAP
- Occurrence in difference habitat types
  - Benthic
  - Pelagic
  - Streams, lakes, estuaries
- Understanding drivers controlling bloom frequency and toxin production, e.g.
  - Nutrient ratios
  - Hydrology
  - Geology: alkalinity

Monitoring Program

- Design
- Innovative Methods
  - Gliders et al. autonomous vehicles
  - Moored sensors
  - Remote sensing and hyperspectral methods
- Data integration and visualization