Modeling Nutrient Loading and eutrophication Response to Support the Elkhorn Slough Nutrient Total Maximum Daily Load

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Workshop on "The Science of Nutrient Transport and Transformation in the Elkhorn Slough Estuary

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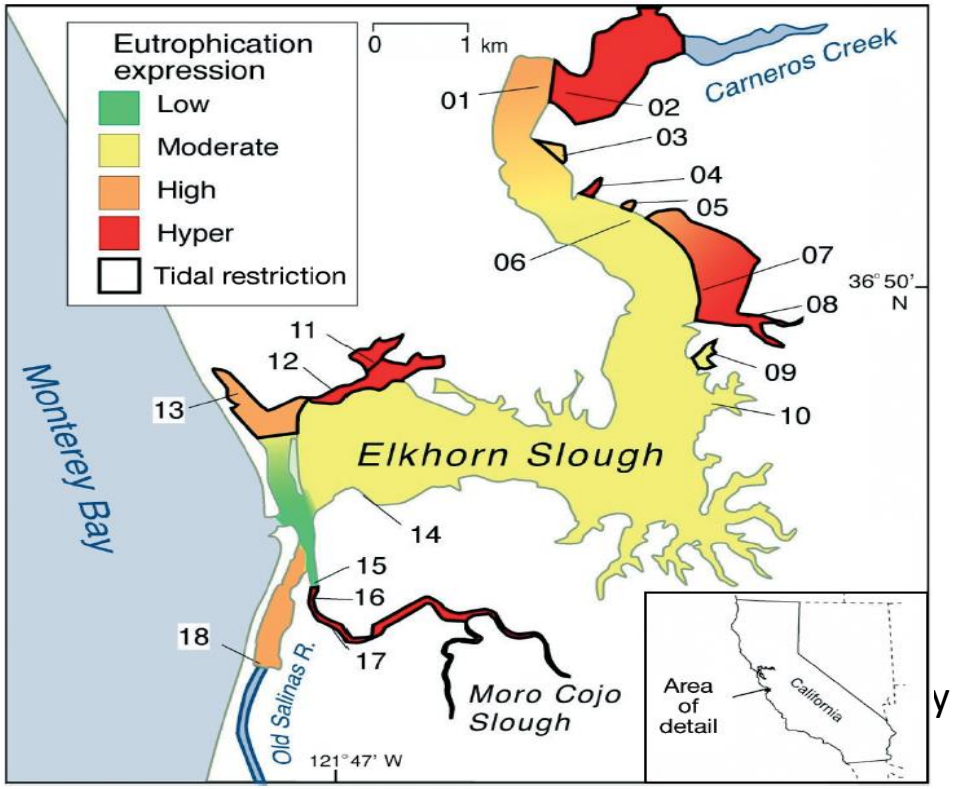
Elkhorn slough on the 303d List for Eutrophication (Biostimulatory Substances)

Eutrophication: the accelerated delivery, *in situ* production, and/or accumulation of organic matter within an aquatic ecosystem (Nixon 1995, Cloern 2001)

Biostimulatory Substances and Conditions: substances such as nutrients (i.e. nitrogen, phosphorus, organic matter) or conditions, such as altered temperature, hydrology, etc. that can cause eutrophication



Spatially interpolated eutrophication indices (from Hughes et al. 2011)

- Low dissolved oxygen/acidification
- High phytoplankton biomass/ macroalgal blooms/toxic HABs
- Light limitation to seagrass
- Poor benthic habitat quality

Project Goals

Science

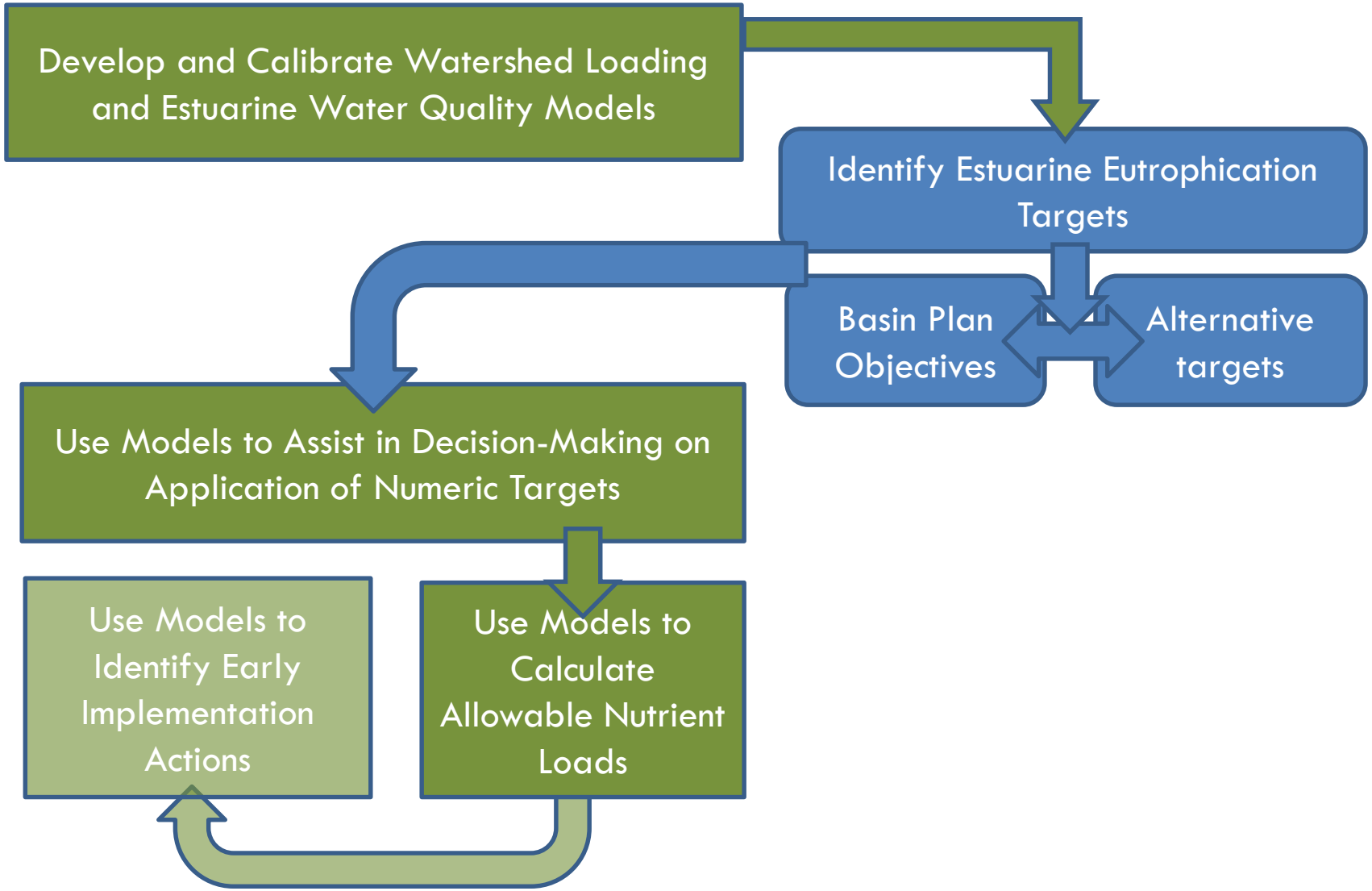
Quantify drivers and responses of eutrophication in Elkhorn Slough through numerical modeling

Management:

To quantify the management actions that can result in the remediation of eutrophication in Elkhorn Slough

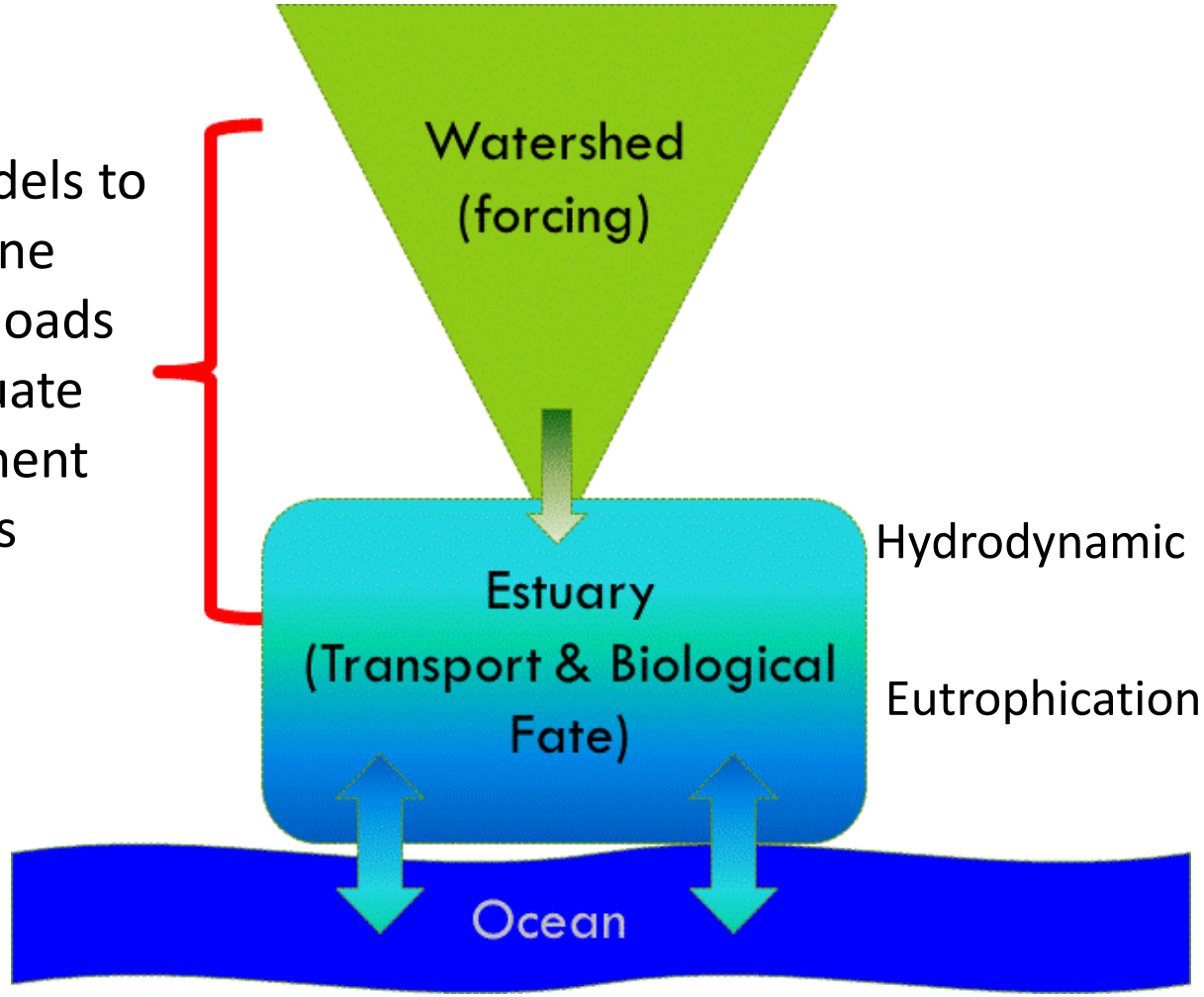
- Nutrient loads (TMDL)
- Other restoration activities?

Technical Approach Elkhorn Slough Nutrient TMDL



Conceptual Approach to Numerical Modeling

Use the models to determine allowable loads and evaluate management actions



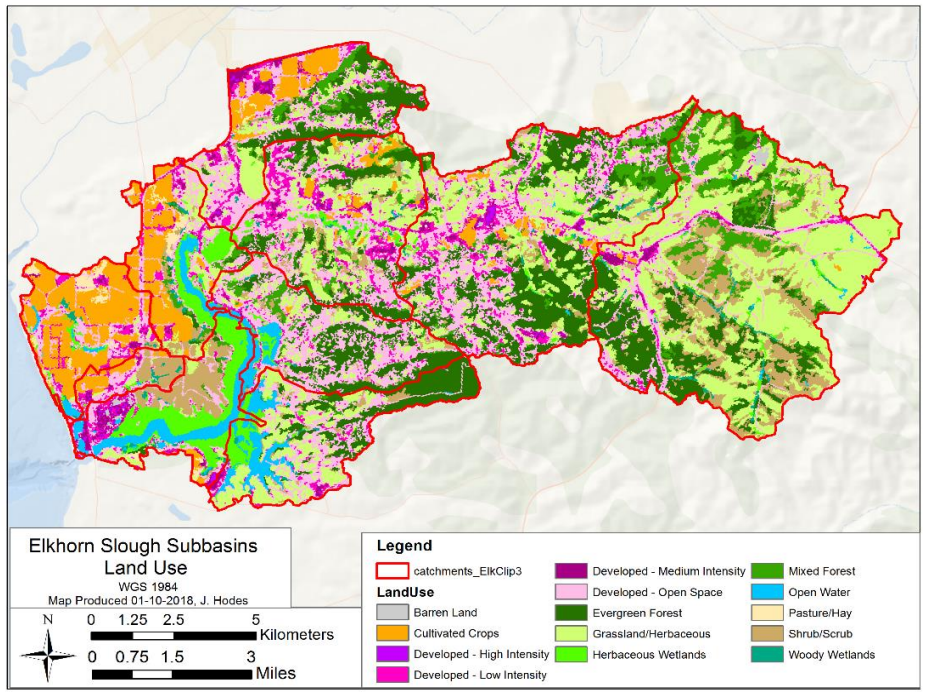
Hydrodynamic

Eutrophication

Estimating External Loads

Tetra Tech (2018) summarized the nutrient sources and pathways to Elkhorn Slough

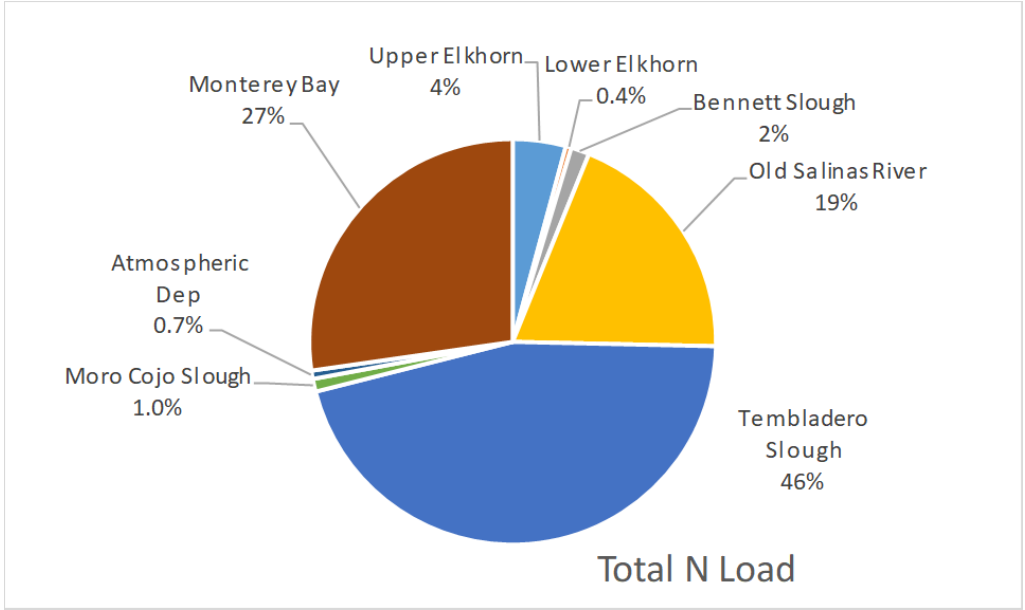
- Direct drainage: STEPL[1] modeling analyses
- Empirical estimates from OSR



[1]Spreadsheet Tool for the Estimation of Pollutant Load (Tetra Tech, 2017)

Developed coarse estimates of external loads, with major uncertainties

- Flow from Old Salinas River
- Groundwater Exchange
- Contributions from Monterey Bay



Tetra Tech (2018) proposes the use of Soil and Water Assessment Tool (SWAT) to estimate watershed loads

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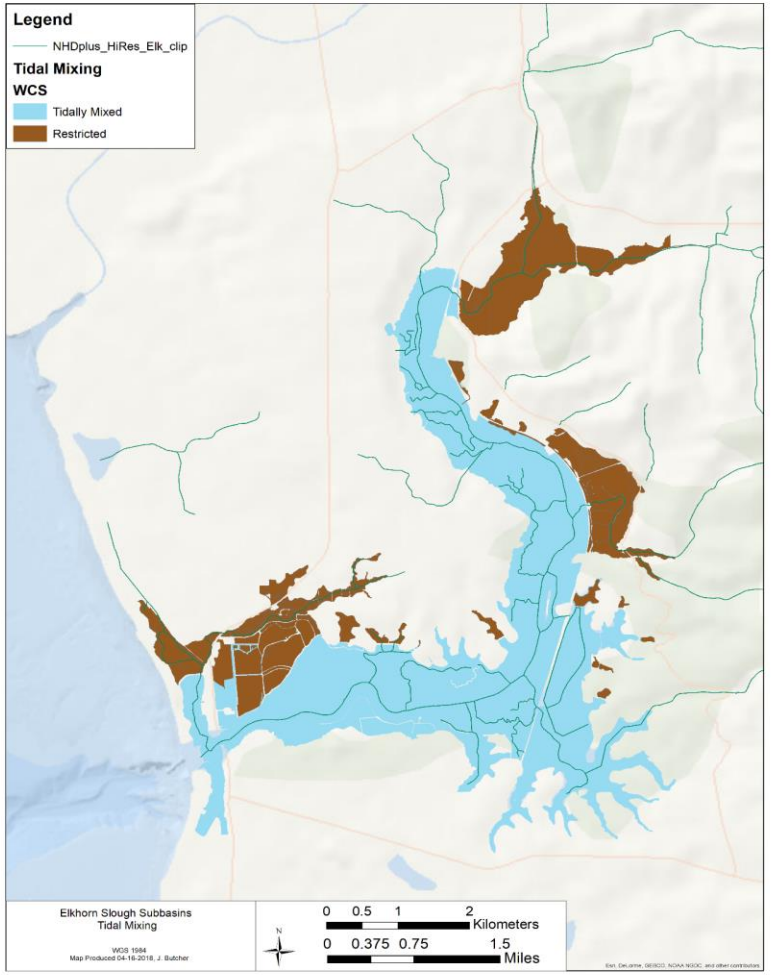
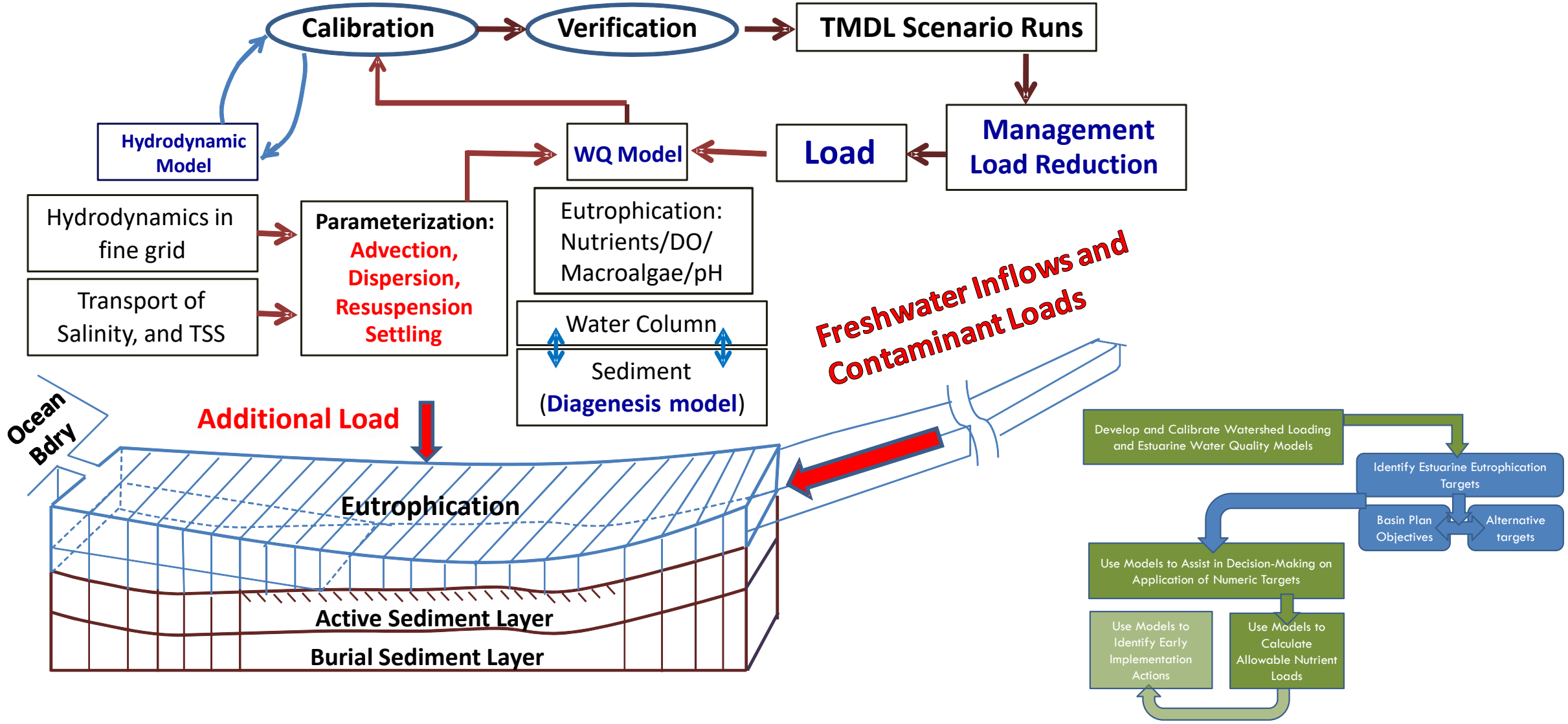
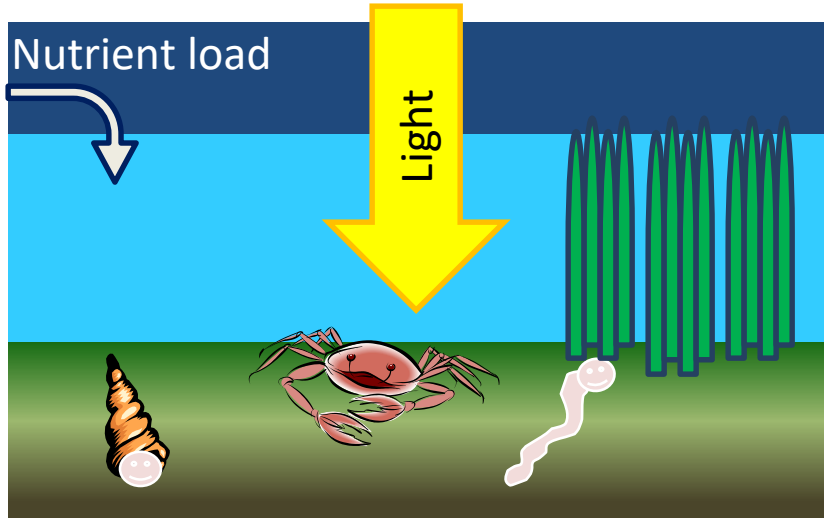
- Initial model development during previous phase of work
- Model refinement and calibration during this phase
- Estimation of contribution to tidally restricted areas a particular focus of SWAT modeling
- Loads from OSR would still be empirically estimated

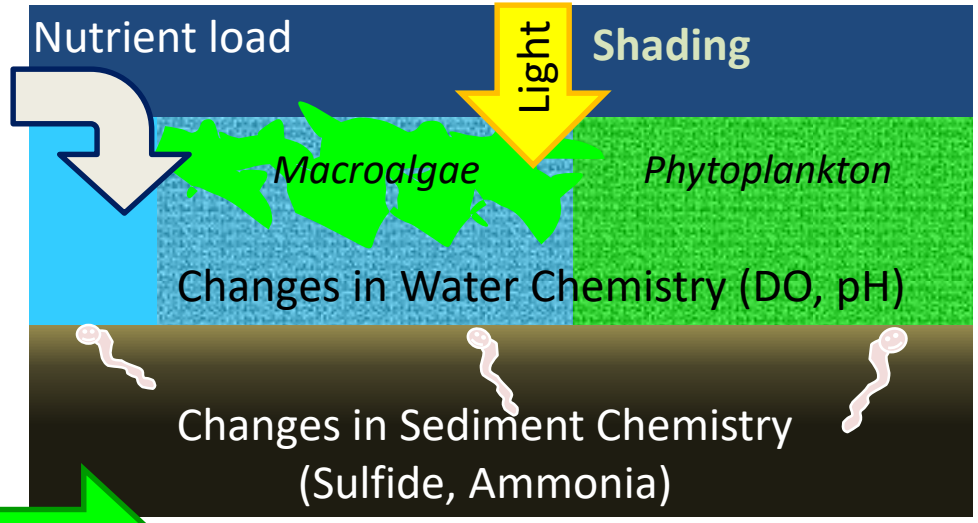


Approach for Estuary Eutrophication Model Entirely Depends on Eutrophication "Management" Targets



Conceptual Model of Eutrophication Symptoms in Mediterranean Estuaries

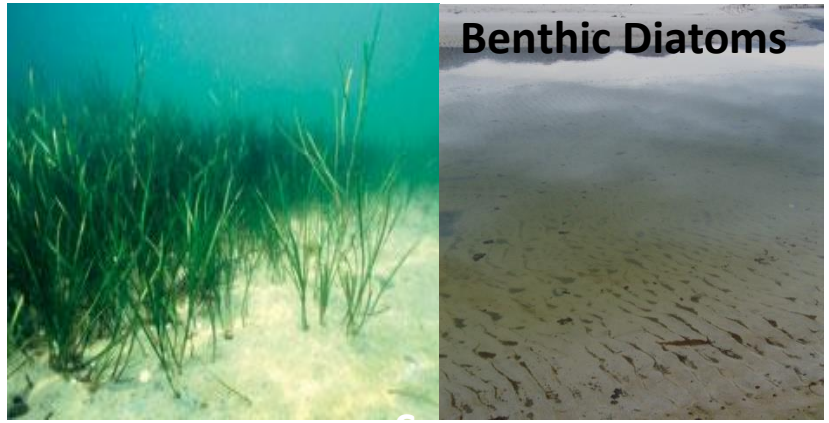




Minimally Disturbed

Increased Nutrient Loading

Affected by Eutrophication



Choice of Estuarine Receiving Water Modeling Depends on a Number of Factors

Options for Targets:

- Nutrient concentrations (Tetra Tech 2018)
- Dissolved oxygen (Basin Plan)
- Carbonate saturation state (pH)
- Macroalgae
- Water column chl-a
  - Seagrass
  - HAB toxins
- Sediment organic matter (Benthic macroinvertebrates)

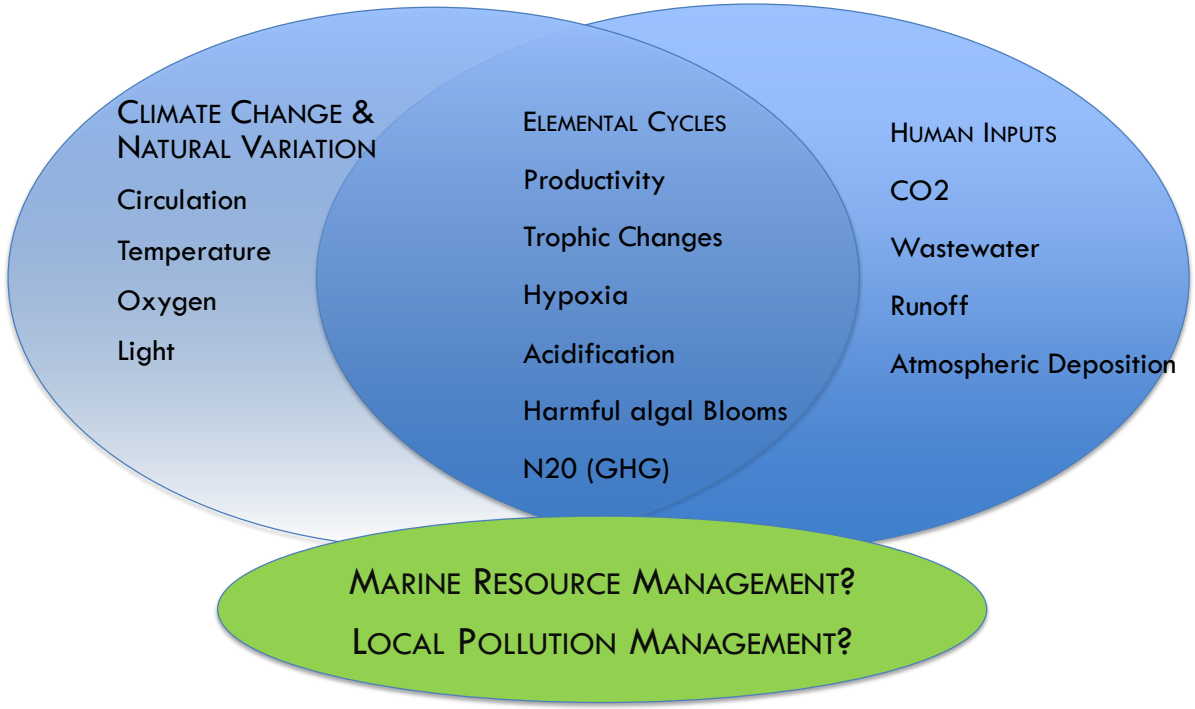
Modeling Approach Will Depend on:

- Complexity of modeling eutrophication response
- Availability of data for model forcing and model validation
  - E.g. alkalinity for carbonate saturation state
  - Availability of biological response data
- Relatively short project window
- Regulatory approach
  - Formal TMDL (with Basin plan amendment)
  - Alternative TMDL

Ocean Forcing to Elkhorn Slough: Will Leverage CA OPC and NOAA Investments in Numerical Ocean Modeling to Support California's Climate Change Actions Plans

- Numerical modeling program goals
  - Disentangle the relative contributions of **climate change, natural variability** and **local pollution impacts** on **OA, hypoxia** (HABs and N20 emissions)
  - Apply model to support policy decisions

- Directly supports elements of CA OA Action Plan recommendations
  - **Manage local pollution sources**
  - Create biologically relevant OA water quality criteria
  - Sequester carbon through habitat restoration



Earth Systems Modeling Approach

Atmospheric forcing

WRF model (Weather and Research Forecast Model; Boe et al., 2011)

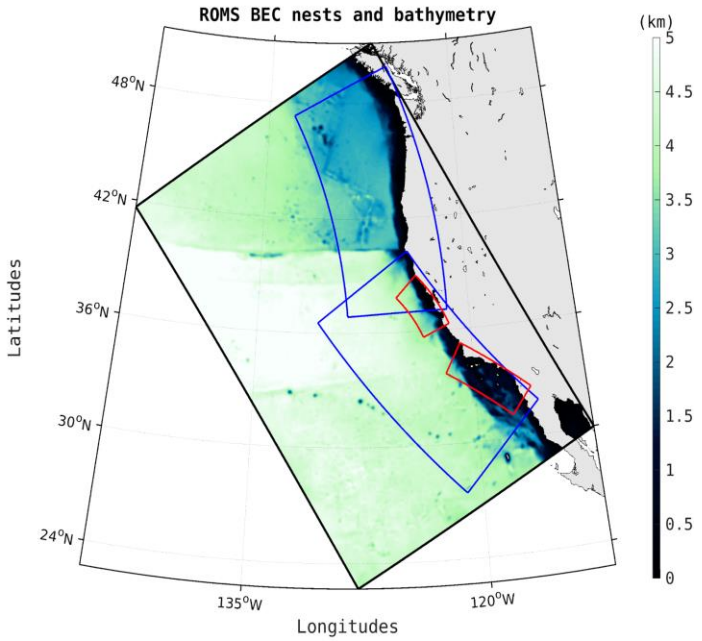
Physical model

ROMS (Regional Oceanic Model System; Shchepetkin and McWilliams, 2003, 2005, 2008, 2011)

Biogeochemistry and Lower Ecosystem

Biogeochemical Elemental Cycling (BEC; Moore et al. 2002)

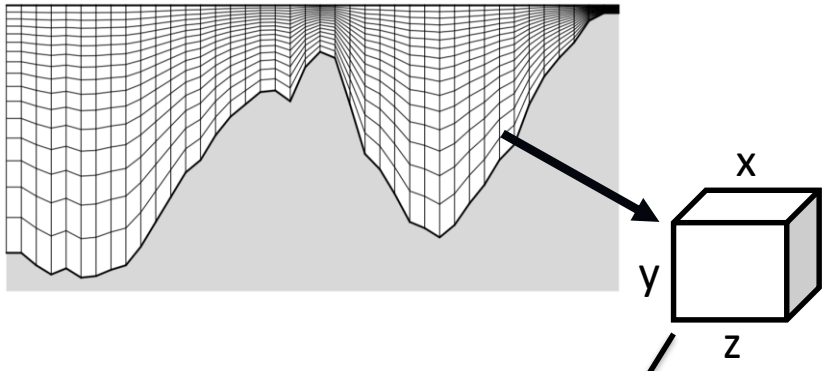
Full model domain is California Current wide at 4 km resolution, with higher resolution grids "nested" inside (1 km to 300 m)

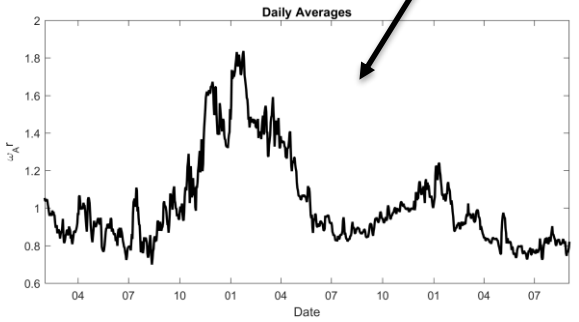


2 subdomains at 1 km resolution for CA, OR and WA

Within the 1 km CA nest, 2 smaller subdomains at 300 m within Southern California Bight and San Francisco/Monterey Coast

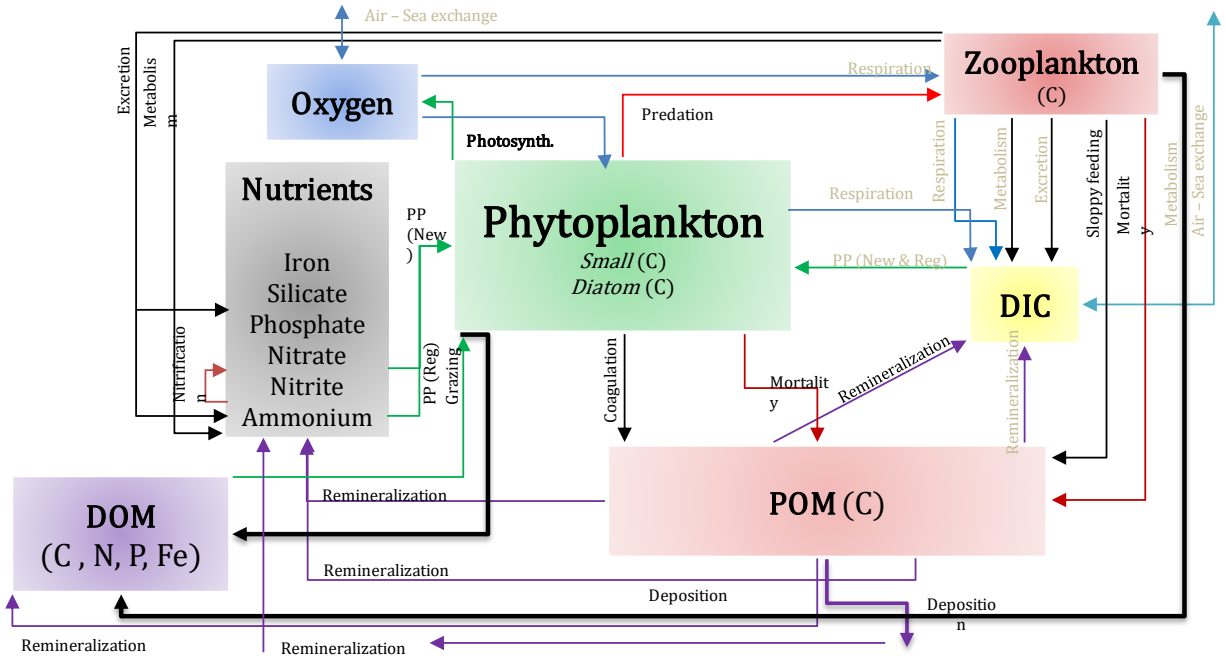
Grid: 60 variable depth levels





aragonite time-series from the model

Biogeochemical Elemental Cycling (Moore et al. 2002)



Developed enhanced nitrogen cycling, explicit sinking of particles and carbonate chemistry

STATE VARIABLES

Ocean physics

Nutrients
Nitrate, nitrite, ammonia
phosphate
silicate, Iron

Plankton
[2 phytoplankton groups an zooplankton biomass]

Organic matter

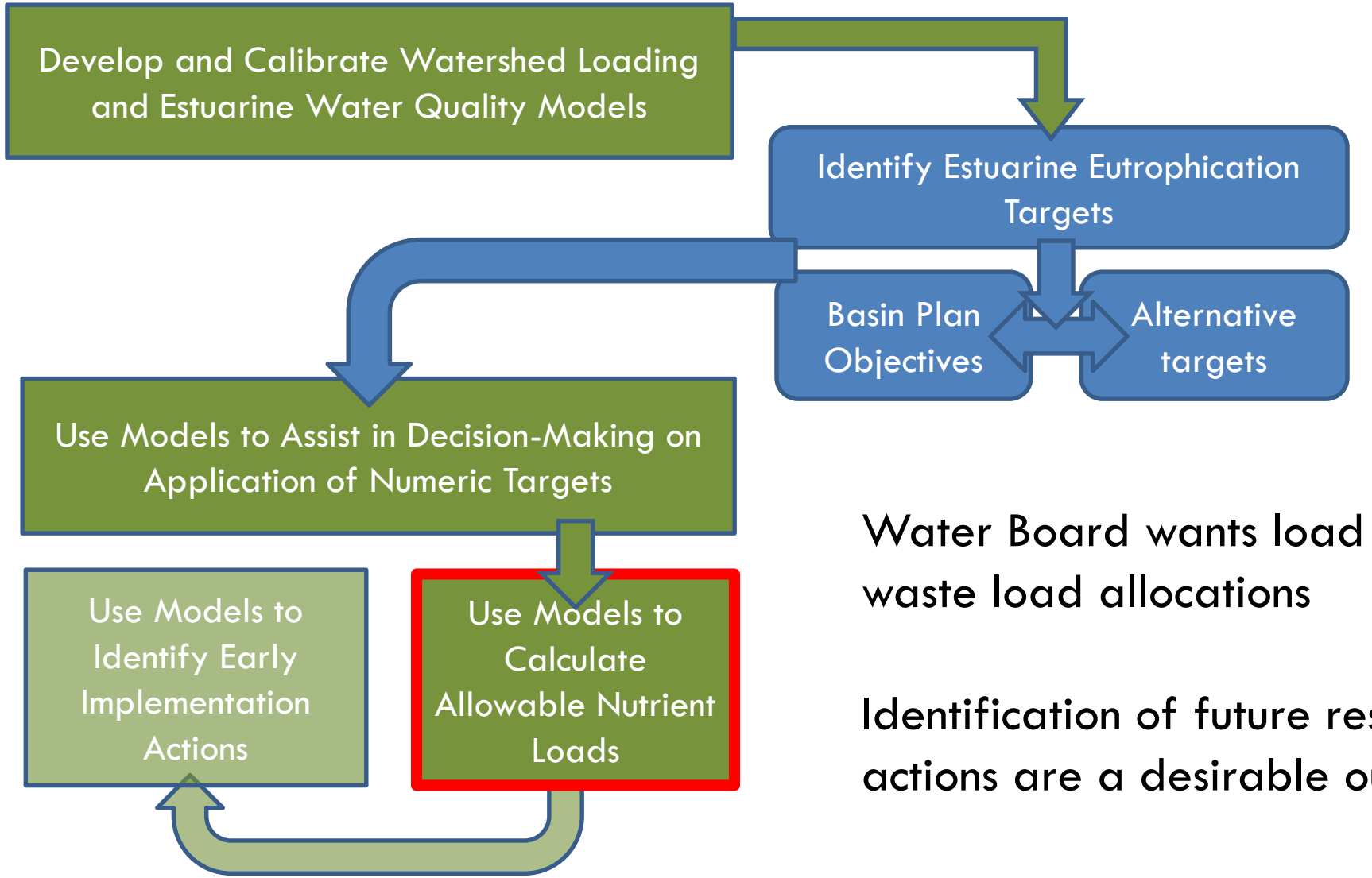
Oxygen

Carbonate system

Key Take Messages for Elkhorn Science Community

- Collaboration with SFEI (Senn) and UCSC (Edwards) to investigate the effects of anthropogenic nutrient and carbon inputs on OA, hypoxia and N20 on San Francisco Coast and Monterey Bay
- Model can provide ocean forcing of nutrients, carbon and oxygen to Elkhorn Slough model
- Elkhorn Slough et al. modeling efforts will provide improved terrestrial forcing to ROMS-BEC assessment of coastal impacts
- We will be running first set of 300-m resolution simulations (3 yr period) this summer

Conceptual Approach Elkhorn Slough Nutrient TMDL



Water Board wants load and waste load allocations

Identification of future restoration actions are a desirable outcome

Thank You!

Questions? Comments

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4-km and 1-km Validation Provide Assurance that We've Appropriately Modeled Ocean Forcing

Good consistency of coast-wide 4-km and 1-km solutions for atmospheric and oceanic physical & biogeochemical outputs against available coast-wide data sets

- spatial patterns, seasonal cycles, and range of natural variability

Oxygen distribution at sigma=26.5 [~100-250m]