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Proposal No.	Region

(Pages A13-A18)

Section 1: Summary Information

1. Project title:	**Quantitative Assessment of Delta Habitat and Food Web Parameters Using Isotopes and Numerical Models**
2. Applicant name:	**U.S. Geological Survey**
3. Contact person:	**Carol Kendall**
4. Address:	**U.S. Geological Survey** **345 Middlefield Road, MS 434**
5. City, State, Zip:	**Menlo Park, CA 94025**
6. Telephone #:	**1-650-329-4576**
7. Fax #:	**1-650-329-5590**
8. Email address:	**ckendall@usgs.gov**
9. Agency Type:	Federal Agency ☒ State Agency ☐ Local Agency ☐ Nonprofit Organization ☐ University (CSU/UC) ☐ Native American Indian Tribe ☐
10. Certified nonprofit organization:	Yes ☐ No ☒
11. New grantee:	Yes ☒ No ☐
12. Amount requested:	**$287,900**
13. Total project cost:	**$369,557**
14. Topic Area(s):	**Ecosystem Water and Sediment Quality (Primary)** **Hydrodynamics, Sediment Transport and Flow Regimes (Secondary)**
15. ERP Project type:	**Research (Primary)**
16. Ecosystem Element:	**Bay-Delta Aquatic Foodweb (Primary)** **Bay-Delta Hydrodynamics (Secondary)**
17. Water Quality Constituent:	**Nutrients and Oxygen Depleting Substances (Primary)** **Salinity (Secondary)**
18. At-Risk species benefited:	**Central Valley winter-, spring- and fall/late fall-run chinook salmon, Central Valley steelhead, delta smelt, longfin smelt**
19. Project objectives:	**The objective is to use models (DSM2 nutrient, RMA 2-D, isotopic) to investigate linkages between DRERIP-defined drivers in the Delta Foodweb and Nutrient conceptual models and Intermediate Outcomes to Primary Productivity. The study area is the Sacramento R. (Freeport to Martinez) and the Yolo/Cache area.**
20. Time frame:	**The estimated time frame is two-three years. The first year will consist of data analysis, analysis of water quality and isotopic parameters, development and analysis of isotopic models, integration of results into the DSM2 QUAL nutrient model and refinement of the current DSM2 QUAL nutrient model calibration. The**

	second year will focus on the development and analysis of hypothesis-driven model scenarios, production of reports and papers. The third year, if necessary, will be a continuation of tasks from year two.

Section 2: Location Information

1. Township, Range, Section: and the 7.5 USGS Quad map name.	**7.5 USGS Quads: Benicia, Vine Hill, Honker Bay, Antioch North, Jersey Island, Rio Vista, Liberty Island, Isleton, Courtland, Clarksburg, Sacramento West**
2. Latitude, Longitude (in decimal degrees, Geographic, NAD83):	**Lat. 38.020 to 38.460; Long 121.050 to122.135 The research in this proposal is focused on the Delta, but there is no field work.**
3. Location description:	**The project is situated within the Delta – including the Sacramento River from approximately Freeport to Martinez, and the Yolo, Cache Slough, Liberty Island area. Howvere, there is no field work included in the current project. All of the work consists of data analysis, measurements of previously-collected water samples, and numerical modeling. See Figure 1C in the proposal text.**
4. County(ies):	**Solano, Yolo, Sacramento, Contra Costa**
5. Directions:	**N/A**
6. Ecological Management Region:	**Delta**
7. Ecological Management Zone(s):	**Sacramento-San Joaquin Delta**
8. Ecological Management Unit(s):	**North Delta, Central and West Delta, Suisun Marsh Islands and Bay**
9. Watershed Plan(s):	**N/A**
10. Project area:	**N/A**
11. Land use statement:	**N/A**
12. Project area ownership:	% Private__ **N/A** __ % State__ **N/A** ___ % Federal__ **N/A** ___ *Enter ownership percentages by type of ownership.*
13. Project area with landowners support of proposal:	**N/A**

Section 3: Landowners, Access and Permits

1. Landowners Granting Access for Project: (Please attach provisional access agreement[s]) **N/A**	
2. Owner Interest: N/A	
3. Permits:	**N/A**
4. Lead CEQA agency:	**N/A**
5. Required mitigation:	**N/A** Yes ☐ No ☒

Section 4: Project Objectives Outline

1. List task information: ***ERP Goal 2 Ecological Processes, Objectives 1, 2 and 4***

In a very general sense, our project aims to address how hydrodynamic conditions, water quality, water temperature, and primary and secondary production are linked within aquatic ecosystems of the Delta and its tributaries and floodplains, and how habitat variables for aquatic organisms are distributed spatially under different river inflow and water temperature scenarios. Isotopic analyses will address the linkage between water quality, nutrient sources and sinks, and primary production. Modeled residence time calculations will address linkages between hydrodynamic conditions and primary production when combined with DSM2-QUAL nutrient model output (*e.g.*, for chlorophyll). Model scenarios will provide a set of spatially-explicit model results (from QUAL and two-dimensional RMA models) to directly address spatial changes for habitat variables under different hydrodynamic regimes. We will not address specific requirements for individual species.

Additional objectives: ***Goal 4 Habitats, Objectives 1, 2 and 5***

1. **Habitat quantity and quality and productivity are characterized by many biotic and abiotic variables.** The DRERIP conceptual models will be used as a guide for identifying important component variables. The combination of nutrient and isotopic measurements, modeled nutrient dynamics and the concurrent characterization of abiotic factors such as residence time, water depth and flow can provide new insight into food web dynamics and seasonal habitat variability. Combining the modeling and visualization tools with recent data from the sampling programs, particularly isotope data, allows us to quantitatively characterize habitat variables.

2. Source(s) of above information: N/A

Section 5: Conflict of Interest

To assist ERP staff in managing potential conflicts of interest as part of the review and selection process, we are requesting applicants to provide information on who will directly benefit if your proposal is funded. Please provide the names of individuals who fall in the following categories:

- Persons listed in the proposal, who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded; and/or
- Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.

Primary Contact for Proposal: **Dr. Carol Kendall (USGS)**
Primary Investigator: **Dr. Carol Kendall (USGS)**
Co-Primary Investigator: **Dr. Marianne Guerin (Resource Management Associates)**
Supporting Investigators: **Dr. Megan Young, Dr. Tamara Kraus (USGS)**
Supporting Staff: **Steve Silva, Doug Choy (USGS)**
Subcontractor: **Dr. Marianne Guerin (Resource Management Associates)**
Subcontractor: **Dr. Randy Dahlgren (UCD)**
Other collaborators: **Dr. Alex Parker (SFSU), Dr. Peggy Lehman (CA-DWR), Dr. Chris Foe (CVRWQCB)**

Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Last Name	First Name	Organization	Role
N/A			

Section 6: Project Tasks and Results Outline

1. Detailed Project Description

The San Francisco-San Joaquin Delta (Delta) is rich in data measurements and observations identifying potential linkages between physical and chemical parameters characterizing the ecosystem and species declines. For example, among the factors hypothesized to be contributing to the recent species decline in the Delta known as the Pelagic Organism Decline (POD), oft-cited candidates are loss of preferred habitat, toxic chemicals, and a decline in the quality and quantity of nutrients and food for pelagic species (Jassby, 2008; Jassby *et al*., 2002; Jassby and Cloern, 2000; Lehman, 1992; Lehman *et al.*, 2007, 2008 and 2009). High concentrations of ammonium ion (NH_4^+) have been hypothesized to suppress phytoplankton blooms (Dugdale *et al*., 2007). Some data suggest that delta smelt larvae are sensitive to high levels of ammonia, low turbidity and salinity (Baxter *et al.*, 2007). High levels of the toxic microcystin chemicals can occur in the Delta during blooms of the cyanobacterium *Microcystis aeruginosa* as water temperatures reach 20-25°C [1]. Food web effects may then occur directly by exposure to the toxins or indirectly by affecting food quality, although these effects are subject to some debate.

The problem that naturally arises is how to interpret and synthesize individual observations such as these to assess the potential of water management decisions to influence habitat quality parameters and food web dynamics, or the survival of individual species. Conceptual models, such as the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)[2] models, have been developed to qualitatively abstract many of these complex interactions in a simplified manner. However, the development and use of numerical models, which provide a quantitative framework to combine these concepts with measurement data in the Delta, has lagged behind. For example, Figure 1A shows the old data used for model calibration; there were a maximum of 4 locations between the SRWTP outflow and the confluence with the San Joaquin River (Greens/Hood, Rio Vista, Emmaton and Pt. Sacramento), but none in Yolo, Cache, or Liberty Sloughs. Figure 1B shows the boundary conditions of the study area. In contrast, newly generated data from several interagency sampling campaigns in 2008-2011 (Table 1) provide a rich set of data for modeling and testing hypotheses about processes in the ecosystem (Figure 1C). Some sites were sampled as frequently as twice-monthly.

The purpose of this interdisciplinary proposal is to advance our understanding of nutrient dynamics and the physical and chemical drivers of primary productivity in the Delta by using numerical models to integrate and synthesize available data. This project would leverage ongoing multidisciplinary collaborative efforts between Carol Kendall (and other USGS team members), Marianne Guerin of Resource Management Associates (RMA), Alex Parker (SFSU), and Peggy Lehman (DWR). Kendall and Guerin are currently funded *via* the State Water Contractors (SWC) and Interagency Ecological Program (IEP). As part of these projects, we have been using numerical models, isotopic analyses, and water quality data to characterize the sources and sinks of nutrients and the algal productivity in our study area – the Sacramento River from Freeport to Suisun Bay and the Yolo/Cache Sl./Liberty Island area. Starting March 2009 and continuing through mid-2011, concurrent sampling programs have been gathering and analyzing data, including isotope data, to characterize spatial and temporal changes in nutrient sources and algal productivity. Sources and sinks of nutrients are being identified and traced using stable isotopic "fingerprints", which can act as a diagnostic tool for interpreting chemical measurements (Finlay and Kendall, 2007; Kendall *et al.*, 2007, 2008a, 2008b, 2010a, 2010b).

The data interpretation and synthesis outlined in this proposal will be conducted within the context of the DRERIP conceptual framework. Our aim is to: incorporate isotopic measurements and nutrient data in numerical models characterizing the physical and chemical attributes of the study area; fill data gaps in isotopic analyses and nutrient model variables using archived water samples: and, use model scenarios to improve our understanding of the ecosystem and of the potential for ecosystem change under water management actions. The best available numerical modeling tools for achieving our objectives are the DSM2, Delta Simulation Model-2 (DMS, 2010), one-dimensional nutrient and hydrodynamic models, QUAL and HYDRO respectively, and the RMA suite of two-dimensional models and visualization tools. HYDRO will be used to provide hydrodynamic data to aid isotopic analyses and the QUAL nutrient model will be used to integrate nutrient and isotopic data and to implement hypothetical scenarios. RMA models and tools will be used to calculate and visualize residence time and other spatially-explicit parameters. The interpretation of isotope data and nutrient model output is intrinsically complicated; hence, results will be presented as two-dimensional contour plots and figures or as animations to simplify interpretation wherever possible.

[1] http://calwater.ca.gov/science/pdf/workshops/POD/CDFG_POD_Microcystis_white_paper.pdf
[2] http://www.science.calwater.ca.gov/drerip/drerip_index.html, http://www.dfg.ca.gov/ERP/conceptual_models.asp

We will use model scenarios to address the following hypothesis:

<u>Hypothesis</u>: Key habitat parameters in the study area can be adaptively managed by manipulating flows, water temperature, and nutrient species/concentrations in the Sacramento River and in effluent discharges.

After establishing historical baseline results, modeling scenarios manipulating flows and nutrient concentrations will be used to quantify the changes in DRERIP-model process drivers, such as water temperature or residence time, and outcome variables, such as algal growth. Consistent with the intended use of the DRERIP models, the quantitative findings from model scenario analysis can be utilized to assist resource specialists implement adaptive management objectives by predicting the consequences for Delta conditions. As there is generally no clear consensus on optimal ecosystem variables (*e.g*., flow, temperature, nutrient concentrations) or the spatial distribution of these variables, it is expected that assessment of their relative importance will be determined independently by individuals or institutions.

Although the analysis and visualization of model scenario results will form a significant proportion of the deliverables in this project, the direct interpretation of water quality data and isotopic analyses are also critical to understanding the ecosystem. Thus, another key project deliverable consist of contour plots visualizing the water quality constituents along data transects through time, and plots of isotope data identifying locations along individual transects where nutrient cycling has significantly altered isotopic compositions.

2. <u>Background and Conceptual Models</u>

Through activities of several ongoing projects, there is a rich dataset of water quality and isotope data from samples collected from March 2009 to mid-2011 along the Sacramento River to Suisun Bay, near the confluence of the Sacramento and San Joaquin Rivers, and in the Yolo Bypass/Cache Sl./Liberty Island area – henceforth called the “study area”. The locations of the sites with the new data are shown in Figure 1C (blue dots). This dataset is unique in that the spatial and temporal density of measurements is much higher than historical sampling (Figure 1A), and that three groups (SFSU, CVRWQCB, and USGS) with independent funding have been conducting collaborative sampling programs, sharing unpublished data, and working as a team to interpret the shared datasets (see Table 1). Drs. Parker and Dugdale (SFSU) and Chris Foe (CVRWQCB) have been collecting samples, allowing Kendall to piggyback isotope samples onto their cruises, and sharing the results of analyses with us. The State of California funded Foe to monitor water quality in the study area from 03/2009 to 02/2010. The SWC provided funding to us to archive a complete set of isotope samples from Foe’s transects starting 05/2009, to analyze isotope samples from Parker/Dugdale transects in March and April 2009, and to collect and analyze chemistry and isotope samples collected in 2010 and 2011 from Miner and Steamboat Sloughs (with matching Sacramento R. sites). IEP funding covers the isotopic analysis of the archived Foe-collected samples, and from recently collected samples from the 04/2010, 08/2010, and 04/011 transects conducted as part of the “Two Rivers Project”.

Through these collaborations, we now have a suite of isotope data (NH_4-$\delta^{15}N$; NO_3-$\delta^{15}N$ and $\delta^{18}O$; seston-$\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$; DOC-$\delta^{13}C$; and water $\delta^{18}O$ and $\delta^{2}H$) and nutrient and elemental data from numerous transects of the study area that have been or will be generated with existing funding; all but the last of the Miner and Steamboat Slough samples should be completely analyzed by fall 2011. Table 1 shows the data collected to date. However, to use the POM-$\delta^{34}S$ data (which shows that phytoplankton derived from the Cache Complex area have a very distinctively low $\delta^{34}S$ value (Figure 8) and other isotopic data to quantity transport of phytoplankton from the Cache Complex area to downstream sites, we need more information about the mixing of water and organic matter downstream of Rio Vista. The new SO4 and Cl concentration measurements, and SO4 isotopes proposed in Task 2 are intended to fill this data gap. Although the initial motivation behind these sampling programs is the hypothesis that high concentrations of ammonium, NH_4^+ denoted herein simply as NH_4, may be a major factor contributing to a reduction in phytoplankton productivity along the Sacramento R. corridor from Freeport to Suisun Bay, the scope of research has subsequently expanded.

The main objectives of this proposal are the refinement and use of numerical modeling and visualization tools to aid in the interpretation and synthesis of this water quality and isotope data, and the use of model scenarios to better understand the impact of management actions on the ecosystem in the study area. The one-dimensional hydrodynamic and water quality models in the DSM2 suite of models, HYDRO and QUAL respectively, are well-accepted models of the Delta (DMS, 2010). These models will be used in the interpretation of nutrient and isotope measurements, and conversely, the nutrient and isotope data will be used to refine the nutrient model conceptualized in QUAL. RMA two-dimensional flow and water quality models, RMA2 and RMA11 respectively (RMA, 2005), and

RMA visualization tools will be used for calculating and visualizing residence time and turbidity, and for the development of spatial contours illustrating nutrient model results. The use of model outputs in interpreting data, and of data in refining the nutrient model in QUAL are each described below – this is an iterative process.

To date, only hydrodynamic variables such as stage, net flow and travel time have been supplied to C. Kendall for use in interpreting existing isotope and chemical data. These data (through 07/ 2009) have been provided through collaboration with M. Guerin (RMA), using Guerin's SWC-funded development of the QUAL nutrient model. For this proposal, HYDRO and QUAL will need to be extended through mid-2011, and QUAL will be recalibrated by incorporating the existing and new nutrient and isotope data available from a much larger set of sites (and dates, and frequency of sampling) than previously available (compare Figure 1A with 1C). QUAL will then be used along with HYDRO and the RMA models to test the main hypothesis using selected scenarios.

The conceptual models describing our project are hierarchical – the highest levels consist of DRERIP-inspired conceptual models, intermediate levels consist of the concepts in numerical models, with the most fundamental level consisting of models for the direct interpretation of nutrient and isotopic data. Figure 2A., based on a DRERIP conceptual model of the Delta system, illustrates the major conceptual components available in our numerical models (processes, habitats and stressors). Figure 2B., based on the DRERIP Fish-Habitat linkage model, shows the model variables that can be quantified and the links between physical processes occurring in the Delta and habitat and food web component variables. Figure 2C., based on the DRERIP Tidal Marsh model, illustrates the interaction between processes, data, isotopes and the DSM2 models HYDRO and QUAL. The Tidal Marsh model is important in the Yolo/Cache/Liberty portion of the study area, although it is more generally applicable. The arrows in Figure 2C. show the direction of influence or information flow between water quality and isotope data and the water quality and flow models, QUAL and HYDRO, respectively. For example, tidal marsh processes are influenced by flow and tidal action (single arrows), while water quality and tidal marsh processes are interactive, as shown with a double-ended arrow.

Figure 3A illustrates the nutrient model concept and variables used in QUAL (Rajbhandari 2003). Utilizing the new dataset, particularly isotopic analyses, in the calibration process offers a unique opportunity to more accurately capture the dominant mechanisms involved in nutrient transformation in the study area. An improved, more accurate nutrient model will provide a major improvement in our ability to predict conditions altering nutrient resources and primary productivity. Isotopes can be used to investigate the temporal and spatial variations in the sources, sinks and transport of ammonium, nitrate, and organic matter (particulate and dissolved, POM and DOM, respectively) as well as other parameters (see Table 2). For example, isotopic measurements can be used to determine the dominant sources of nutrients (*i.e.,* WWTP, fertilizer, or marine sources) as these different sources usually have distinctive compositional ranges for several isotopes. Isotopes are used to calculate rates of nutrient cycling processes such as nitrification and denitrification (Sebilo *et al.*, 2005; Bohlke *et al*., 2008; Cifuentes *et al.*, 1989), and rates of algal growth (Baird et *al.*, 2001). Isotopic analyses are also used to interpret changes in water quality constituents due to processes like dilution or consumption of nutrients through bacterial or algal growth. Conversely, knowledge of the source of waters at any location in the model domain (as calculated in QUAL), can be used to verify and interpret the results of isotopic analyses, and hydrodynamic variables from HYDRO such as net flow and stage can constrain isotopic models; an example of the latter using a mixing model is discussed below.

Specifically, the nutrient dataset can be used directly in QUAL to help constraint boundary concentration where they are currently unknown. In some regions of the model, nutrient sources are poorly resolved due to inadequate data to set model boundary conditions. For example, due to a lack of available measurements in the Yolo/Cache/Liberty area 1990 - 2008, the boundaries and model parameters were set at "reasonable" values to maintain fidelity with downstream measurements. Similarly, the magnitude of agricultural influence, represented by the Delta Island Consumptive Use[3] (DICU) model in DSM2, is poorly understood, and nutrient data and isotopic fingerprints can also help constrain these model variables. Table 2 lists a variety of ways isotopic analyses can be used to refine the QUAL nutrient model parameterization.

In nutrient model applications, model rate coefficients are typically set using rates measured in laboratory experiments. However, in most rate-dependent processes field rates will vary significantly from laboratory rates (Cifuentes *et al.*, 1989; Sugimoto *et al*., 2009; Lund *et al*., 1999). Because of our dense datasets, rate calculations of modeled processes (such decay of NH_4) for different dates and sites can be used: in the QUAL recalibration process to refine the current values assigned to these rates; to estimate projected concentrations for downstream sites in the absence of mixing and other competing processes (e.g., to project nitrification rates from the mainstem river into the Yolo area); and, to compare with projected concentrations calculated using isotope data and isotope fractionation models.

[3] http://www.iep.ca.gov/dsm2pwt/reports/DSM2FinalReport_v07-19-02.pdf, http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/DICU_Dec2000.pdf

Figure 3B and Figure 3C illustrate how NH_4, NO_3 and NO_2 measurements have been used in conjunction with DSM2-calculated travel times to estimate decay rates for reactions at five locations along the Sacramento R. The calculation scheme is illustrated in Figure 3B, while Figure 3C shows the results of these calculations in comparison with measured data. Using this simplified model of nutrient decay, decay rates for ammonium to nitrite and nitrite to nitrate averaged 0.22 day-1 and 0.20 day-1, respectively.

Our conceptual model for the biogeochemistry of the study area, Figure 4A, forms the basis for interpretation of the isotope measurements. The aquatic biogeochemistry is represented by the materials analyzed for N-C-S-O-H stable isotopic composition and the "fingerprints" provided by isotope analyses. Figure 4A shows a typical N-cycling model for the San Francisco Estuary identifying the significant external sources as including waste water treatment plants (WWTPs), agricultural sources, and wetlands. Assuming conservative mixing is the main process affecting the distribution of nutrients in the estuary, the $\delta^{15}N$ of NH_4 (or, similarly NO_3) at a location in the estuary can be estimated from a simple mass balance equation: $[NH_4]_{(total)}*\delta^{15}N_{(total)} = [NH_4]_{(A)}*\delta^{15}N_{(A)} + [NH_4]_{(B)}*\delta^{15}N_{(B)}$, where A and B are the two main endmembers (*e.g*., riverine NH_4 and tributary NH_4) comprising the total $[NH_4]$. If the nutrients are not conservative because of biological processes (*e.g.,* uptake or nitrification), the changes in concentration and $\delta^{15}N$ during progressive reaction can be calculated using isotope fractionation models.

Each of the N-pools (constituents) illustrated in Figure 4A probably has a different $\delta^{15}N$ value, and the processes that convert one constituent to another often causes distinctive changes in $\delta^{15}N$. Figure 4B is a cartoon showing how two common processes, nitrification and uptake, result in significant changes in the $\delta^{15}N$ of algae and of the new NO_3 and residual NH_4. For example, if isotopic fractionation (denoted ε) by algal uptake involves a single-step unidirectional reaction in a closed system, the relationship between changes in $\delta^{15}N$ and NH_4 concentration can be described by classical "Rayleigh" fractionation (Mariotti *et al.,* 1981), with the reaction favoring the preferential incorporation of ^{14}N into algae, while the $\delta^{15}N$ of the residual substrate (i.e., NH_4) exponentially increases as the reaction proceeds. Isotope fractionation factors, derived from the literature or estimated using isotope data from reaches of the river dominated by a single process, can be added to N-cycling models (Figure **5**5) so that mass balance calculations not only account for changes in the species of N and the concentrations of the different N-species, but also the changes in the $\delta^{15}N$ values. Hence, isotopic data provide extremely useful constraints on biogeochemical models – especially in multi-isotope and multi-tracer studies like ours (*i.e.,* we can estimate independent nitrification fractionations using $\delta^{15}N$ of NH_4, $\delta^{15}N$ of NO_3, and $\delta^{18}O$ or NO3). However, it is important to note that there is almost no data on several potentially important N cycling mechanisms (i.e., sinks of N) shown in Figures 4A and 5 that could be affecting both the chemistry and isotopic compositions in the water column in some locations, especially in biogeochemically active areas in wetlands (where denitrification and uptake by macrophytes may be important N sinks) or immediately downstream of SRWTP (where uptake by bacteria or absorption on sediments may be important sinks).

Changes in flow, temperature, residence time, and turbidity (among many other parameters) can affect NH_4, NO_3 and other nutrients, algal productivity, and the utilization of algae by organisms higher up the food web. Similarly, changes water quality parameters can change the habitat suitability of a particular region of the Delta for a given species. As suggested in Lehman *et al*. (2007) and (2009), changes in flow, residence time, or temperature regimes may change conditions for algal growth and the exchange of nutrients in the Yolo Bypass and Liberty Island, or eliminate conditions favored by harmful or undesirable bacteria or algae. Water depth may be another important parameter influencing primary productivity (Cloern, 2007) in areas such as Liberty Island. These variables (flow, water depth, *etc*.), which are also identified in DRERIP models, will be tracked in our model scenarios to investigate their sensivity to changes in management actions, implemented through changes to model boundary conditions.

Within the study area, the Yolo/Cache/Liberty area has a special significance in the present – and potentially in the future – both as a source of habitat for delta smelt during sensitive life stages and as a potential source and/or sink of nutrients and food that may affect the food web downstream on the Sacramento River. The Yolo Bypass is an engineered floodplain that provides a valuable spawning and rearing habitat area to many native fish species (Sommer *et al*., 2001) including delta smelt and as a source of nutrients for their food. The Yolo/Cache/Liberty area is currently considered a likely area for restoration under the Bay-Delta Conservation Plan[4] (BDCP). The area in and around Suisun Bay is also considered important habitat with sufficient nutrients to support the rearing of juvenile fish, including delta smelt. These areas will also be a focus in our data analyses and in the analysis of model scenario results.

Hydrodynamic and water quality models can be used to generate information to assess flow effects -- for example, net flow, stage, transit time, residence time or exposure time, dilution, and water quality effects -- at any spatial and temporal density. Model results can also be used to produce spatial maps of metrics such as water depth,

[4] http://baydeltaconservationplan.com/default.aspx

temperature or turbidity visualized in contour plots, such as those shown in Figure 6 for exposure time, or can be used to develop animations.

Residence time, defined here as the cumulative amount of time a parcel of water is contained within a specified domain (defined elsewhere as exposure time), and similar metrics quantifying transport time scales (*e.g*., exposure time and age) have been defined and redefined in the literature (Monsen *et al*., 2002; Lucas *et al*., 2006; Olivera and Baptista, 1997; Abdelrhman, 2005; Jouon *et al*., 2006; Bilgili *et al*., 2005; Chen, 2007; Wang *et al*., 2004). Residence time, however it is defined, is a critical component in understanding nutrient dynamics, habitat suitability for aquatic species, exposure to toxic constituents and other factors such as the transport of pelagic plankton[5] (Monsen *et al.,* 2002). In a given domain, these metrics vary spatially and temporally with flow conditions, tidal cycle at the start of the measurement and various other conditions. The RMA two-dimensional models will be used to calculate metrics quantifying residence time in user-defined area, as well as to calculate turbidity estimates.

Ecosystem productivity in the Delta may be influenced by the time scales for nutrient transport between different habitat types (Cloern, 2007). If the growth rate of primary producers in nutrient-rich habitats matches transport time scales, ecosystem-scale efficiency of nutrient utilization may be optimized (Cloern, 2007), and if mismatched, nutrients may be underutilized. Quantifying the time scales for the exchange of nutrients between the Sacramento River and the Yolo/Cache/Liberty area can increase understanding of the primary productivity regime and the exchange of nutrients in this region of the study area. Analysis of field sampling data (Lehman *et al.*, 2009) indicates that the export of nutrients from the Yolo/Cache/Liberty area varies on several time scales, from tidal to seasonal. Our isotopic analyses and preliminary mass balance calculations (Kendall *et al.*, 2010b) indicate that this area can also act as a significant sink of nutrients. Using the historical models of the hydrodynamics and nutrient dynamics in the study area (HYDRO, QUAL and the RMA models) in combination with the isotopic analyses, we hope to clarify the seasonal nature of the sources and sinks in the Yolo/Cache/Liberty area.

Figure 7 illustrates the relationships between NH_4 concentration and the $\delta^{15}N$ of NH_4 and $\delta^{15}N$ of NO_3; concentrations are plotted as $Ln(NH_4)$ so that processes such as nitrification, where the changes in isotopic composition with concentration should show exponential relations, would result in data points that plot along a straight line. Deviations from linearity indicate nutrient additions, other competing processes, or changes in process rates that would affect fractionation factors. The direction and extent of the deviations can be used to test hypotheses about causes of the deviations. The cross over points near Rio Vista and the confluence (denoted with vertical arrows) may indicate increased biological activity due to increased residence in tidally-influenced open water areas and/or the mixing of water sources (*e.g.*, new water from the San Joaquin River, with low $[NH_4]$ and high $[NO_3]$, inducing algal blooms). Residence time maps can clarify such hypotheses by using a volumetric loading calculation on a user-defined area. In addition, isotopic insight combined with the residence time calculations can help refine the rates of nutrient reactions locally and in upstream open water areas in QUAL. For example, Figure 8 shows that $\delta^{34}S$ of POM shows a large drop at RM12 (Rio Vista), presumably due to phytoplankton (C:N of POM <8.0) from the Yolo Tributaries which have very low $\delta^{34}S$ values. Yolo tributaries have low $\delta^{34}S$ values, probably due to sulfate reduction in the wetlands (Brian Pellerin, personal communication). Figure 9A shows that the $\delta^{34}S$ of phytoplankton-rich POM provides information about the source of chlorophyll at sampling sites. Effluent from the WWTP also has a distinctive value compared to upstream $\delta^{34}S$ values, and a SWC-funded pilot study (Kendall et al., 1010b) shows that the chemical and isotopic compositions of mainstem Sacramento River water samples from Isleton are almost always statistically significantly different than samples collected in the Yolo/Cache Complex (see Figure 9B). Hence, isotopic tools provide unique information about nutrient and organic matter sources in the study area. Hence, the inclusion of S-isotopes in our suite of measurements adds a significant additional piece of information to help us sort out the puzzle of nutrient dynamics in the study area.

3. Approach and Scope of Work

TASK 1 – Project Management

Investigator: Dr. Carol Kendall, US Geological Survey.

Background: Kendall currently has funding from the SWC and IEP to perform isotopic analyses on Delta samples collected 2009-2011. However, the funding does not extend into analysis of results using QUAL's nutrient model or for a synthesis of results into an ecosystem perspective. This proposal is intended to leverage this existing funding and fill

[5] http://www.science.calwater.ca.gov/pdf/workshops/POD/2007_IEP-POD_synthesis_report_031408.pdf

this data and interpretive gap.

Definition of Work: Standard project management: coordinate periodic reporting; co-ordinate the timing of major tasks; administer contracts; communication and distribution of results.

Staffing: Kendall will manage the project, assisted by Young. Kendall has an extensive background in project management during 20+ years as a USGS research project chief.

Budget:

Kendall: No funds are requested for Kendall's time (her salary is viewed as cost sharing in the budget). $13,016 (gross)

TASK 2 – Measurement of additional water quality parameters and data acquisition

Investigator: Dr. Megan Young and Steve Silva, US Geological Survey

Background: Although concurrent sampling programs in the study area have included multiple water quality and nutrient parameters and multiple isotopes (see Table 1), several important constituents have not yet been analyzed: chloride and sulfate as conservative tracers of water and mixing along the estuarine continuum; SO4-δ^{34}S and δ^{18}O to improve our ability to determine sources of phytoplankton using the existing POM-δ^{34}S data; and, there are insufficient nutrient data for model development at some sites (*e.g.*, no dissolved organic-P (DOP) data for critical sloughs).

Definition of Work: Young will organize the processing and QA/QC of selected samples for additional analyses, and incorporation of the new data into project databases. In specific, we propose to analyze: 200 archived samples from 2009-2011 for chloride and sulfate concentrations (to supply conservative tracers of water source), and 100 of them for SO4-δ^{34}S and δ^{18}O (to better trace slough sources of OM); 50 selected Delta samples that will be collected 2011-2012 in collaboration with Calla Schmidt (UCSC/USGS) as part of her new CALFED post-doc project for DOP and other nutrients (to fill data gaps for DSM2); and 50 selected samples that will be collected 2011 as part of a proposed SWC-funded mini-project to assess whether the equivalence of the biogeochemistry of the important but undersampled Miner and Steamboat Sloughs and the Sacramento River source water is justified (Kendall *et al.*, 2010b) for SO4-δ^{34}S and δ^{18}O*.* The chemical analyses will be performed at Dr. Randy Dahlgren's lab at UC Davis, and the δ^{34}S and δ^{18}O at the USGS. Effluent data for 2010 will be obtained from the Regional Water Quality Control Boards.

Staffing: Young, Silva and Choy (USGS)

Budget: $51,040 (gross). These data are needed for improvements to models, especially in regards to transport of OM from the Cache Complex to downstream sites.

Methods and techniques: All nutrient samples collected as part of Foe's transects were analyzed in Dahlgren's lab; hence, this lab was chosen for additional nutrient analyses to maximize data compatibility. Nutrient methods and QA/QC are described in Foe et al. (2010), and Dahlgren et al. (2010). SO4-δ^{34}S will be analyzed using the Giesemann et al. (1994) method, with precision of better than 0.2 permil.

TASK 3 - DSM2 historical model and QUAL nutrient model update - calculate hydrodynamic parameters for measurement transects with HYDRO

Investigators: Dr. Marianne Guerin, RMA technical staff.

Background: In 2009-2010, there were important developments in DSM2 that enhanced its modeling capabilities. QUAL[6] was calibrated (Guerin, 2011) for nutrients and temperature in the Delta from 1990 to 2008, with a focus on the Sacramento River and ammonia dynamics. The DSM2 model grid was later extended in the area of Liberty Island, which flooded in 2000. The recalibrated DSM2 "Liberty grid" gives a much-improved representation of the tidal exchange of water between the Sacramento River and Yolo/Cache/Liberty area. QUAL was recalibrated in mid-2010 when the DSM2 grid was updated and when the nutrient conceptual model was corrected, and recalibrated again after a data update in late-2010. QUAL nutrient model results using the new Liberty grid suggest that tidal dynamics and exchange in the Yolo/Cache/Liberty area can have an important effect on nutrient dynamics downstream of Rio Vista.

The recently generated data in the study area (Figures 10 and 11) have a much greater spatial and temporal density than the historical measurements used in the initial nutrient model calibration (Figure 1A). The data measurements used to calibrate the current nutrient model are relatively sparse spatially -- *e.g.*, there are only four historical locations between Freeport and the confluence of the Sacramento and San Joaquin Rivers – compared with the transect data will be incorporating (see Table 1 and Figure 11). In addition, the transect data has greater temporal density, as historical measurements were collected monthly, and in some months not at all, depending on the constituent.

Once incorporated in the calibration process, the uncertainty in the nutrient model results can be reduced and the accuracy can be increased both through the intensity and extent of the data-gathering effort and through comparison

[6] Funding through the State and Federal Water Contractors is gratefully acknowledged.

of additional measurements from different investigators. For example, comparison of uptake rates (Dugdale *et al.* 2007 and unpublished data) with nutrient and chlorophyll concentrations can be used to better interpret origins of phytoplankton and dominant source of N. Nutrient concentrations and $\delta^{15}N$ values have demonstrated that nitrification is by far the dominant N cycling process in the Delta, allowed calculation of nitrification rates (Figure 3B and 3C), and have shown the effect of the bacteria involved in the nitrification process on DOC concentrations, DOC-$\delta^{13}C$, and presumably DOC quality (Kendall et al., 2010b).

Definition of Work: This task involves incorporating the recent data and the results of analyses into the existing HYDRO hydrodynamic model and the QUAL nutrient model both as boundary conditions, constraints on boundary conditions, and to update the spatial rate parameters. Currently, the modeled period ends in mid-2009 for HYDRO and in 2008 for the QUAL nutrient model. The incorporation of new data will extend the modeled period through mid-2011 for both models. The QUAL nutrient model will be re-calibrated, and calibration and validation statistics will be documented. This task also requires QA/QC of data, filling data gaps, and potentially synthesizing data where none exists. Once the models are updated, hydrodynamic parameters from HYDRO such as stage and net flow and QUAL calculations for travel time can be performed to help interpret isotope data.
Staffing: Dr. Guerin and RMA staff.
Budget: $53,438 (gross)
Input: Data from Task 2 and the current DSM2 historical hydrodynamic and nutrient models.
Methods and techniques: The updating of model boundary conditions and model calibration and validation will follow standard model procedures. The calculation of hydrodynamic parameters is also performed using standard methodology.

TASK 4 – Modeling of scenarios and visualization of results
Investigators: Dr. Marianne Guerin
Background: DRERIP conceptual models supply the broad outline in this project defining the interaction of models and data. The product of Task 4 will be a set of results that can be used to help predict the response of ecosystem parameters identified in DRERIP models to proposed adaptive management of Delta habitat and food web conditions. Component variables (e.g., temperature, nutrient concentrations) from conceptual models can be calculated using existing tools and data, and model scenarios can be used to evaluate changes in these variables under changed Delta conditions, consistent with the intended use of DRERIP conceptual models.

The hydrodynamic models HYDRO[7] and RMA2 (RMA, 2005) have both been recently calibrated. Both have been extensively used to simulate both historical and hypothetical Delta conditions. QUAL calibration and validation statistics using the available monthly to bi-monthly data indicated that the model is applicable at a monthly time scale at a minimum. With incorporation of newly collected nutrient data at a significantly greater spatial and temporal resolution, the model should be applicable at a daily time step. However, most QUAL results will be presented on a monthly and/or seasonal basis. All of the models and model applications proposed in this project have been used recently for similar purposes in the BDCP process. RMA has developed a methodology for the near-real-time forecasting of turbidity using its 2-dimensional flow and turbidity models. RMA has developed visualization tools that can be used to create contour plots of QUAL results, and has long had tools for the visualization of RMA model results.

Definition of Work: Using the historical DSM2 and RMA2 models and visualization tools and the results from Tasks 2 and 3, we will run a series of one-year scenarios, sketched below, and prepare a set of results plotting spatial distributions of the DRERIP conceptual model components on a monthly and/or seasonal basis. The scenarios will be developed to address the main Hypothesis: *Key habitat parameters in the study area can be adaptively managed by manipulating flows, water temperature, and nutrients concentrations in the Sacramento River and in effluent inflows*.

Most of the model scenarios will be run with DSM2 only. Scenarios applying a range of inflow conditions will also be run with RMA2 to determine changes in residence time. Scenarios applying a range of turbidity values will be run with RMA11 using turbidity relationships developed in RMA's real-time turbidity modeling project. The following are the proposed scenarios – the exact values of the perturbations may be changed:

1. Base/Historical Case: What are the base/historical values and spatial distributions of temperature, the nutrients, residence time, and turbidity in the study area?
2. Scenario 'Shift Temperature': Given the answer to the Base Case questions, what does shifting Sacramento R temperature do to monthly and seasonal average temperatures? Approach Run DSM2 by SHIFTING temperature boundary conditions by +/- 5 deg C.

[7] http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/DSM2UsersGroup/DSM2_Recalibration_102709.pdf,

3. Scenario 'Shift N and P': Given the answer to the Base Case questions, how does shifting the nutrient load at historical flow levels change monthly/seasonal nutrient distributions? Approach Run DSM2 by increasing and decreasing the concentration of all boundary condition N or P constituents by +/- 20 %.
4. Scenario 'Shift Inflow' – Given the answer to the Base Case questions, how does changing flow levels change monthly/seasonal distributions of the DRERIP parameters? Approach Change Sacramento R. and Yolo Bypass inflow by +/- 20 % in selected seasons, holding concentration constant.
5. Scenario 'Turbidity': Given the answer to the Base Case questions, how does shifting the turbidity at changed flow levels change monthly/seasonal turbidity distributions? Approach: Run RMA11 by changing the turbidity concentration at the flow boundaries using flow-based relationships.
6. Scenario 'No effluent': Given the answer to the Base Case questions, what does removing all effluent do to monthly/seasonal nutrient distributions? Approach Remove all effluent boundary inflow.

The effects will be determined spatially and temporally for each scenario, and RMA visualization tools will be utilized for this task. Each scenario will be compared with the Base Case (Historical) model.
Staffing: Dr. Guerin will perform and analyze RMA and DSM2 models and scenario output with help from RMA staff for the preparation of visualization results for DSM2.
Budget:: $58,520 (gross)
Input: The updated DSM2 Historical nutrient model from Tasks 2 and 3 is used as a Base Case. The RM2 and RMA11 historical model boundary conditions will be updated using the data compiled from Tasks 2 and 3.
Methods and techniques: The modeling of scenarios and visualization of model results will follow standard modeling and analysis procedures. Specific hypotheses will be formulated in the development of model scenarios.

TASK 5 – Analysis of spatial isotope results and spatial modeling and visualization of habitat and food web DRERIP conceptual model components
Investigators: Drs. Carol Kendall, Marianne Guerin, Megan Young, and Tamara Kraus; and Steve Silva.
Background: One of the main difficulties in synthesizing large amounts of data is formulating an appropriate set of variables and an analysis methodology. The DRERIP conceptual models provide a firm basis for selecting a relevant set of variables for the evaluation of habitat and food web in the study area. Spatial visualization (*e.g.,* Figure 6) of biotic and abiotic parameters calculated by well-known models provides a relatively easy way to interpret these results in the context of the main hypothesis applied to the results from the scenarios. The results are designed to produce information and analyses relevant to water management issues.
Definition of Work: This task involves the collation and interpretation of spatial visualization results from isotopic and model analyses (*e.g.,* residence time, water temperature, turbidity). Thepurpose of the visualization plots is to develop a clearer picture of historical habitat and food web parameters and the same parameters under the changed conditions developed in the scenarios. All will share in the preparation of deliverables.
Staffing: Drs. Kendall and Guerin lead the task, with others assisting.
Budget:
Kendall: No funds are requested for Kendall's time (her salary is viewed as cost sharing in the budget).
$111,886 (gross)
Input: Results from Tasks 2-4.
Methods and techniques: The investigators will analyze and synthesize data and model output. Specific hypotheses will be formulated in the development of model scenarios, and results will be assessed to test each hypothesis.

4. Deliverables

Reports: Two interim reports and a Final report will be produced and delivered to DFG. One report will focus on isotopic analyses and nutrient data analysis and another will focus on the analysis of modeling scenarios and model development. The Final Report will be a compendium of all information, data descriptions, and analyses. The quantitative results will be evaluated in the context of the project hypothesis where relevant in each report.
Presentations: At a minimum, the results of the modeling scenarios and the description of model development, including the use isotope analyses to constrain nutrient model parameters, will presented at California Water and Environment Modeling Forum annual meetings, at a Delta Science Conference, at an IEP meeting, at AGU, and as part of one or more Webinars.
QUAL nutrient model: The calibrated model and calibration data will be publically available through the Delta Modeling Section, Department of Water Resources, after their internal review.
Visualization and animation: Analysis of isotopic data has indicated that some open water areas have a strong influence on nutrient dynamics in nearby waters, and that mixing processes may explain some intriguing isotopic shifts. Animations using RMA modeling tools, such as particle tracking and residence time calculations; that visualize hydrodynamic processes may lend insight that static calculations cannot offer.

Database: An appropriate on-line location for the data will be identified, and all data posted after peer-reviewed publication (subject to agreement by all data collectors).
Journal article: At least one article intended for a peer-reviewed journal will be prepared.

5. Feasibility

The timelines for incorporating the isotope data into models are dependent on (1) when the isotope data from the new IEP project are available (about half the samples have been analyzed, and dataset will be QA/QC'd by fall 2011), and (2) the level of funding available for the second year of the IEP project when the data would be interpreted and journal papers written. Hence, this proposal potentially has a variable time frame (24 - 36 months). Kendall will be responsible for overall project management and timing.

For the modeling components and hypothesis testing, we are limiting our focus to DRERIP conceptual model variables that have a generally accepted importance (*e.g.,* water temperature, residence time, nutrient concentrations and algal growth) and therefore potentially have the greatest influence on managing Delta operations and future Delta habitat and food web changes. We will use isotopic analysis and numerical model results to calculate historical conditions in the study area, and model scenarios to estimate how the ecosystem responds to changes in physical and chemical parameters at intermediate time and spatial scales – months and kilometers, respectively. Isotopic analyses provide an additional source of information for nutrient model calibration that adds qualitative, and perhaps semi-quantitative, insight into nutrient cycling that chemical data alone cannot provide (seeTable 2). Furthermore, the modeling information provides added value to the interpretation of the isotopic data. Isotope data are also very useful for developing hypotheses about processes and sources that can be tested with chemical data and model scenarios. All the types of isotope measurements are well established tools for ecosystem studies, and all but NH4-δ^{15}N had previously been applied to recent San Joaquin River monitoring and research studies (Kendall et al., 2008a). Each model used in the project is well-known and generally accepted.

6. Relevance to the CALFED ERP

Relevance to this PSP:

The proposed project is collaborative and interdisciplinary in nature, focuses on the integration and synthesis of existing information, extends previous research funded by other institutions, and extends the analysis and interpretation of information collected under currently funded projects. The intent of the modeling components is to clarify and quantify ecosystem level responses to changes in water management and nutrient loads in the study area using selected DRERIP ecosystem conceptual models and variables, for example, changes in residence time and nutrient concentrations. Using model scenarios, the proposal aims to better understand the impact of possible management decisions and the potential for adaptive management of key DREIP-defined drivers and outcomes for primary production (see, *e.g.*, the DRERIP Foodweb Model).

As mentioned in Section II of the PSP, the ERP Priority 2 states a need for: *Research that tests hypotheses identified in the Delta Regional Ecosystem Restoration Implementation Plan DRERIP evaluation of the BDCP conservation measures and National Research Council Operations Criteria and Plan (OCAP) Biological Opinion (BO) review and address uncertainties.* Our research will address the following items identified in Priority 2:

- Develop temporal regimes for water movement that minimizes adverse effects on fisheries.
- Address potential factors affecting productivity (e.g. contaminants).
- Conduct research to determine scale and balance of flow, sediment, and organic material inputs needed to restore riverine ecosystem function.

We will use model scenarios to address the following hypothesis:

Main Hypothesis: Key habitat parameters in the study area can be adaptively managed by manipulating flows, water temperature, and nutrient species/concentrations in the Sacramento River and in effluent discharges.

Habitat quantity and quality and productivity in the food web are characterized by many biotic and abiotic variables. The DRERIP conceptual models will be used as a guide for identifying important component variables. The combination of nutrient and isotopic measurements, modeled nutrient dynamics and the concurrent characterization of abiotic factors such as residence time, water depth and flow can provide new insight into food web dynamics and seasonal habitat variability. Combining the modeling and visualization tools with recent data from the sampling programs, particularly isotope data, allows the following questions (among others) that are directly relevant to Priority 2 goals to be addressed:

- Which areas act as nutrient sources and sinks? What processes are involved? How do they behave under altered flow and nutrient boundary conditions? Can we identify the specific sources (*e.g*., agricultural vs. effluent)?
  - Do nutrient and food sources from the Yolo/Cache/Liberty area support the food web? Under what conditions? What about other open water areas such as Sherman island?
  - What system drivers *(e.g*., inflow changes) can be used to control algal growth rate?
  - Can flow changes be used to control water temperature and potentially inhibit the cyanobacterium *Microcystis aeruginosa*?

In a very general sense, our project aims to address how hydrodynamic conditions, water quality, water temperature, and primary and secondary production are linked within aquatic ecosystems of the Delta and its tributaries and floodplains, and how habitat variables for aquatic organisms are distributed spatially under different river inflow and water temperature scenarios. The isotopic analyses will address the linkage between water quality, nutrient sources and sinks, and primary production. The residence time calculations will address linkages between hydrodynamic conditions and primary production when combined with QUAL output *(e.g.*, for chlorophyll). The model scenarios will provide a set of spatially explicit model results (from QUAL and RMA models) to directly address spatial changes for habitat variables under different hydrodynamic regimes. We will not address specific requirements for individual species.

We have chosen to use a set of spatially-explicit model outputs, based on variables identified in DREIP models, at monthly and seasonal time scales to describe habitat and food web in the study area. Contour plots are generally more accessible and easier to interpret than tables of data. RMA has a long history of developing high quality visualization tools - we believe these tools provide a solid basis for interpretation. Contour plots can be easily displayed as time-dependent “movies’ (animations) showing the progression of model results with time.

Relevance to CALFED Issues Outside this PSP

As mentioned previously, the results in this proposal extend currently funded projects (IEP, SWC) investigating the status of the Delta’s food web and habitat issues. Paraphrasing the goal of the BDCP is: *To identify water and habitat restoration actions to recover endangered species and their habitats in the Delta*. This proposal provides the tools and structure to supply information to assist BDCP in reaching their goal – many of the models and analysis types are similar to BDCP types (RMA is a team member for the CH2M HILL team working on BDCP). In terms of the CALFED goals of Improving Ecosystem Quality and Water Quality, the outcomes of this proposal provide information to help improve water management policies to achieve these goals. The quantitative findings from model scenario analysis can be utilized to predict the consequences of adaptive management of Delta conditions, and potentially to assist resource specialists in implementing management objectives.

7. Expected quantitative results (project summary):

The main goals of this project are to:

- Use existing archived and maybe new samples to fill-in data gaps: analysis of archived samples for Cl and SO4 concentrations provide better conservative tracers of water than EC; more importantly, the analysis of chemistry and isotope samples from the previously undersampled Miner and Steamboat Sloughs (not original parts of any of the transects).
- Extend HYDRO (hydrodynamics) and QUAL (nutrient and temperature) models through the end of concurrent data collection efforts (through April 2011).
- Calculate travel time estimates to use in analysis of isotopic data along transects.
- Calculate stage, net flow and other abiotic parameters to help interpret isotopic results.
- Utilize isotopic analyses and other measurements to inform and constrain the current nutrient model parameterization and improve the nutrient model calibration by:
  - identifying the dominant processes involved in the transformation of nutrients *via* distinctive shifts in isotopic composition,
  - providing a means of calculating rate parameters for individual nutrient transformations (*e.g.*, nitrification, algal growth), and,
  - identifying and constraining nutrient sources (*e.g.* waste water *vs.* agricultural).
- Develop and implement model scenarios to use in testing the project hypothesis.
- Calculate residence time and turbidity during the sampled period using RMA models.

- Develop a set of monthly and/or seasonal contour plots (and possibly animations) comparing historical and scenario computational output from DSM2 and RMA models for the following parameters:
    - Nutrients, temperature, chlorophyll a, and DO (QUAL)
    - Residence time, net flow, water depth, and turbidity (RMA)

8. Other products and results:

N/A.

9. Qualifications

The principal investigators for the tasks are each expert in their fields, and are intimately familiar with the associated datasets, models and issues. Dr. Kendall, elected an AGU Fellow in 2010, is an internationally recognized expert in using isotopes to interpret nutrient and organic matter dynamics, and has managed numerous projects during her 20+ years as the project chief of the Isotope Tracers Project of the USGS National Research Program. Dr. Guerin has expertise in both 1-D and 2-D models of the Delta, and is currently the only expert in the application of both the DSM2 and RMA suites of models (or, in the application of DSM2 and any other higher dimensional model). Dr. Guerin has developed and calibrated the QUAL nutrient model, is involved with nutrient modeling in the BDCP process, has developed a turbidity forecasting methodology using RMA 2-D models, and has produced and interpreted model results similar to the ones proposed in this project. Dr. Guerin has expertise in flow and transport modeling at all spatial scales, with extensive practical and theoretical experience, and has managed or worked in numerous multi-disciplinary projects in academia and government research laboratories in the U.S. and abroad. Drs. Kendall, Guerin, and Young have been actively collaborating on analyzing and modeling the water quality and nutrient data since 2009, and have several joint papers in-progress; both Kendall and Guerin have presented talks on the background data and models in this project.

Dr. Kendall will coordinate the overall management of the project, ensure timely delivery of reports and presentations, and supervise the staff working at the USGS. Dr. Guerin will coordinate the conceptual and numerical modeling aspects and any staff from RMA. Dr. Young will coordinate the collection of selected new samples and the selection of archived samples for further chemical and isotopic analyses laboratory results, submission of the samples to Dr. Dahlgren's lab, the QA/QC of the new data, incorporation of the new data into laboratory databases, and distribution of the data. Drs. Kendall and Young will share responsibility for at least one paper using modeling results from the project to enhance interpretation of nutrient and organic matter sources in the Delta using the isotope and chemical data.

Previous SFE Projects Funded by State Agencies:

Kendall:

co-PI on CALFED DWP project "DOC Release from Delta Wetlands", 2003-2006.
co-PI on CALFED DWP project "Improving Delta drinking water quality: managing sources of disinfection byproduct-forming material in the State Water Project", 2004-2006.
PI on Task 7 "BOD Isotope Study" of Will Stringfellow's SJR Up-Stream DO TMDL Project, 2005-2009.
PI on CALFED Prop. 50 DWP PIN 700 project "Determination of Sources of Organic Matter and Nutrients in the San Joaquin River**",** 2005-2009.
co-PI on 3 other CALFED Prop. 50 DWP projects: PIN 755, PIN 508, PIN 396; 2006-2010(11).
PI on SWC-funded project "Application of stable isotope techniques for determining NH4 and NO3 sources and cycling mechanisms related to POD-decline in the Sacramento River, Delta, and northern San Francisco Bay", 2009-2011.
PI on IEP-funded project "Evaluation of the effect of seasonal variations in flow on the spatial and temporal variations of nutrients, organic matter, and phytoplankton in the Sacramento River and northern San Francisco Bay", 2010-2011.
PI on IEP-funded project "Determination of the causes of seasonal and spatial variations in NH4 sources, sinks, and contributions to algal productivity in the Sacramento River, Delta, and northern San Francisco Bay using a multi-isotope approach", 2010-2012.

Guerin:

PI on CALFED Science grant (# 1042) in 2006: "The Consequences of Operational Decisions on Water Quality: Reconciling Delta Smelt, Salmon and Human Needs".

Table 1. Transect dates and data types (site locations shown in Figure 1C)

Transect Dates	PI and project	Isotope samples *	SR-Cache-Delta samples +	Chemistry (includes measured values and ones and calculated by difference) #
Monthly $	USGS Polaris	No	0-0-8	see http://sfbay.wr.usgs.gov/access/wqdata/ for details.
3/26-27/09	Dugdale SWC	Yes	10-2-13	NO3, NO2, NH4, PO4, urea, DIC, silica, Chl-a, Pheo, POC, PON, EC, T, uptake rates (C, NO3, NH4), OBS, T, etc.
4/23-24/09	Dugdale SWC	Yes	10-3-12	
3/9/09	Parker WB	No	7-0-1	NO3, NO2, NH4, PO4, urea, DIC, silica, Chl-a, Pheo, Chl 5u, POC, PON, EC, T, uptake rates (C, NO3, NH4), flow cytometer, SCUFA, T, etc.
4/6/09	Parker WB	No	7-0-1	
5/8/09	Parker WB	No	7-0-1	
3/16-17/09	Foe WB	No	5-4-4	NO3, NO2, NH4, TN, DON, TP, TDP, PO4, DOC, Chl-a, Pheo, EC, pH, DO, NTU, T, etc.
3/30-31/09	Foe WB	No	5-4-4	
4/13-14/09	Foe WB	No	5-4-4	
4/27-28/09	Foe WB	No	5-4-4	
5/11-12/09	Foe WB	No	5-4-4	
5/26-27/09	Foe WB	Yes	5-4-4	
6/8-9/09	Foe WB	Yes	5-4-4	
6/22-23/09	Foe WB	Yes	5-4-4	
7/14-15/09	Foe WB	Yes	5-4-4	
8/3-4/09	Foe WB	Yes	5-4-4	
9/28-29/09	Foe WB	Yes	5-4-4	
10/20-21/09	Foe WB	Yes	5-4-4	
11/9-10/09	Foe WB	Yes	5-4-4	
12/7-8/09	Foe WB	Yes	5-4-4	
1/25-26/10	Foe WB	Yes	5-7-4	
2/22-23/10	Foe WB	Yes	5-7-4	
4/26/10	Dugdale 2Rivers	Yes	22-0-4	NO3, NO2, NH4, PO4, urea, DIC, silica, Chl-a, Pheo, POC, PON, EC, T, uptake rates (C, NO3, NH4), OBS, T, etc. at the 10-0-4 Dugdale sites; only NO3, NH4, PO4, and silica data are available at the additional 5-12 “grab sample” sites.
8/25/10	Dugdale 2Rivers	Yes	16-0-4	
4/19/11	Dugdale 2Rivers	Yes	15-0-4	

NOTES:

* Isotope analyses include NH4-δ^{15}N; NO3 δ^{15}N and δ^{18}O; DOC-δ^{13}C; POM δ^{13}C, δ^{15}N, δ^{34}S, C:N, C:S; and water δ^{18}O and δ^{2}H. Samples are archived for future DOM δ^{13}C, δ^{15}N, δ^{34}S, C:N, and C:S; and SO4 δ^{34}S and δ^{18}O.

+ Sites are divided into the categories “SR” (I-80 to Isleton), “Cache” (tributaries and sloughs in the Cache/Yolo Complex), and “Delta” (Rio Vista downstream to San Pablo Bay). Hence, 4-2-4 means 4 sites in the SR, 2 in the Complex, and 4 in the Delta. Foe sites sampled on the San Joaquin River are not included in this table.

This is a list of the chemistry data we have access to; other data may be available.

$ Data are site-dependent; for example, nutrient data only available for a subset of sites.

Table 2. The value of isotopic measurements for the interpretation of water quality data and in parameterizing the QUAL nutrient model.

Tracer type (*new data from this project)	Interpretive Value for Processes	Value for QUAL Nutrient Model
Particulate organic matter (POM) $\delta^{15}N$, $\delta^{13}C$, $\delta^{34}S$, C:N, C:S	Information about the source of C, N, and S and the biogeochemical reactions that cycle them; Quantify algal *vs* terrestrial contributions to biomass; Evaluate role of algal-based foodwebs, contributions of marine sources of POM & nutrients.	Evaluate and constrain the modeled contribution of DICU nutrients *vs.* riverine or marine sources (*i.e.*, from the Martinez boundary) , or mixing of waters from different boundary inflows
Nitrate $\delta^{18}O$ and $\delta^{15}N$	Quantify nitrate from different sources (fertilizer, wastewater, wetlands, etc); Role of algae and degree of recycling; Evidence for denitrification or assimilation.	Constrain sources of nitrate – distinguish between nitrate from boundary inflow (*e.g.*, wastewater or other sources) or as a product of reaction kinetics
Ammonium $\delta^{15}N$	Quantify NH_4 from different sources (fertilizer, wastewater, wetlands, etc); Role of algae and degree of recycling; Evidence for nitrification or assimilation.	Constrain sources of NH_4 – distinguish between NH_4 from boundary inflow, or sources of nitrate as a product of reaction kinetics
Water $\delta^{18}O$ and $\delta^{2}H$	Ideal conservative tracers of water sources and mixing; useful for quantifying flow contributions from different tributaries and groundwater.	Evaluate the modeled contribution of DICU inflow and mixing of waters from different boundary inflows
Dissolved organic carbon (DOC) $\delta^{13}C$	Information on sources of DOC; evidence for degradation of organic matter; quantify algal vs terrestrial contributions to DOC.	Evaluate the modeled contribution of DICU nutrients *vs.* riverine or marine sources. Evaluate the respective roles of algae and bacteria in the transformation of nutrients.
* Sulfate $\delta^{34}S$ and $\delta^{18}O$	Quantify sulfate from different sources (upper Sacramento River, marine, wastewater, sulfate reduction in the wetlands, etc), and source of phytoplankton that incorporates the S during growth (upper Sacramento River, Yolo/Cache Slough, marine, or estuarine).	Combined with POM-$\delta^{34}S$ data, constrain sources of phytoplankton; evaluate the modeled contribution of DICU inflow and mixing of waters from different boundary inflows

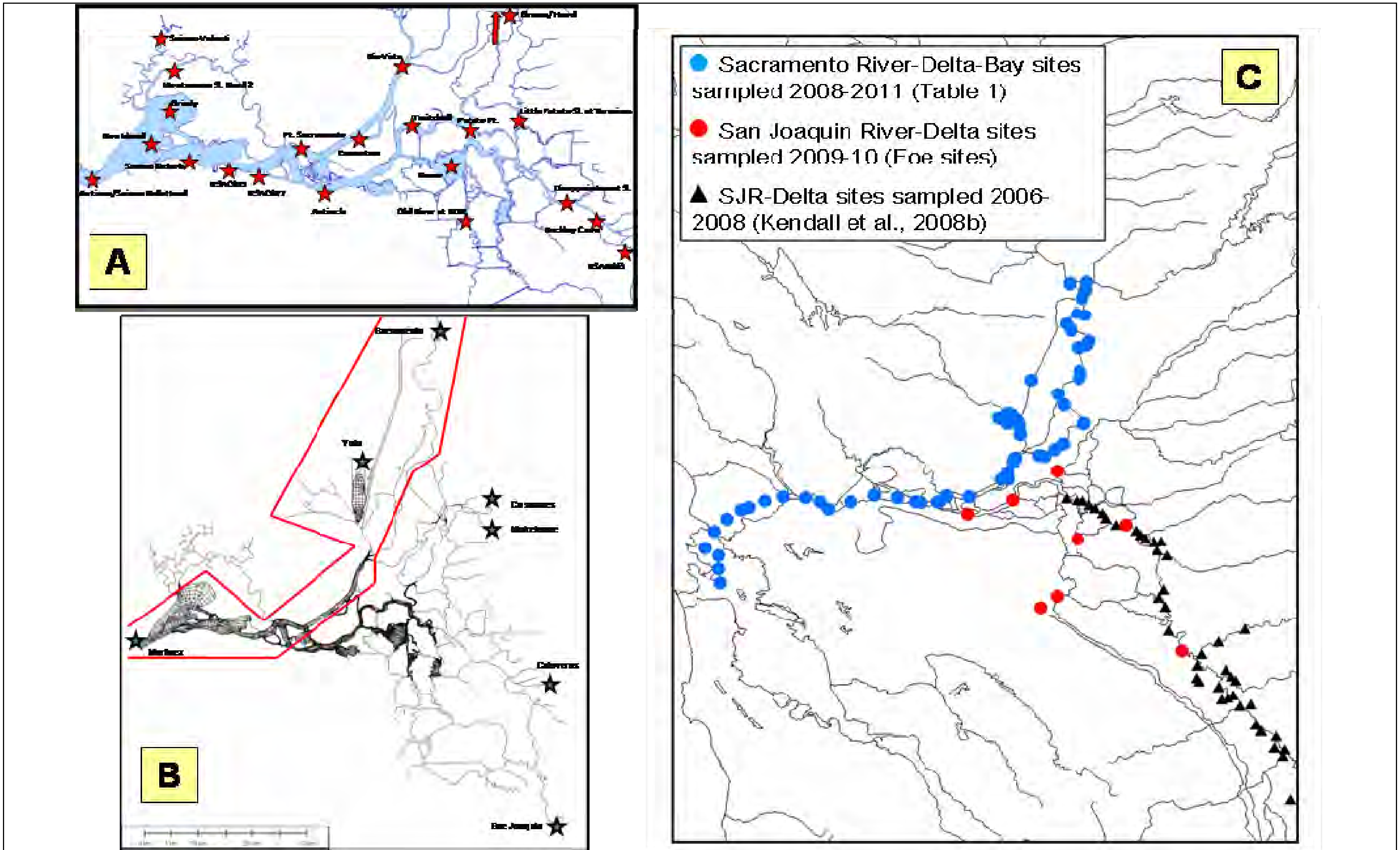


Figure 1. Maps comparing old and new sites where data are available for use in recalibrating the DSM2 model.
A: This map shows the old data used for model calibration; there are a max of 4 locations between the SRWTP outflow and the confluence (Greens/Hood, Rio Vista, Emmaton and Pt. Sacramento), and none in Yolo/Cache/Liberty, etc.
B: Red lines give the approximate boundaries of the study area. Stars give the approximate location of the model inflow boundaries. The grid is from RMA's 2-D models.
C: This map shows the sites with newly available data (Table 1). Compare this with the old data available in the previous calibration (Figure 1A).

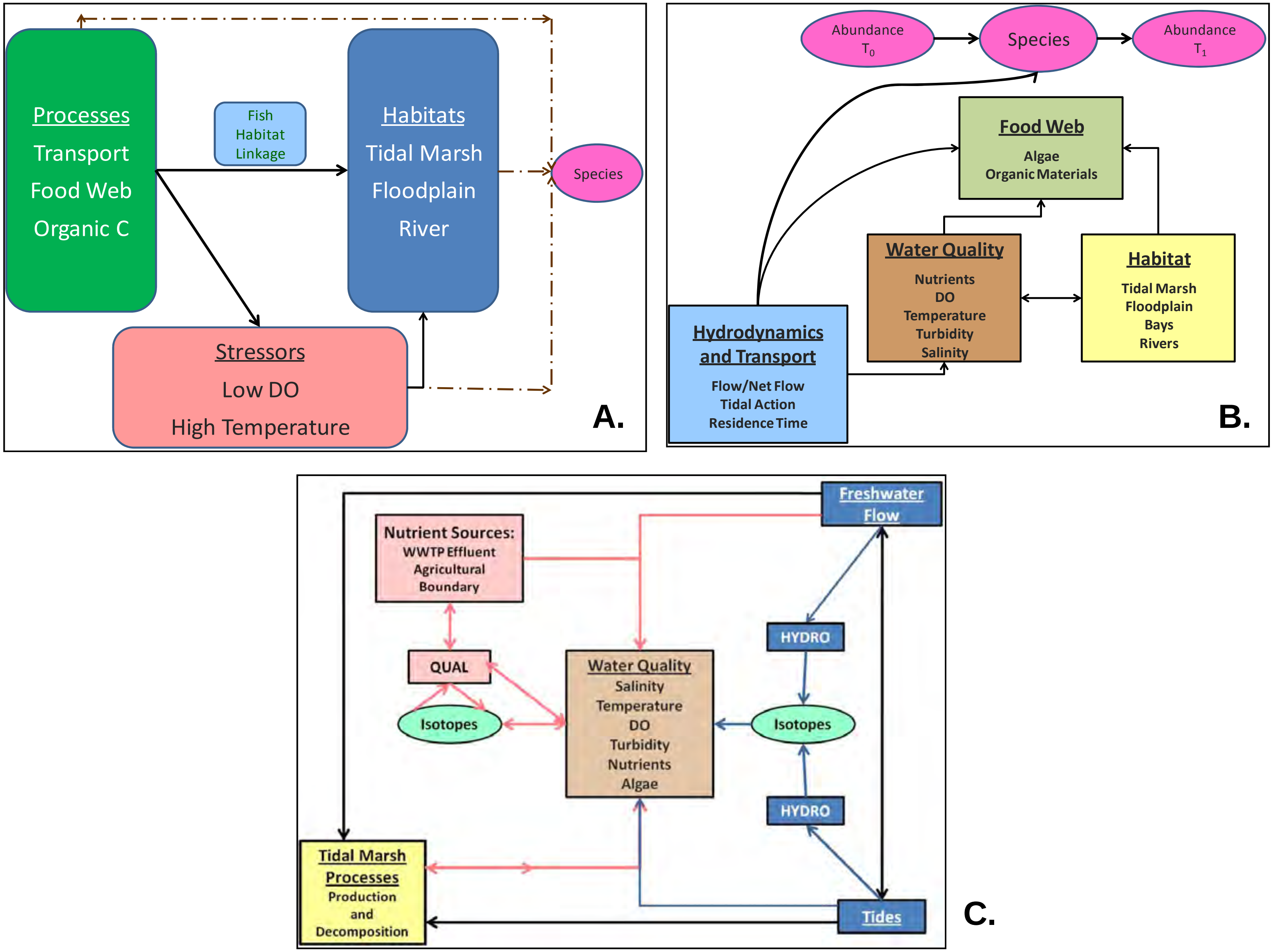
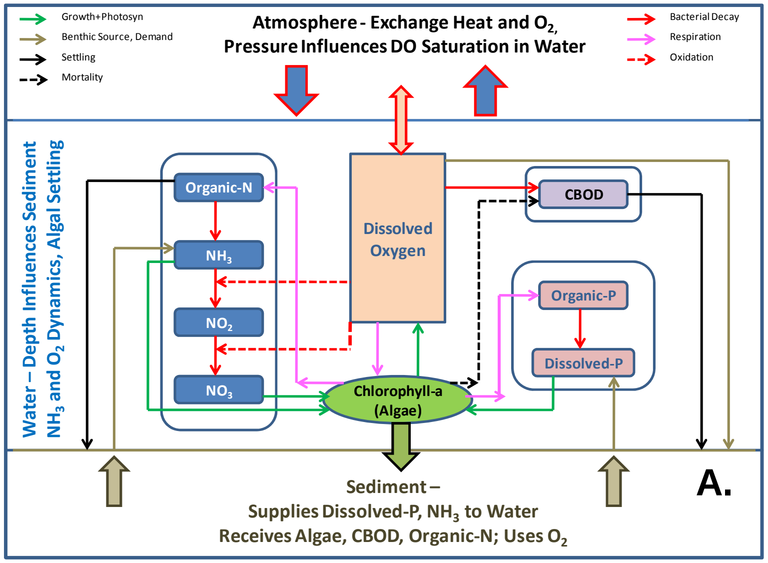
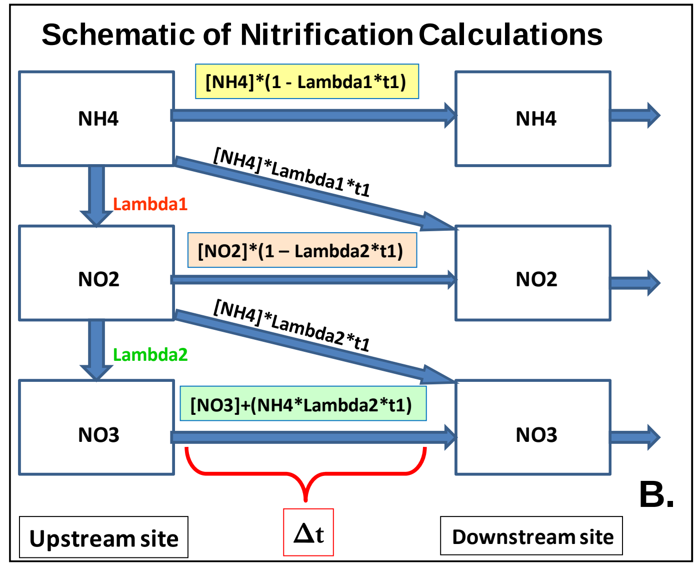


Figure 2. Figures are simplifications of DRERIP conceptual models used in the project. (We will not be using species conceptual models).
Figure A. is the highest level concept.
Figure B. is based on the DRERIP model for Fish Habitat Linkage showing relationships between model components and the food web.
Figure C. shows interaction between processes, data, isotopes and the DSM2 models HYDRO and QUAL, based on the DRERIP Tidal Marsh model.





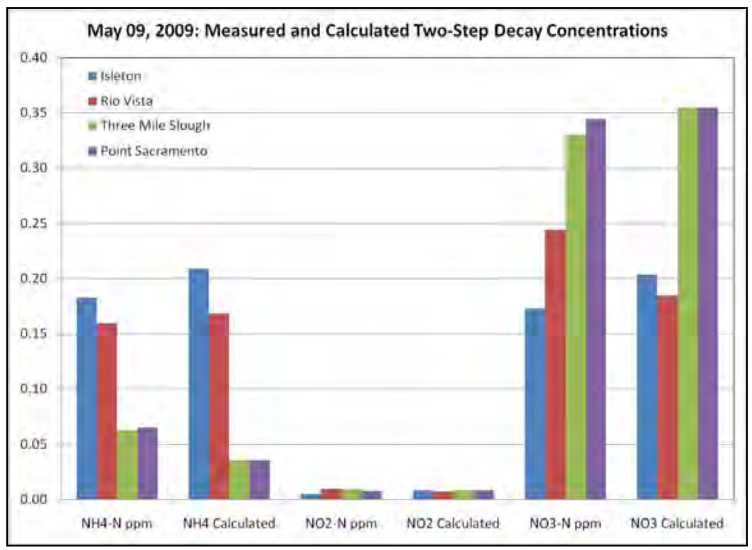
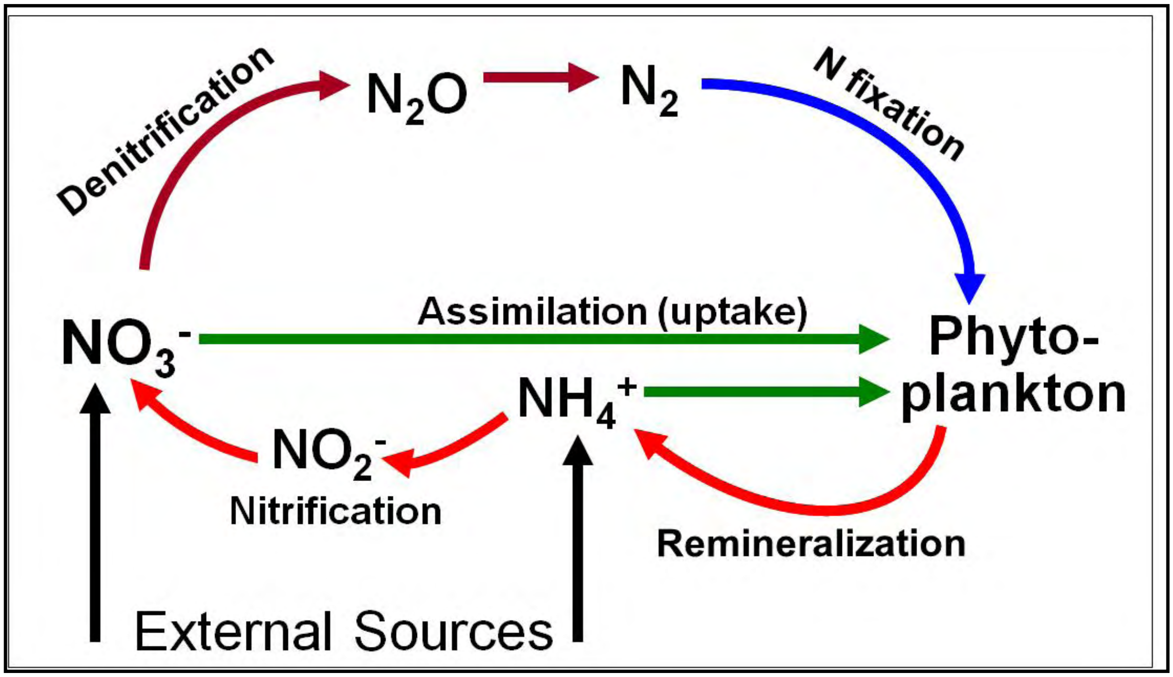


Figure 3. A. The conceptual model of nutrient dynamics used in QUAL – boxes and oval in the water/blue section are model variables. Process rates (arrows) and other parameter values will be refined using water quality and isotope data.

Figure B. Schematic of model assumed plug flow (no mixing) and constant concentration at Hood. Travel time, Δ_t, was estimated with QUAL tracer models. Ammonia and NO_2 decay linearly as traveling; Lambda2 < Lambda1. Decay of NO_2 to NO_3 directly was ignored.

Figure C. Comparison of constituent measurements and concentrations for the May 09, 2009 transect calculated using DSM2-calculated travel times and the simplified conceptual model of nitrification illustrated in Figure 3B.



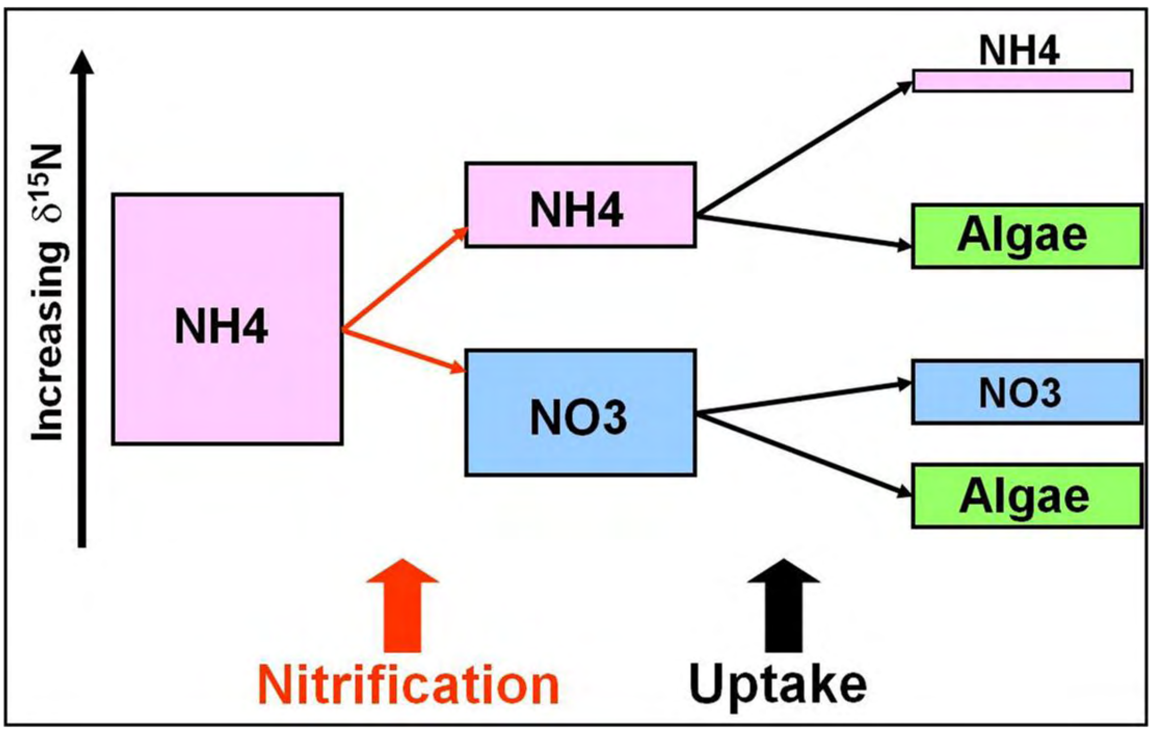


Figure 4A (upper): This cartoon shows the main sources of N and processes that cycle-N in aquatic systems. External sources include waste water treatment plants, agricultural loads, and wetlands.

Figure 4B (lower): Conceptual model showing how biological processes can produce distinctive changes in isotope composition. Boxes are different pools of N, size is proportional to size of N-pool, and position reflects its average $\delta^{15}N$. Nitrification produced new NO3 with a lower $\delta^{15}N$ and residual NH4 with a higher $\delta^{15}N$ than the original NH4. Uptake of the NH4 or NO3 by algae (phytoplankton) results in algae with different $\delta^{15}N$ values depending on the source of the N. Therefore, the $\delta^{15}N$ of the algae can be used to determine whether NH4 or NO3 was the dominant source of N to uptake.

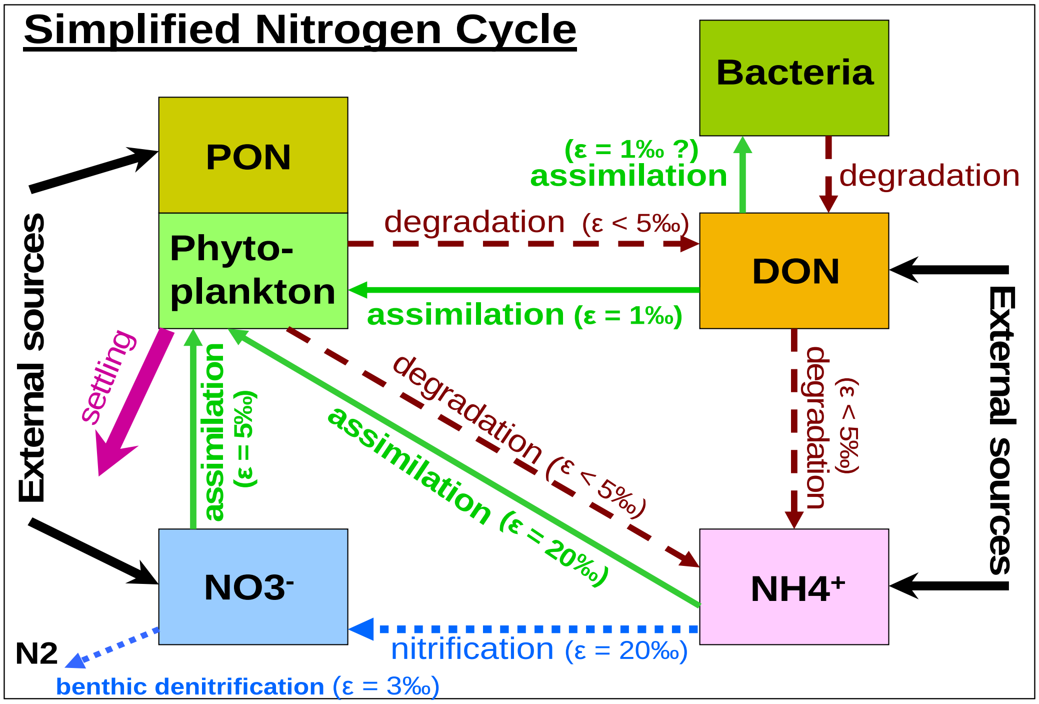


Figure 5. This cartoon shows the main internal and external N-sources, N-bearing constituents, and biogeochemical processes moving N between pools, along with approximate isotopic fractions (ε) of each reaction.

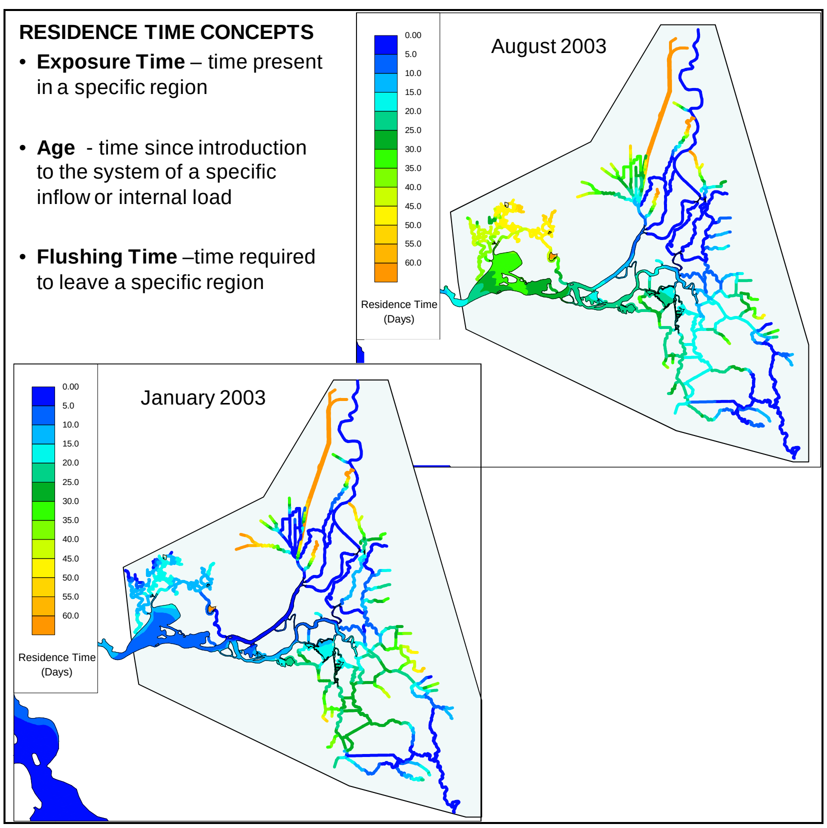


Figure 6. Residence time can be calculated in RMA models – these figures show the metric exposure time in the Delta area upstream of Martinez in January and August of 2003.

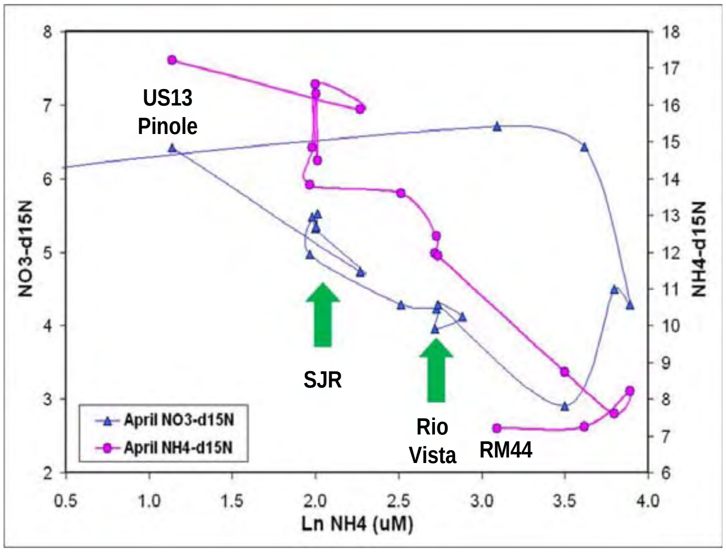


Figure 7. Plot illustrates the cycling of nutrients at Rio Vista and near the confluence of the Sacramento and San Joaquin Rivers – possibly indicating increased residence time of waters in upstream open water areas.

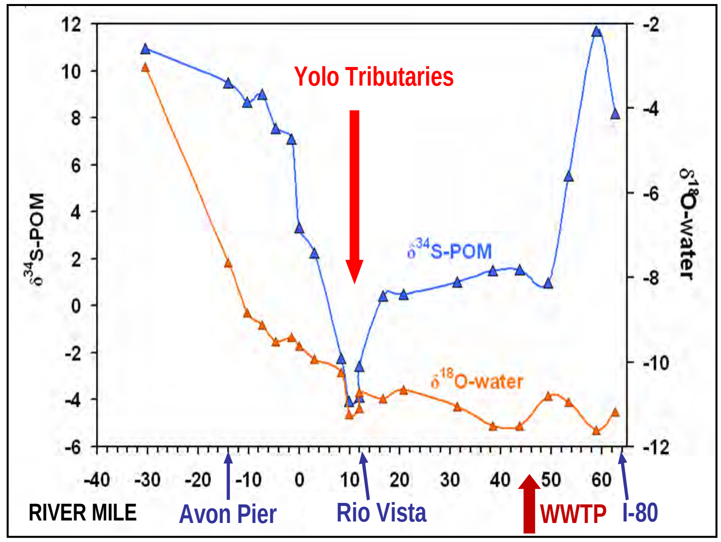


Figure 8. $\delta^{34}S$ of POM shows a large drop near RM12, presumably due to organics from the Yolo Tribs which have very low $\delta^{34}S$ values, probably due to sulfate reduction in the wetlands. $\delta^{34}S$ values then increase downstream due to mixing with phytoplankton with a marine "isotopic signature" (ie, ~+20‰). If simple 2-endmember mixing dominated, then the $\delta^{34}S$ values should have plotted along a straight line. The curvature of the $\delta^{34}S$ data reflects additional sources of phytoplankton grown in environments with varying amounts of marine-derived SO4. The water $\delta^{18}O$ values are useful as a conservative tracer of water source.

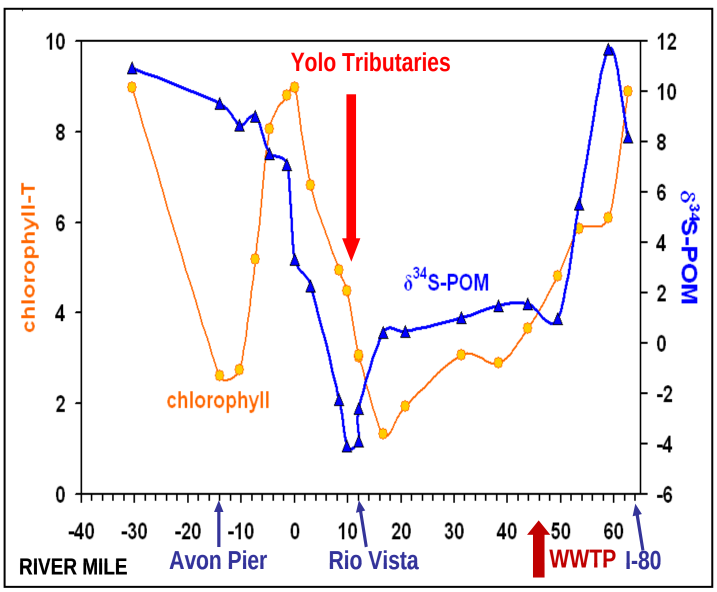


Figure 9A. Chlorophyll concentrations (Dugdale, unpub. data) show a maximum near the confluence of the SJR in April 09, showing the influence of nutrient-rich SJR inflow. The correlation of increasing $\delta^{34}S$ of the phytoplankton-dominated POM (C:N <8) with increasing chlorophyll, plus other data, can be used to estimate the location how much of the phytoplankton are derived from

	t-Test				PAIRED t-Tests					
					TRANSECT DATA			FOE DATA		
Parameter⁺	# River samples	# Trib samples	P value^	Trib vs. River	# Tribs	P value^	Trib vs. River	# Tribs	P value^	Trib vs. River
NO3-$\delta^{15}N$	3	25	0.181	T>R	9	0.001	T>R			
NO3 $\delta^{18}O$	3	35	0.895	NS	9	0.034	T>R			
NH4-$\delta^{15}N$	2	17	0.004	T>R	3	0.066	T>R			
H2O-$\delta^{18}O$	3	25	<0.000	T>R	9	0.002	T>R			
H2O-$\delta^{2}H$	3	25	0.017	T>R	9	0.010	T>R			
POM-C:N (at)	3	25	0.143	NS	9	0.057	T>R			
POM-$\delta^{13}C$	3	25	0.030	T<R	9	0.007	T<R			
POM-$\delta^{15}N$	3	25	0.601	NS	9	0.367	--			
POM-$\delta^{34}S$	10	22	<0.000	T<R	5	0.022	T<R	8	0.001	T<R
DOC-$\delta^{13}C$	3	25	0.313	NS	9	0.027	T<R			
DOC	15	25	0.001	T>R	9	0.004	T>R	16	<0.000	T>R
DON	16	16	0.131	NS				16	<0.000	T>R
DIC	2	5	0.063	NS	5	0.026	T>R			
NO3 + NO2	15	25	<0.000	T>R	9	0.083	T>R	16	<0.000	T>R
NO3	12	21	0.002	T>R	5	0.157	T>R	16	<0.000	T>R
NO2	13	21	0.001	T>R	5	0.026	T>R	16	0.001	T>R
PO_4	12	21	<0.000	T>R	5	0.133	T>R	16	<0.000	T>R
NH_4	15	25	<0.000	T<R	9	<0.000	T<R	16	<0.000	T<R
Si(OH)4	2	5	0.705	NS	5	0.221	--			
chla	14	17	<0.000	T>R	9	0.068	T>R	16	0.001	T>R
Sp. Cond.	15	25	<0.000	T>R	9	0.024	T>R	16	0.001	T>R

Figure 9B. Statistical comparisons between waters from the SR@ Isleton (just upstream of the Yolo/Cache tributaries) and tributary samples collected as part of the Dugdale and Foe transects, showing that most chemical and isotopic data show that these waters are distinctively different. The P values < 0.1 are highlighted in yellow and the ones <0.05 are highlighted in orange. T>R means that the tributary value is higher than the river value.

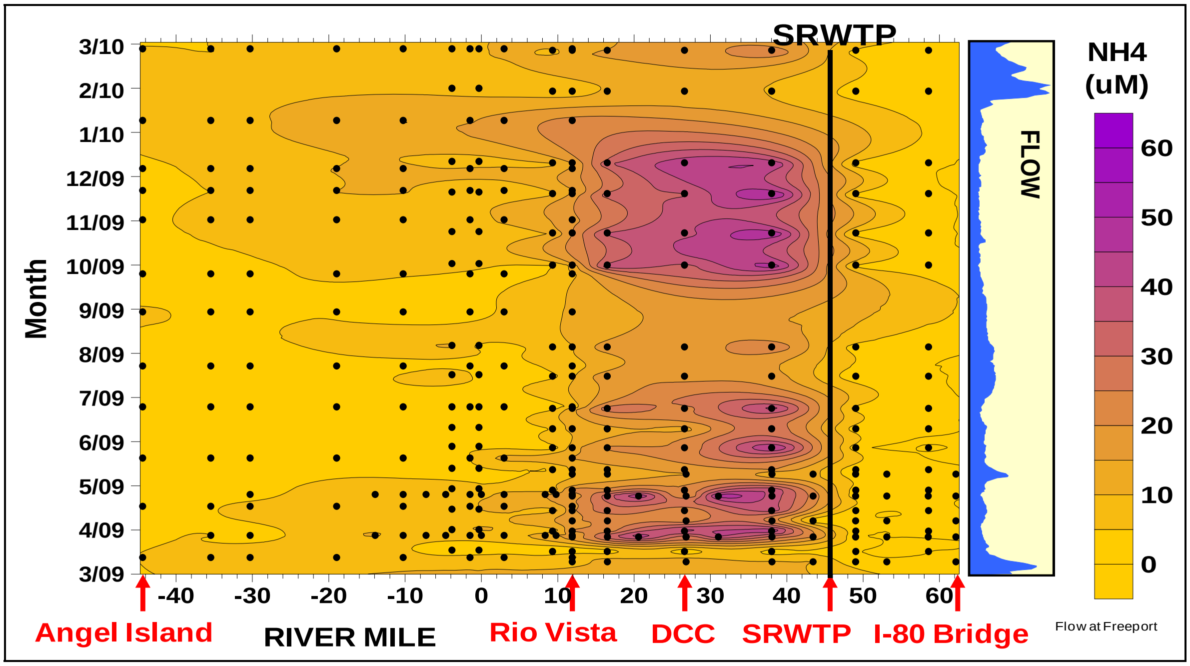


Figure 10. Contour plots of measurements, such as the NH4 concentrations shown above, will be used in the direct interpretation of nutrient sources and sinks in the study area. Dots show the locations of the actual data. The net flow at Freeport is shown to the right.

The data in the contour plot come from several sources:

1) USGS data from the R/V Polaris monthly monitoring of Bay-Delta sites (http://sfbay.wr.usgs.gov/access/wqdata).
2) Foe *et al.* (2010).
3) Parker *et al.* (2010).
4) Unpublished Dugdale/Parker data for SWC-funded cruises.

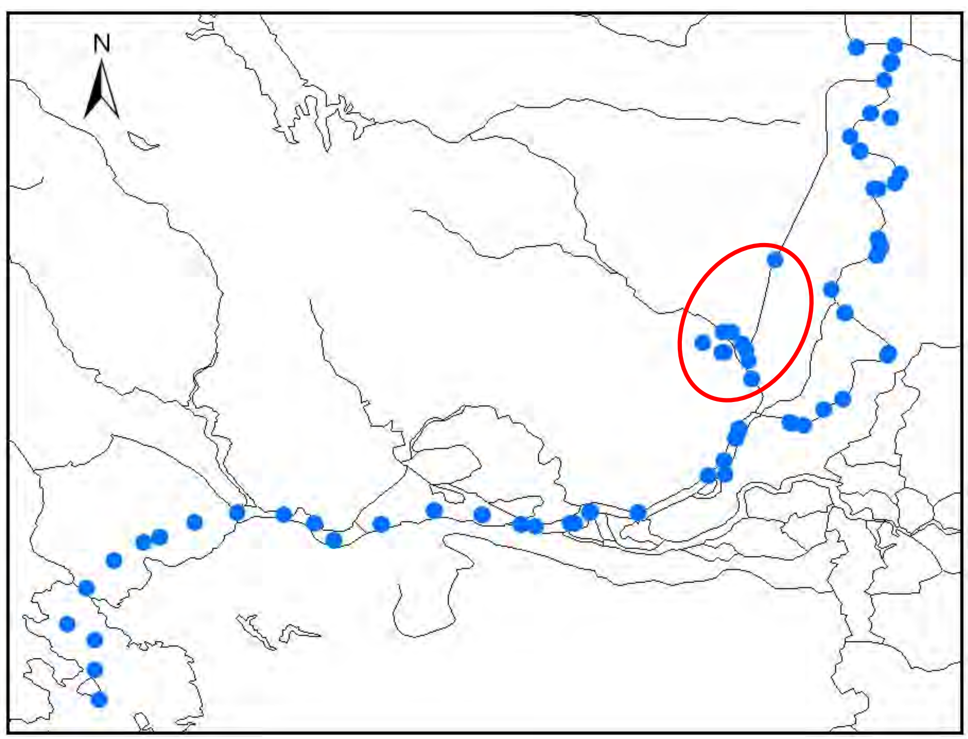


Figure 11. Site map showing the locations of all the data points in the figure above. Data from the Yolo/Cache sites (circled in red) were not used for the contour plots because they are not mainstem sites.

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Section 7: Project Budget

1. **Detailed Project Budget** ***(Excel spreadsheets can be used)***

Budget			
Quantitative Assessment of Delta Habitat and Food Web Parameters Using Isotopes and Numerical Models			
			Totals
PERSONAL SERVICES			
Staff Level	**Number of Hours**	**Hourly Rate**	
Carol Kendall, GS-15	(640)	(66.28)	($42,419 cost-share funds)
Steve Silva, GS-13	160	57.01	9,122
Megan Young, GS-12	400	42.26	16,904
Tamara Kraus, GS-13	160	55.00	8,800
Doug Choy, GS-9	320	30.54	9,773
Subtotal			44,599
Staff Benefits @ 25 % of salary (average rate)			11,150
TOTAL PERSONAL SERVICES			**55,749**
OPERATING EXPENSES (net)			
Description			
Subcontractor Costs			
Resource Management Associates (Dr. Marianne Guerin and Staff)			
Task 3 Budget			34,700
Task 4 Budget			38,000
Task 5 Budget			42,000
Total Budget for RMA:			114,700
UCD – Dr. Randy Dahlgren's lab (SO4, Cl, and nutrient analyses)			5500
Supplies for SO4 isotope analyses, splitting of archived samples for contractor, etc			5000
Photographic Supplies			0
Printing, Duplicating, GIS, and Publication Charges			4000
Office supplies, computer supplies and software			1000
General Expense			500
Travel and Per Diem			500
Training			0
Total Operating Expenses			131,200
EQUIPMENT			0
SUBTOTAL	55,749	131,200	186,948
OVERHEAD @ 54% (Less Equipment)			100,952
GRAND TOTAL			**$287,900**

2. **Budget justification:**

Additional information may be found in the full proposal document in the Scope of Work Section. The in-kind contribution of Dr. C. Kendall's time is described in the Cost Share document provided with this proposal.

TASK 1 – Management[#]
Investigator: Dr. C. Kendall and Dr. M. Young (both USGS).
Cost (gross):
$ 0 for Dr. Kendall (cost sharing = $40,828 gross)
$13,016 (gross) Dr. Young

Justification of Work and Cost – Standard project management: project oversight; cost verification and administration of contracts; data handling; coordination and preparation of reports for periodic reporting; co-ordinate the timing of major tasks; communication and distribution of results.
Staffing Detail: Kendall will manage the project with the budgeted time allocated under a cost share basis.
Output/Deliverable Maintaining schedule of reports, coordinating communication of results to interested parties.

TASK 2 – Measurement/water quality analyses and data
Investigator: Dr. M. Young, US Geological Survey
Cost (gross):
$ 6,508 Dr. M. Young
$ 8,780 S. Silva
$18,813 D. Choy
$ 8,470 subcontract to Dr. R. Dahlgren
$ 8,470 misc OE
Justification of Work and Cost –Young will organize the processing of archived samples from 2005-2010 along the Sacramento R. and in the Yolo/Cache/Liberty area for additional water quality parameters and nutrients. Analyses will be performed at UC Davis by Dr. R. Dahlgren as his laboratory facilities are cost efficient, are known for producing high quality results, and are capable of analyses not available at Kendall's laboratory. Effluent data for 2010-2011 will be obtained from the Regional Water Quality Control Boards by USGS staff.
Staffing Detail: Dr. Young will co-ordinate the work of USGS staff and interact with Dr. Dahlgren for the delivery of water quality analyses. Silva operates and maintains mass spectrometers, performs data corrections, oversees sample prep; Choy prepares the samples and helps analyze the samples.
Output/Deliverable: - The results of analyses and documentation of the effluent data collected will be incorporated in project summary documents. Water quality analyses and effluent data will be used as boundary condition input and calibration data for the DSM2-QUAL nutrient model, and in the interpretation of isotope data.

TASK 3 - DSM2 historical model and QUAL nutrient model update - calculate hydrodynamic parameters for measurement transects with HYDRO
Investigators: Dr. M. Guerin.
Cost (gross):
$ 51,040 Dr. M. Guerin and RMA staff
Justification of Work and Cost – As mentioned in the proposal text, the numerical modeling of the hydrodynamic and water quality parameters in the study area is currently unfunded. These projects (IEP and SWC) require numerical model output for the analysis of isotope data and the interpretation of water quality results. Dr's Kendall and Guerin have been collaborating in the interpretation of earlier data. Dr Guerin recently (2010) completed calibration of the DSM2-QUAL nutrient model in the Delta, and is the individual uniquely qualified to provide modeling expertise for the completion of this task. Data, including effluent data, and the results of new water quality and isotope analyses will be incorporated into the existing DSM2-HYDRO and QUAL historical models both as boundary conditions, constraints on boundary conditions, and for an update of the nutrient model calibration. The incorporation of new data will extend the definition of the model through 2011. The DSM2-QUAL nutrient model will be re-calibrated to produce an acceptable set of calibration statistics. The task also requires QA/QC of data, filling data gaps, and potentially synthesizing data where none exists. Once the models are updated, hydrodynamic parameters from HYDRO such as stage and net flow and QUAL calculations for travel time can be performed to help interpret isotope data. Results will be supplied as time series and as contour plots using current RMA visualization tools.
Staffing Detail: Dr. Guerin will perform the work with RMA staff assisting in the preparation of and visualization of model output.
Output/Deliverable: Results will be incorporated in project summary documents. The re-calibrated DSM2-QUAL nutrient model will be available for public distribution. Hydrodynamic output will be supplied to Dr. Kendall at all required locations and times.

TASK 4 – Modeling of scenarios and visualization of results
Investigator: Dr. Marianne Guerin
Cost (gross):
$ 53,438 Dr. M. Guerin and RMA staff
Justification of Work and Cost – As mentioned in the proposal text and in the justification for funding in Task 3, Dr. Guerin is uniquely qualified for the work in this task involving DSM2. In addition to developing the recent DSM2-QUAL nutrient model, Dr. Guerin is involved in an update of the nutrient model for the BDCP process, and will be using the nutrient model for modeling the BDCP scenarios. In addition, this task involves using the RMA models and visualization tools for producing residence time and turbidity contour plots for the base historical model and for scenarios. Dr. Guerin is uniquely qualified for this portion of the task as the primary investigator in an ongoing project to develop a near-real-time

modeling capability for turbidity in the Delta using both RMA models and DSM2. All of the models used in this project have been used recently for similar purposes. The collection and use of the data was described in the Background section of this proposal. RMA has developed visualization tools that can be used to create contour plots of QUAL results, and has long had visualization tools for the RMA model results.
Staffing Detail: Dr. Guerin will perform and analyze RMA and DSM2 models and scenario output with help from RMA staff for the preparation of visualization results for DSM2.
Output/Deliverable: The main output from this work will be a portfolio of spatial distributions for DRERIP conceptual model components on a monthly and/or seasonal basis for both DSM2 and RMA models.

TASK 5 – Analysis of spatial isotope results and spatial modeling and visualization of habitat and food web DRERIP conceptual model components
Investigators: Dr. C. Kendall, Dr. M. Guerin, Dr. M. Young, Dr. T. Kraus
Cost (gross):
$0 for Dr. Kendall (cost sharing)
$ 64,680 Dr. Guerin
$ 13,016 Dr. Young
$ 16,940 Dr. Kraus
$ 8,780 S. Silva
$ 8, 470 other OE
Justification of Work and Cost – This task involves the collation and interpretation of the numerical results from the historical models and the scenarios, and of the spatial visualization results from isotopic and model analyses in the context of the DRERIP component variables. The intent of the portfolio is to develop a clearer picture of (DRERIP conceptualized) current habitat and food web parameters and the same parameters under the changed conditions developed in the scenarios. All of the staff involved in this task have been collaborating on previously funded projects using data from the 2009-concurrent water quality and nutrient sampling in the study area.
Staffing Detail: Kendall and Guerin lead the task, with Young assisting with GIS and Kraus assisting with the statistical analysis of data. All will share in the assist in the analysis and interpretation of data and model results, and article writing.
Output/Deliverable: - The results will be accompanied by an evaluation of the results in the context of the project hypothesis. All of the project results will be documented in writing in the required reports, in technical papers, or possibly as peer-reviewed articles.

COST SHARING:
Tasks 1 and 5 include “Cost Share” funds that are in-kind contributions from the USGS for Dr. Kendall’s time. Since Kendall is a full time permanent USGS employee whose salary is 100% covered by the National Research Program of the USGS, she does not need to ask for any additional funds for her contributions to the project. The amounts of cost-share are itemized in the individual tasks.

TOTAL COST SHARE FUNDS: $81,657 (including salary, benefits, and overhead)
These funds represent ~ 22% of the total requested budget for this proposal.

3. Administrative overhead:

The standard USGS overhead rate for non-DOI customers is 54% of net. This overhead rate is charged on funding for salary, supplies, and equipment. Note: for years other than the first year, the USGS overhead rate may change and, therefore, the distribution of funding between direct and indirect costs may change as well.

If the part of the budget for the RMA subcontractor were contracted directly to RMA by the State of CA, considerable USGS overhead funds would be saved and used for other activities.