

*Proposal submission for the  
CALFED 2007 Supplemental PSP*

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Title of Supplemental Proposal: How Abiotic Processes, Biotic Processes, and Their interactions Sustain Habitat Characteristics and Functions in River Channels and Their Floodplains: An Investigation of the Response of How a Reach of the Merced Rivers Responds to Restoration

Funding Amount Requested: \$ 299,998

Original Proposal Title: How Abiotic Processes, Biotic Processes, And Their Interactions Sustain Habitat Characteristics And Functions In River Channels And Their Floodplains: An Investigation of the Response of A Gravel-Bed Reach of the Merced River To Restoration.

Year of Original Proposal Submission: 2004

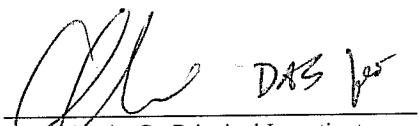
THE REGENTS OF THE UNIVERSITY OF CALIFORNIA  
c/o University of California, Santa Barbara  
Santa Barbara, California 93106

- I. PROPOSAL SUBMITTED TO: Shem Ayalew  
California Bay-Delta Authority Science Program  
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- II. TITLE OF PROPOSAL: How Abiotic Processes, Biotic Processes, and their  
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Functions in River Channels and their Floodplains:  
An Investigation of the Response of how a Reach of  
the Merced River Responds to Restoration.
- III. PROJECT PERIOD: 7/01/2008 – 5/31/2009
- IV. SUPPORT REQUESTED: \$299,998.000 (Supplement)

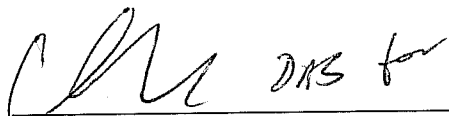
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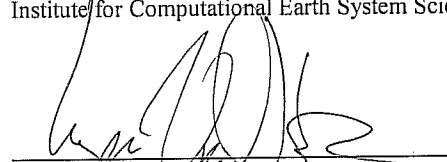


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# HOW ABIOTIC PROCESSES, BIOTIC PROCESSES, AND THEIR INTERACTIONS SUSTAIN HABITAT CHARACTERISTICS AND FUNCTIONS IN RIVER CHANNELS AND THEIR FLOODPLAINS: AN INVESTIGATION OF HOW A REACH OF THE MERCED RIVER RESPONDS TO RESTORATION

## BACKGROUND OF THE SUPPLEMENTAL STUDY

The over-arching scientific question driving the project is:

- *How do abiotic and biotic processes in a restored, simplified channel-floodplain system interact to develop conditions that favor a set of native and endangered species of plants and animals?*

The project consists of four tightly linked components, concerning: (i) the physics of flow sediment transport and evolution of channel-floodplain morphology in the reconstructed channel and valley floor; (ii) channel-bed invertebrate communities; (iii) use of the reach by resident and anadromous fish; and (iv) development of riparian-floodplain plant communities. The project involves both field monitoring and mathematical modeling, and it is intended that the results will be assembled into multi-faceted answers to the following policy-relevant questions:

- *How can knowledge of these relationships be translated into successful river management?*
- *Can the restoration of these physical processes create self-sustaining habitats that support an abundance of native species with only limited management interventions?*

The questions relate to the original PSP study topics inquiring about (i) processes and their relationships to water management and key species, and (ii) improving tools for performance assessment and evaluating implications of future changes. The questions also address one of the fundamental concepts underpinning the CALFED Program, --- restoration of physical processes is the best way to restore habitat for populations of native organisms [CALFED, 2000].

**The PIs are investigating how a widespread form of river restoration (restructuring and rescaling of a channel and floodplain to diminished flows) influences physical processes, and how the altered physical conditions affect aquatic organisms and floodplain plants.** The focus is on how river restoration affects the abundance and distribution of salmonid and non-salmonid fishes at critical life stages, initially at the scale of a single project reach (the Robinson reach, ~1.4 miles of the Merced River), but we have begun to extend comparative measurements and modeling into the (~1 mile long) unrestored reach upstream. We are also studying at the process level the connection between the channel and floodplain, also considered to be critical to sustainable river restoration [CALFED, 2000]. After progress in characterizing and interpreting processes in the restored and unrestored reach upstream, we are developing plans to take advantage of the newness and simplicity of the Robinson reach (described and illustrated in the original proposal) to design **four field experiments on biological responses to manipulation of physical conditions:** (i) addition of woody debris to the reach; (ii) gravel augmentation in the reach; (iii) effects of coarse spawning gravel on the survival of Chinook eggs to alevins; and (iv) irrigation and planting to accelerate native woody plant establishment on the floodplain.

This proposal requests salaries for some project personnel to work for a year on these interdisciplinary experiments that will greatly increase the utility of the currently funded study, and for a lidar survey of the valley floor, which will allow us to improve our quantitative modeling of the biological response to hydrological interactions between the channel and

floodplain. We also request funds for Dr. Brad Cardinale, an expert in the ecology of restored rivers (see resume), to help as a Consultant to experiments (i) and (iii).

### **SUPPLEMENTAL PROJECT GOALS AND WORKPLAN**

With the understanding gained from the field surveys and modeling of flow, sediment mobility, and channel change that we outlined in the original proposal, we are planning four field experiments to test hypotheses on habitat quality and biological responses in restored reaches:

1. Installation of anchored woody debris in the simplified constructed channel will diversify the flow field, channel cross-sectional shape, and habitat quality, creating enhanced feeding, resting, and refuge zones for young anadromous and resident fish.

2. Gravel augmentation can be designed to intensify sediment transport, bar-pool and riffle evolution (including spawning and shallow-water resting sites), and to alter flow structure in a manner favorable to habitat restoration for invertebrate prey and fishes, including salmonids, as commonly articulated in conceptual models of river restoration [Trush et al., 2000].

3. Survival of eggs to alevins in restored channel reaches constructed with coarse gravel is reduced by vigorous intragravel flow and predation in large pore spaces.

4. It is possible to manipulate water supply to the floodplain (by irrigation or controlled flows) at critical times in the growing season to promote native tree recruitment on the site.

### **A. FIELD EXPERIMENT ON PHYSICAL AND BIOLOGICAL EFFECTS OF ADDING WOOD STRUCTURES TO A CHANNEL REACH TO PREDICT FISH-HABITAT QUALITY RELATIONSHIPS**

The simplicity of the restored reach makes it a useful system for developing measurement programs and models, but biological production and diversity in the reach remain curiously low 7 years after restoration. This simplicity raises questions about its underlying causes and creates an opportunity for conducting experiments to explore methods for increasing production and diversity of invertebrate and fish communities. Preliminary surveys indicate lower abundances and taxonomic diversity of fishes in the simplified restored channel than in the unrestored reach upstream. The Robinson reach was designed mainly to provide spawning habitat for salmonids. Although salmon use the restored reach for spawning [Mager and Wyzga, 2005], the value of this reach for rearing juvenile salmon and other native species remains unknown. Simple habitat structure, such as one finds in newly restored channels, is frequently associated with low diversity and abundance of organisms [Poff and Allan, 1995]. Establishment of fish assemblages like those in complex rivers depends on the ability of species to thrive in the simpler channel.

A common form of river restoration involves adding woody debris to channels to promote physical complexity to enhance recovery of species populations and the ecological processes they perform. The assumption behind this practice is that the structures create new habitat and flow 'refuges' that prove beneficial to juvenile fish and their invertebrate prey. This assumption has rarely been tested directly in a restored stream and in the few instances where it has, the experimental units have not been replicated. As a result, researchers have almost no statistical power to say conclusively whether and to what extent woody debris enhances fish and invertebrate populations. More importantly, researchers rarely link the response of organisms to the physical habitat features and processes – meaning, they offer no quantitative insight into the *mechanisms* by which woody debris matters. Thus, it is difficult to develop quantitative expectations for new projects or to scale up results from single experimental sites or reaches.

Therefore, we propose a controlled experiment in which we will establish differing densities of identical woody structures along the restored channel, and then we will measure the responses of invertebrates and fish to changes in physical habit. Our experiment will utilize riffle and bar-pool sites where, because of the newness and simplicity of the reach, the topography and macro-flow conditions are all similar, and have been modeled and measured. We will directly link biological responses of invertebrates and fish to key hydraulic and topographic changes that accompany the addition of in-stream structures and that can be modeled under other conditions.

**To test the hypothesis that woody structure influences the abundance, spatial distribution, and species composition of fish and invertebrates in the restored reach**, three wood density treatments of 2, 3 and 4 units will be placed in each of two replicate riffles and pool-bars in the restored reach and sampled for fauna after 60 days, an adequate time to allow fish and invertebrates to colonize. Each unit will consist of  $\sim 2 \text{ m}^3$  of woody debris, anchored to the riverbed, with the debris comprised of natural riparian vegetation. After 60 days, fish will be counted visually in a  $3\text{-m}^2$  area around each replicate wood density treatment in each replicate riffle and pool-bar, and in three riffles and bar-pools without wood structures (“references”). Invertebrates and cryptic fishes will be sampled using a kick net in a  $1\text{-m}^2$  area immediately downstream of 2 randomly selected wood structures in each treatment. Two samples will also be taken in each reference area. Block nets will then be placed around the entirety of each replicate riffle or pool-bar, wood structures will be removed, and the areas will be exhaustively seined to collect all fishes.

**To test the hypothesis that wood structure influences the distribution, habitat affinity, retention-escapement, and survival of juvenile Chinook salmon**, we will collect a sample of 100 juvenile Chinook from the hatchery upstream and fit them with radio tags. They will be released from the hatchery or immediately upstream of the restored reach and tracked weekly to measure whether, how quickly, and to what degree they congregate in reaches with differing densities of wood, including whether they move between installations, and whether they leave the reach, and where, potentially why, and when they die. After 60 days, the tagged fish will be collected in the seines referred to above.

**To test the hypothesis that the density of woody debris influences invertebrate and cryptic fishes**, the abundance of key species, total abundance, and species richness will be compared in a 3-way analysis of covariance (ANCOVA), in which sampling plot (nested within wood density), wood density, and habitat (riffle vs. pool-bar) are the main factors, and distance within the reach, bed grain size, and mean average flow speed of the habitat are co-variates. Variation in relative species abundance among treatments will be analyzed in a similar statistical framework using multi-response permutation procedures on the treatment by species abundance matrix. This procedure is a non-parametric alternative to MANOVA based on Euclidian distances between treatments in multivariate space. Data from the tagging study will be analyzed by using a Poisson regression to calculate the probability that an individual Chinook will remain in a pool-bar as a function of the density of wood in that habitat. Data collected in this study will be examined to determine whether they can be used in a previously-funded portion of our study exploring bioenergetics of the river food web.

Before and during the experiment, we will measure the velocity and turbulence fields in the vicinity of each structure, and will survey the topographic change in bed morphology. We continue to extend, detailed topographic and hydraulic surveys of the channel and flow at a range of discharges, which have allowed us to calibrate and validate a 2-dimensional flow model of the reach [U.S. Geological Survey, [http://wwwbr.cr.usgs.gov/projects/GEOMORPH\\_Lab/project-](http://wwwbr.cr.usgs.gov/projects/GEOMORPH_Lab/project-)

[MDSWMS.html](#)] (Figures 1,2,3). With the model we can compute spatial fields of flow depth, velocity, shear stress, and turbulence intensity, and also patterns of bed scour associated with the structures. We can also directly measure the topographic changes and the flow features with our acoustic Doppler flow profiler, even in the vicinity of complex channel features [Harrison, 2007]. We are now in a position to compute 3-dimensional flow environments for interpretation of invertebrate communities and spatial patterns of fish use of the channel at a range of flows to provide quantitative explanations of fish usage of the structures by fish and invertebrates, connected to a method for rescaling the results to various densities of wood and channel dimensions or discharges. The results will give us a means to test Hypothesis 1 above and to provide direct links to the mechanisms by which the woody structures affect flow environments that might affect the energetics and feeding behavior of young salmonids during the post-emergence period and of resident fishes during the rest of the year.

The structures will be removed from the river when our study is completed. Planning the exact form of the field study would depend on negotiation with CADWR and CDFG and the regulatory agencies concerned with flood conveyance. Much of this negotiation would depend on detailed modeling of the hydraulic effects of the structures in the planning phase. However, we do not intend to use structures that would make a significant difference to the flood conveyance capacity of the channel, and they would be firmly anchored [Abbe, 2003; Abbe and Black, 2007; Hall and Moler, 2006] and used only outside of the flood season.

## **B. FIELD EXPERIMENT ON THE RESPONSE OF THE CHANNEL AND HABITAT QUALITY TO GRAVEL AUGMENTATION**

Because many gravel-bed rivers in the Central Valley have suffered reductions of gravel supplies or have been reconstructed with relatively coarse gravel in recent years, fish populations in many channels are suspected to be spawning-limited. Furthermore, a conceptual model that influences many CalFed and other restoration projects emphasizes the value of bar building to drive channel migration that creates various favorable habitat characteristics for both spawning and rearing [Stillwater Sciences, 2001, 2002; Trush et al., 2000]. For these reasons a considerable amount of money has been invested in artificial augmentation of river gravel, and in a key CalFed-funded lab flume study of gravel augmentation [Stillwater Sciences, 2007].

We cannot conduct a replicated set of gravel injection experiments at a single field site in a two-year period, but through application of an experimental design based on the flume experiments and monitoring of the results we can **test two hypotheses: (1) that we can accurately model the physical results of the injection on the flow field, bed mobility, sediment transport, and channel form for purposes of restoration project design, and (2) that the increased bed mobility will affect invertebrate populations in the channel bed and changes to spawning sites and pool characteristics favorable to fish.**

Through a combination of field and aerial photographic survey of channel topographic changes (Figure 4) and bed mobility, we have developed methods for quantifying channel change [Legleiter and Roberts, 2005; Legleiter et al., 2005], bed material transport [Wydzga et al., 2005, 2007], and for modeling spatial fields of flow, shear stress, turbulence, bed mobility and transport and changes in channel form in the restored and unrestored reaches with a two-dimensional flow model referred to above. We propose to use this modeling capability to compute the changes to be expected from a gravel augmentation experiment, and then to test our predictions by monitoring changes in channel topography and bed texture and mobility for at least two years after the injection. We will also monitor velocity fields before and during the

passage of the wave of gravel along the reach to understand changes in the mechanics of sediment transport and the state of the bed induced by the augmented gravel supply. We will also attach radio tags to gravel particles of various sizes to trace their movement during a flood in order to test our ability to model their transport. These results will allow us to calculate changes in habitat quality for invertebrates and fish related to bed texture and mobility, flow speed, and depth as a means of understanding the biological changes that are already monitored in the study.

The details of injection volume and texture, placement, and timing of such an experiment will have to be negotiated with the landowner and the appropriate resource management and regulatory agencies. However, the gravel with which to conduct the experiment was stored at the site during project construction in anticipation of the need for such a gravel augmentation. We propose to design an experiment that would take advantage of what we have already learned from the flume studies carried out by the UC Berkeley group and Stillwater Sciences [2007]. One of our team members (Wydzga) participated in the laboratory experiments [Fadde et al., 2007] and has been studying gravel mobility at the Merced field site [Wydzga et al., 2005, 2007]; she is well placed to replicate some of the detailed measurements and calculations of gravel mobility that were made in the flume study.

We would like to test two important results of the flume study of gravel augmentation that are particularly relevant to river restoration: (1) that a pulse of injected gravel will move through a reach as a wave that translates and disperses, and interacts differently with the plane bed of a riffle and the asymmetrical features of a bar-pool reach; and (2) that a mixture of fine gravel with coarser gravel will enhance the mobility of the coarse sediment in the channel bed by decreasing flow resistance and increasing near-bed velocities, which we will measure before and after the injection with a Doppler flow profiler. The observations from this experiment will be combined with observations we have made of the unplanned gravel augmentation event that has already occurred in the upper four bends of the reach as a larger-than-expected wave of gravel has intensified bar building, pool development, channel shifting, channel cross-section asymmetry (Figure 4), and alterations of spawning and shallow-water habitats. These channel changes have been accompanied by differences in invertebrate communities that we have been monitoring bi-weekly and in resident fish (mainly pike minnows, Sacramento suckers and sculpins) that we made during the summer of 2007 by snorkeling and seining.

Our gravel augmentation experiment would build on the existing data by monitoring invertebrate and fish populations before and during the evolution of the sediment pulse. This would effectively integrate the anticipated geomorphic response of enhanced bed mobilization and channel change with the observed ecological response. Invertebrates would be sampled every 3 months with kick nets, server samplers, and where appropriate core samplers. Samples would be taken simultaneously from areas within reach upstream of the augmentation. Such a design would allow us to test the specific hypotheses that invertebrate abundance, distribution, and species composition will vary as a function of (1) sediment augmentation in various parts of the sediment wave passing through the restored reach, comparing before vs. after augmentation samples, (2) grain size, comparing before vs. after augmentation in the perturbed and unperturbed reaches, and (3) augmentation in riffles vs. bar-pool sections. These hypotheses will be tested by multivariate analysis of variance (MANOVA), in which restoration condition (restored vs. unrestored), location (upper, middle and lower section of the wave), time, and key physical characteristics (grain size and mean discharge rates) are used in various combinations as factors in the analyses.

The initial simplicity of the Robinson reach increases the likelihood of being able to extend the flume studies of gravel augmentation to field scale, and the predictability of managed, sustained flow releases in the Merced provides an opportunity to accumulate results quickly by means of such experiments. We also plan to test whether and how the proposed experiments as well as the experiment of the restoration project itself can yield information directly relevant to plans for restoration activities on the Merced and other rivers. In this way, we intend to test the viability of an adaptive management approach to aquatic habitat design.

### **C. EXPERIMENTS ON THE EFFECTS OF PHYSICAL CONDITIONS AND INVERTEBRATE PREDATORS ON THE SURVIVAL OF EGGS TO ALEVINS IN A COARSE RESTORED RIVER BED**

This Merced restoration project is one of many in the Central Valley aiming to restore spawning habitat by placing ‘artificial’ gravels in the river. These gravels are termed artificial because the grain-size distribution is not controlled by natural fluvial transport and sorting but by engineering specifications. The grain-size distribution is typically based on calculations aiming to ensure that the bed gravels are stable during smaller floods (i.e. sub-bankfull) and are of a suitable size for redd construction. The grain-size distributions are typically sieved to omit the largest and smallest fractions. Studies in the Mokolumne River found that salmon egg survival was greater in river reaches that had been enhanced with gravel additions [Merz et al. 2004; Merz and Setka 2004]. Greater survival was associated with larger median substrate size in enhanced sites and the authors suggested a relationship between pore size, intragravel flow rate, and favorable physicochemical characteristics (dissolved oxygen, suspended solids, temperature). Although these results suggest that gravel additions are beneficial for egg survival, the authors acknowledge that the use of egg tubes in the study provided protection from mechanical agitation and predation that eggs would be exposed to in natural redds. However, Milich [2006] found that egg survival was low in areas with high intragravel flow and suggested that mechanical damage may negatively impact egg survival in coarse gravels.

We propose to **test a series of hypotheses** regarding the relationship between grain size of redds and the eggs-to-alevin portion of the Chinook life cycle:

1. Large pore sizes in artificial gravels enhance predator access and thus rates of predation on Chinook eggs are greater in restored sites.
2. Mechanical agitation of eggs within the large pore spaces of artificial gravels reduce egg survival relative to eggs in naturally sorted gravels.
3. Combined effects of mechanical agitation and predation best explain egg survival.

H<sub>1</sub>: For this experiment we will create artificial redds embedded with unfertilized eggs, and then exclude or allow access by natural communities of predators. The experiments will be performed in three replicate riffles in the restored and unrestored (up-river) areas. Predators will be excluded from redds using solar-powered ‘fences’, which emit low-voltage, 1-amp/sec charges that can exclude organisms > 5 mm without any permanent harm. Such fences are widely employed by stream ecologists to exclude invertebrates and fish in field experiments.

H<sub>2</sub>: To address the role that mechanical agitations plays in egg survival over the course of this experiment, artificial eggs made of Teflon balls will be placed in flexible plastic mesh bags (n= 3 balls per bag) in each redd at the beginning of the experiment. The density of scars on each ball will be recorded at the end of the experiment under a dissecting microscope and used as a proxy for the physical agitation that an egg experiences within natural and artificial gravels.

The experiments will yield critical data on the link between physical characteristics of artificial substrates and egg maturation in restored reaches of Central Valley Rivers.



#### **D. PLANTING AND IRRIGATION EXPERIMENT TO PROMOTE ESTABLISHMENT OF WOODY, NATIVE FLOODPLAIN VEGETATION**

Team members Davis and Soong have worked with Karen Dulik of CADWR to analyze post-restoration floodplain vegetation dynamics using 4 years of vegetation plot data collected by DWR and annual high-resolution digital air photos. They evaluated the relative strength of biotic vs. abiotic controls on early community development. They also analyzed the effectiveness of restoration treatments (seeding with sterile barley, seeding with native species, mycorrhizal inoculum) on native plant species cover and diversity [Soong et al. 2007]. In general, abiotic controls have dominated vegetation recovery on the site. Plant community composition is strongly related to moisture regime and unaffected by an initial cover crop of barley. Effects of native seeds and mycorrhizal treatments were only observable for 1-2 years; management efforts to set initial community composition have been largely overshadowed by colonization and establishment of weedy species sorted along soil moisture gradients. The initial floodplain vegetation development has been dominated by soil hydrology, but under the current regulated flow regime of the Merced River it is unlikely that the floodplain will develop self-maintaining riparian woodland and forest communities. We propose to conduct field experiments to manipulate water to maintain soil moisture or raise the local water table (by irrigation or controlled flows) at critical times in the growing season to promote tree recruitment on the site before weed communities become more firmly established.

We propose to conduct factorial experiments to determine single and interactive effects of timed irrigation, vegetation disturbance (weed control), and seeding on riparian tree establishment. Trial species will include *Alnus rhombifolia*, *Populus fremontii*, *Salix lasiolepis* and *Quercus lobata*. Our design will be similar to that of Friedman et al [1996], who used replicated belt transects oriented perpendicular to the channel, except that we will follow their recommendations and increase the scale from 1x2 m subplots to larger areas with more widely spaced (e.g., 2-3 m) planting sites to reduce competition between trees as they develop. We will also increase the number of replicates from three blocks of transects to five blocks to improve the statistical power of the design. We have been collaborating with a high-school ecological restoration class from the Merced School District, and hope to involve student volunteers in restoration plantings and weed control on the site. Since the data collection and analysis techniques will be accessible to high-school science students we hope to create a significant learning experience for the students.

In order to tailor an experimental irrigation regime for the Robinson Reach we must model soil water dynamics vertically and spatially based on detailed topographic surveys, soil sampling to characterize spatial variation in the soil profile (texture and drainage properties) and vegetation. We need detailed topographic data to model water flows and hydroperiods across the floodplain in order to locate experimental transects across a representative range of geomorphic conditions. (These topographic data would also be valuable for reconstructing post-restoration hydroperiods to better understand current vegetation patterns on the floodplain, and will ultimately be needed to couple ongoing hydrological and geomorphological investigations by Dunne and Harrison to ecological studies on the floodplain. We propose to procure a LIDAR-derived digital elevation model with 15-20 cm vertical resolution and 3-5 m horizontal resolution as a base for the moisture regime modeling.

Irrigation lines were installed on the Robinson Reach when the floodplain was initially restored but irrigation was abandoned due to complications with the system. We will work with

the landowner to assess the feasibility of putting that system back into operation and to estimate operating cost. The main costs will be labor, new valves and lines, and fuel.

Flow and inundation modeling would be conducted by Harrison and Dunne, using the flow model referred to above, with calibration based on water-level surveys that we have already conducted in a 5 –year overbank flood of 4600 cfs. Vegetation studies would be conducted by Soong, Davis, and Dr. Claudia Tyler. We intend to complete topographic surveys and soil sampling during Spring 2008 and planting experiments would begin in early summer 2008. The experiments would be monitored for a minimum of 2 years but we expect the experiment to have lasting value and would seek funds for long term monitoring. The calibrated flow model will be used to reconstruct the floodplain inundation history following channel reconstruction, in order to assess the potential for the establishment of floodplain vegetation within the managed flow regime. Results from the irrigation experiments will be coupled with the modeling simulations to explore patterns of overbank flooding, seed dispersal and plant recruitment under a range of flow magnitudes. The modeling framework will be used to explore whether different flow release strategies can be used by agencies and managers to promote the establishment of floodplain vegetation or whether irrigation will be necessary, with or without planting or weeding.

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## SCIENTIFIC RESULTS FROM THE UCSB MERCED PROJECT SO FAR

### Publications

1. Legleiter, C.J., and Roberts, D.A., *Effects of channel morphology and sensor spatial resolution on image-derived depth estimates*. **Remote Sensing of Environment**, 95(2): 231-247, 2005

### Conference Presentations

6. Soong, O., K. Dulik, B. Hendrickson, W. Moise, L. Castro, and F. W. Davis. *Site, management, and plant species effects on riparian vegetation development on a restored floodplain of the Merced River, California*. Abstract, **Annual Meeting of the Ecological Society of America**, San Jose, California, 2007.
5. Wydzga, M. A., C. J. Legleiter, and T. Dunne, *Predicting Riverbed Mobility on a Rehabilitated Reach of the Merced River, CA*. **American Geophysical Union**, San Francisco, CA, 2007
4. Fadde, J., J. G. Venditti, L. Sklar, M. A. Wydzga, P. A. Nelson, and W. E. Dietrich, *Propagation of Sediment Pulses in Flume Experiments Simulating Gravel Augmentation in Armored Channels Downstream of Dams*. **4th CALFED Bay-Delta Program Science Conference**, Sacramento, CA, 2006.
3. Legleiter, C.J. *Geospatial geomorphology: remote sensing and geostatistical methods for characterizing river channel morphology and in-stream habitat*. **Salmonid Restoration Federation Annual Conference**, Feb. 24– 25, Santa Barbara, CA, 2006.
2. Wydzga, M. A., M. Hassan, J. G. Venditti, and T. Dunne, *Can Interlocked Grains Reduce the Mobility of Gravel Bed Rivers?* **American Geophysical Union**, San Francisco, CA, 2005
1. Legleiter, C.J., Wydzga, A.M., Faulkenberry, K., Encinas, D., Kyriakidis, P.C., and Dunne, T. *Morphologic response of a restored, gravel-bed reach of the Merced River to sustained high flows*. **4th CALFED Bay-Delta Program Science Conference**, Sacramento, CA, 2006.

### SCIENTIFIC RESULTS FROM PREVIOUS CALFED FUNDING TO DUNNE

T. Dunne and M.B.Singer received a grant from the CALFED Science Program entitled “Developing a Flow and Sediment Transport Model for Channel and Floodplain Restoration on the Sacramento River, CALFED Bay-Delta Program.” The grant extended from 2002 to 2005, and was funded at \$390,252. We continue to disseminate results from this grant:

#### Publications

8. Singer, M.B., R. Aalto, and T. Dunne; *Analysis of spatial and temporal patterns in overbank sediment deposition along the Sacramento River, California*. In Preparation
7. Constantine, C. R., T. Dunne, and G. J. Hanson, *Examining the physical meaning of the bank erosion coefficient used in meander migration modeling*, (Submitted to **Geomorphology**.)
6. Singer, M.B.; *A new sampler for extracting bed material sediment from coarse and mixed beds in navigable rivers*. **Earth Surface Processes and Landforms**, 2008
5. Singer, M.B.; *Influence of major dams on hydrology through the drainage network of the Sacramento Valley, California*. **River Research and Applications**, 23(1):55-72. 2007
4. Singer, M.B. and T. Dunne; *Modeling the decadal influence of river rehabilitation scenarios on flow and sediment transport in large, lowland river basins*. **Water Resources Research**, 42, W12415, doi:10.1029/2006WR004894 2006

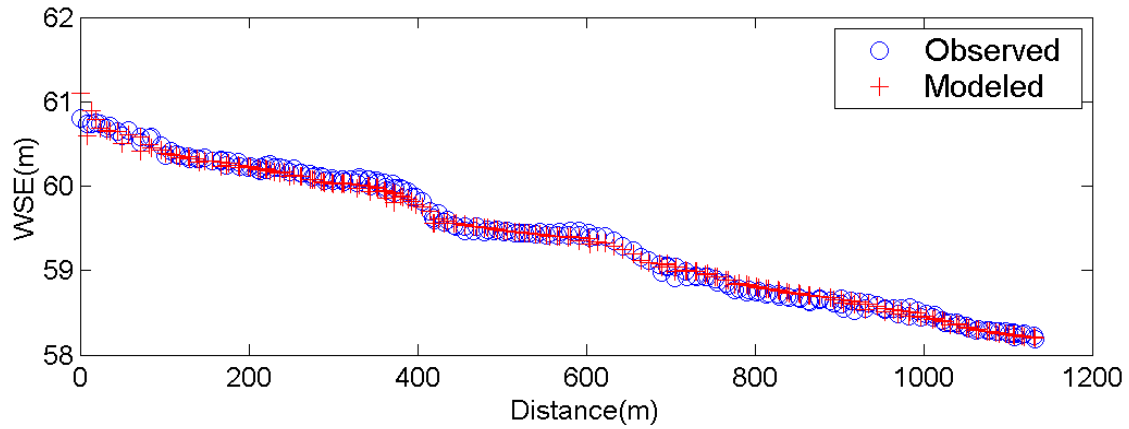
3. Singer, M.B. and T. Dunne; *An empirical-stochastic, event-based program for simulating inflow from a tributary network: Framework and application to the Sacramento River basin, California.* **Water Resources Research**, 40, W07506, doi:10.1029/2003WR002725. 2004
2. Singer, M.B. and T. Dunne; *Modeling decadal bed-material sediment flux based on stochastic hydrology.* **Water Resources Research**, 40, W03302, doi: 10.1029/2003WR002723. 2004
1. Singer, M.B. and T. Dunne; *Identifying eroding and depositional reaches of valley by analysis of suspended sediment transport in the Sacramento River, California.* **Water Resources Research**, 37(12):3371-3382. 2001

### Conference Presentations

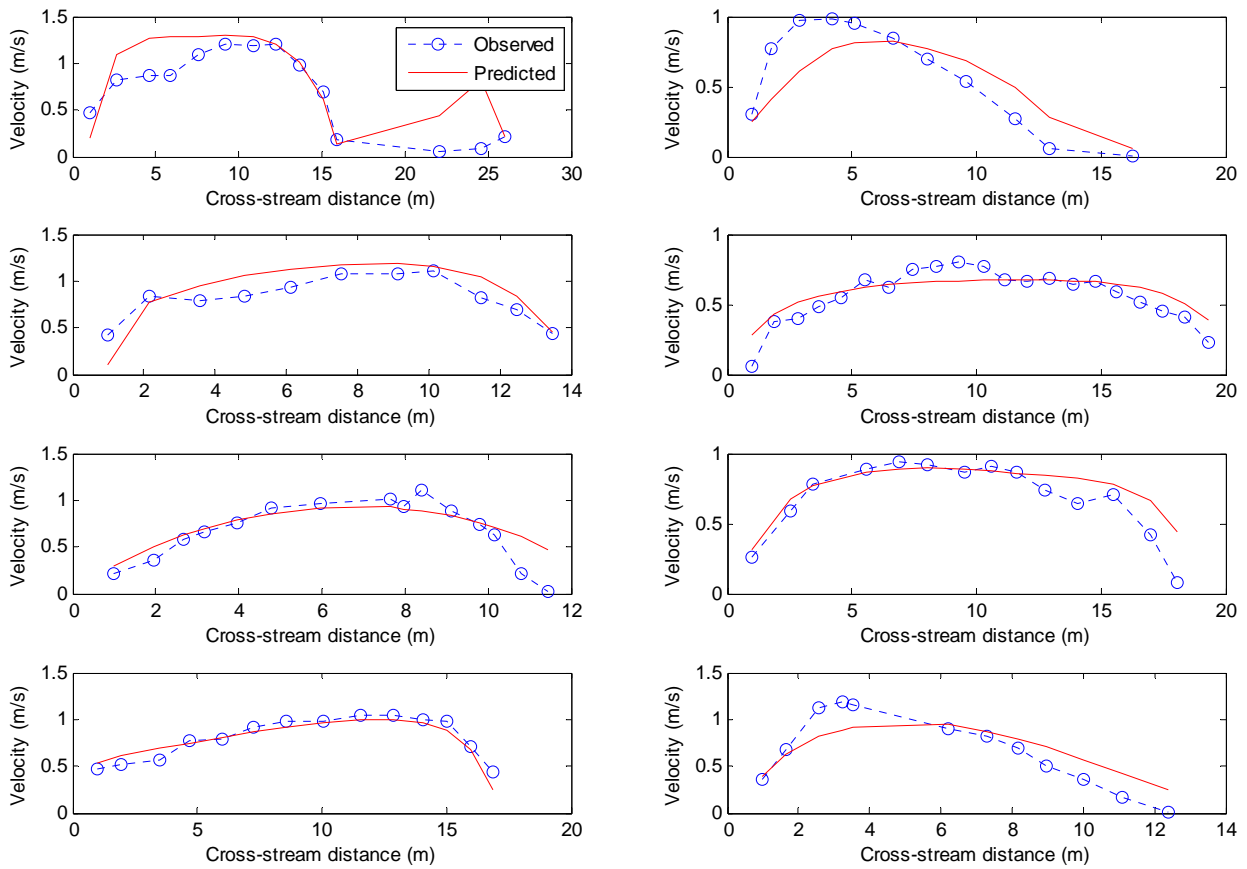
15. Singer, M.B.; *Downstream patterns of bed-material grain size in the Sacramento River and implications for habitat,* **Sacramento River Restoration Science Conference** Chico, CA 2007
14. Singer, M.B. and R. Aalto; *Event-based washload transport and sedimentation in and around flood bypasses: Case study from the Sacramento Valley, California,* **CALFED Science Conference** Sacramento, CA 2006
13. Singer, M.B., S. Cepello, and A. Henderson; *An apparatus for bed material, sediment extraction from coarse river beds in large alluvial river,* **Federal Interagency Sedimentation Conference** Reno, NV, 2006
12. Singer, M.B., A. Henderson, J. Cooper and S. Cepello; *An apparatus for bed material sediment extraction from coarse river beds in large alluvial rivers* (POSTER), **American Geophysical Union Fall Meeting** San Francisco, CA, 2005
11. Singer, M.B. and R. Aalto; *Event-based washload transport and sedimentation in and around flood bypasses: Case study from the Sacramento Valley, California.* (POSTER), **American Geophysical Union Spring Meeting**, New Orleans, LA 2005
10. Springborn, M., M.B. Singer, and T. Dunne; *A mass balance analysis of total mercury flux through a large, managed floodplain.* (POSTER), **American Geophysical Union Spring Meeting**, New Orleans, LA, 2005
9. Singer, M.B.; *Influence of major dams on hydrographs through a river network: Examples from the Sacramento Valley, California.* (POSTER), **CALFED Science Conference** Sacramento, CA, 2004
8. Singer, M.B.; *Influence of major dams on hydrographs through a river network: Examples from the Sacramento Valley, California.* (POSTER), **Assessing and Re-naturalizing Streams Impacted By Dams and Dam Removal**, Missoula, MT 2004
7. Singer, M.B.; *Influence of major dams on hydrographs through a river network: Examples from the Sacramento Valley, California.* (POSTER), **International Geological Congress** Florence, Italy 2004
6. Singer, M.B.; *Downstream patterns of bed-material grain size in a large, lowland alluvial river.* (POSTER), **International Geographical Congress**, Glasgow, Scotland 2004
5. Singer, M.B., T. Dunne, R. Aalto, C.A. Nittrouer, J. Nittrouer.; *Event-based sedimentation in a flood bypass: examples from the Sacramento Valley, California.* (POSTER), **American Geophysical Union**, San Francisco, CA 2003
4. Singer, M.B. and T. Dunne; *Stochastic assessment of decadal patterns in Sacramento River bed material transport,* **Association of American Geographers Annual Meeting** New Orleans, LA 2003

3. Dunne, T. *River Restoration as a Challenge to Hydrological Science*, Invited Langbein Lecture at the Nice, France and San Francisco Meetings, April and Dec. 2003, **Amer. Geophysical Union**. PowerPoint presentation posted on AGU website. ([www.agu.org](http://www.agu.org)), 2003.
2. Singer, M.B and T. Dunne; *Long-term stochastic assessment of gravel augmentation strategies in the Sacramento River*, CALFED **Science Conference** Sacramento, CA 2003
1. Singer, M.B and T. Dunne; *Stochastic assessment of decadal patterns in Sacramento River channel sediment transport*, **American Geophysical Union**, San Francisco, CA 2002

## Figures for Dunne et al. CalFed supplementary proposal

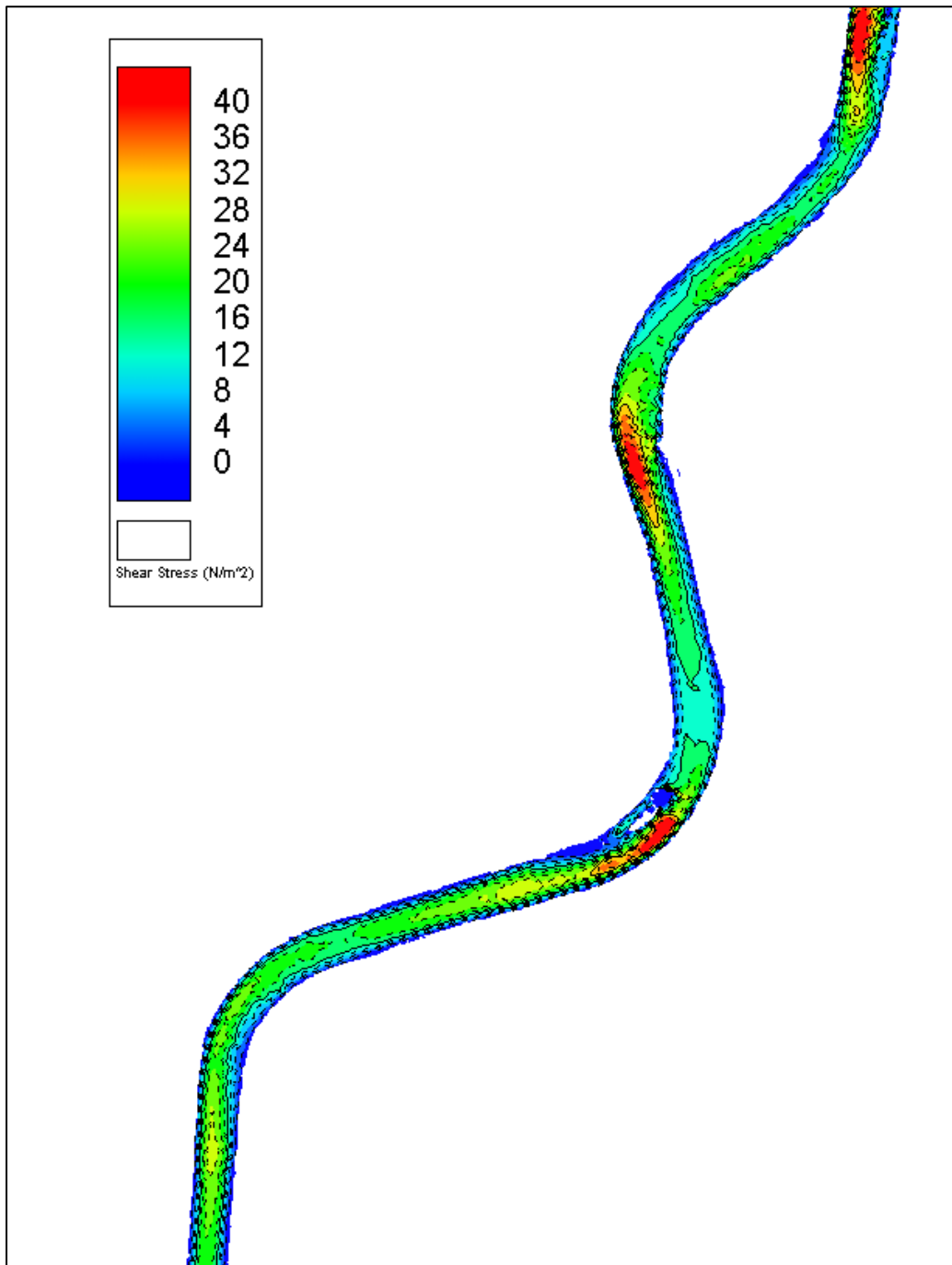


**Figure 1.** Comparison between observed and predicted water surface elevation versus streamwise distance at a discharge of 1,150 cfs. The model, which is now calibrated at a range of flows is capable of reproducing the measured water surface elevation values, thus promoting our confidence in the predictions of other hydraulic variables at a range of flow magnitudes (See Figure 2 for a test of this hypothesis.)

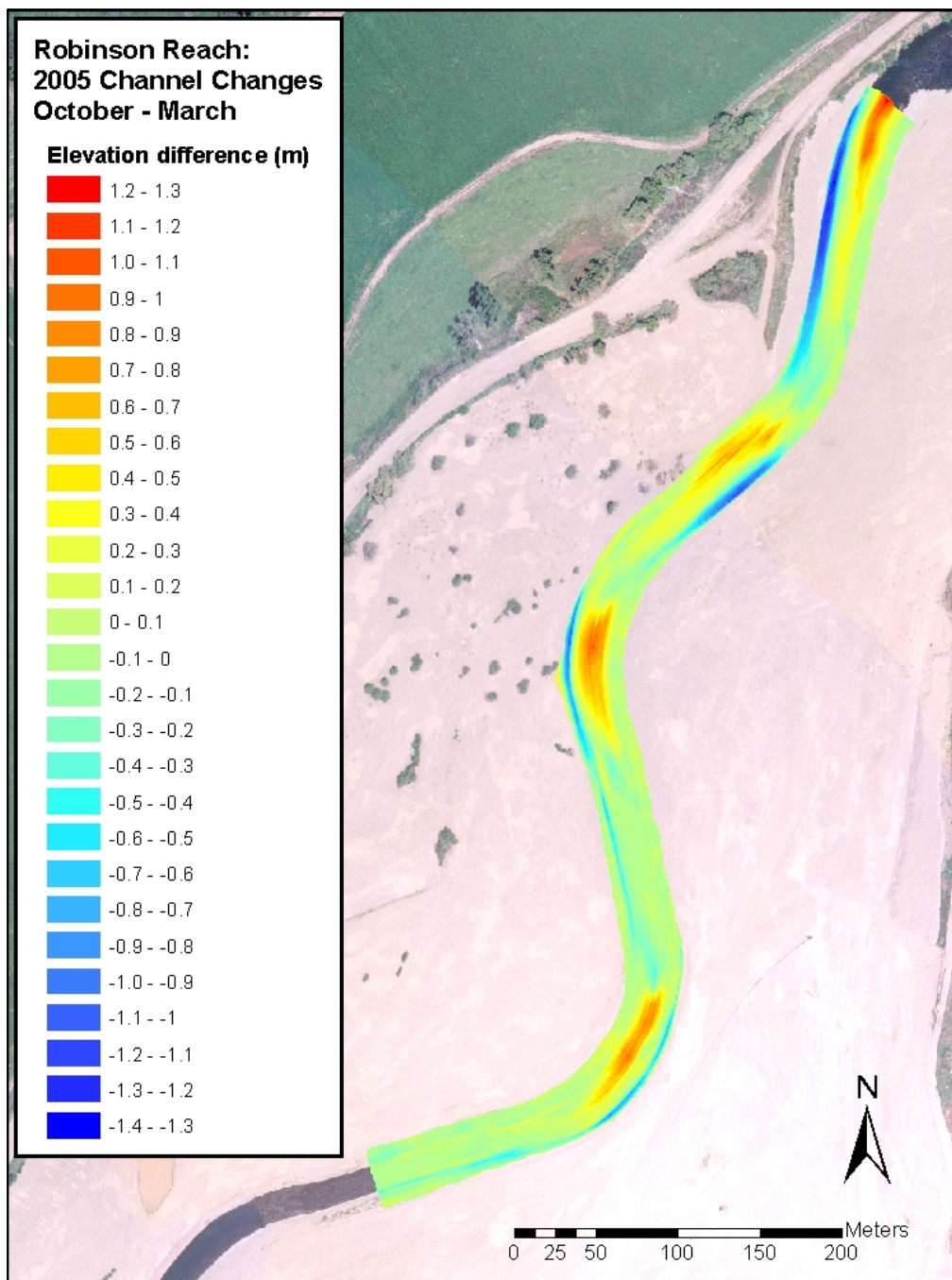


**Figure 2.** Example of observed versus predicted velocity in various cross sections at a discharge of 220 cfs. In general, the predicted and observed velocities are in good agreement. Future field efforts will involve collecting high-flow velocity measurements when bed material is being entrained.





**Figure 3.** Example of modeled bed shear stress for a discharge of 1,150 cfs. The simulation highlights the lateral gradient in shear stress along bar-pool reaches, which causes sediment to be routed through pools and deposited on point bars. This pattern is often a desired outcome in restoration projects and suggests that the channel is evolving towards a self-maintaining condition.



**Figure 4.** Changes in channel bed elevation in the Robinson Reach in the 2005 peak discharge of nearly 4,600cfs, which was approximately the 5 year post-dam flood event. The differences in bed elevation were mapped before and after the flood by ground survey and aerial photogrammetry using a new technique developed by our team (Legleiter and Roberts, 2005), and they illustrate clearly the pattern of bar deposition, pool scour, and small amounts of bank erosion on the outside of some bends that were a goal of the original restoration plan.

## THOMAS DUNNE: CURRICULUM VITAE

### ADDRESS

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### PROFESSIONAL PREPARATION:

Cambridge Univ., Geography B.A. 1964  
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### APPOINTMENTS:

1995- Professor, Donald Bren School of Environmental Science and Management, and  
Departments of Earth Science and Geography, University of California, Santa Barbara  
1973-1995 Asst. Prof. to Professor, Dept. of Geological Sciences, Univ. of Washington (Chair  
1984-1989)  
1971-1973 Assistant Professor, Department of Geography, McGill University, Canada, 1969-  
1971 Assistant Professor, Department of Geography, University of Nairobi, Kenya.  
1968-73 (WAE) Research Hydrologist, Water Resources Division, US Geological Survey,  
Washington DC  
1966-1968 Research Associate, Agricultural Research Service, US Department of Agriculture,  
Vermont

### CURRENT RESEARCH INTERESTS IN HYDROLOGY AND GEOMORPHOLOGY

1. Field and theoretical studies of drainage basin and hillslope evolution
2. Hydrology, sediment transport, and sedimentation in river channels and floodplains
3. Field studies and modeling of river-basin sediment budgets
4. Sediment transport, channel migration, and oxbow lake sedimentation in rivers of the Central Valley, California.

### PUBLICATIONS (last 5 years)

- E. J. Gabet and T. Dunne, A stochastic sediment delivery model for a steep, Mediterranean landscape, **Water Resources Research**, 39, doi:10.1029/2003WR002341, 2003.
- L. Benda, D. Miller, J. Sias, D. Martin, R. Bilby, C. Veldhuisen, and T. Dunne, Wood recruitment processes and wood budgeting, In: **Ecology and Management of Wood in World Rivers**, (eds. S. Gregory, K. Boyer, and A. Gurnell), American Society of Fisheries, pp. 49-74, 2003.
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- E.J. Gabet and T. Dunne, Sediment detachment by rainpower, **Water Resources Research**, 9(1), 1/1 – 1/12. 1002, doi:10.1029/2001 WR000656, 2003.
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- R. E. Aalto, L. Maurice-Bourgoin, T. Dunne, D. R. Montgomery, C. A. Nittrouer, and J-L. Guyot, Episodic sediment accumulation on Amazonian floodplains influenced by El Niño/Southern Oscillation, **Nature**, 425, 493-497, 2003.

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- T. W. Biggs, T. Dunne, and L. A. Martinelli, Natural controls and human impacts on stream nutrient concentrations in a deforested region of the Brazilian Amazon basin, **Biogeochemistry**, 68(2) 227–257, 2004.
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- R. E. Beighley, T. Dunne, and J. M. Melack, Understanding and modeling basin hydrology: Interpreting the hydrogeological signature, **Hydrologic Processes**, 19, 1333–1353, doi: 10.1002/hyp.5567, 2005.
- D. Alsdorf, T. Dunne, J. Melack, L. Smith, and L. Hess, Diffusion modeling of recessional flow on central Amazonian floodplains, **Geophysical Research Letters**, 32, L21405, doi:10.1029/2005GL024412, 2005.
- E. B. Safran, P. R. Bierman, R. E. Aalto, T. Dunne, K. X Whipple, and M. Caffee, Erosion rates driven by channel network incision in the Bolivian Andes, **Earth Surface Processes and Landforms**, 30 (8):1007-1024, 2005.
- R. E. Aalto, T. Dunne, and J-L Guyot, Geomorphic controls on Andean denudation, **Journal of Geology**, 114, 85-99, 2006.
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- T. W. Biggs, T. Dunne, T. Muraoka, Transport of water, solutes, and nutrients from a pasture hillslope, Southwestern Brazilian Amazon, **Hydrological Processes**, 20 (12), 2527-2547, 2006.
- E. B. Safran, A. Blythe, T. Dunne, Spatially Variable Exhumation Rates in Orogenic Belts: An Andean Example, **Journal of Geology**, 114, 665-681, 2006.
- M. B. Singer and T. Dunne, Modeling the decadal influence of river rehabilitation scenarios on flow and sediment transport in large, lowland river basins, **Water Resources Research**, 42, W12415, doi:10.1029/2006WR004894, 2006
- D. Alsdorf, P. Bates, J. Melack, M. Wilson, and T. Dunne, Spatial and temporal complexity of the Amazon flood measured from space, **Geophysical Research Letters**, 34, L08402, doi:10.1029/2007GL029447, 2007
- L. A. K. Mertes and T. Dunne, The effects of tectonics, climatic history, and sea-level history on the form and behavior of the modern Amazon River, In: **Large Rivers** (ed. A. Gupta), Wiley & Sons, 2007
- T. Dunne and L. A. K. Mertes, Rivers of South America, In: **The Physical Geography of South America** (eds. T. Veblen, K. Young, and A. R. Orme), Oxford University Press, pp 76-90, 2007.

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### Frank W. Davis

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#### Education

B.A. 1975 Biology Williams College, Massachusetts  
Ph.D. 1982 Geography and Environmental Engineering The Johns Hopkins University

#### Professional Experience

1995-1998: Deputy Director, National Center for Ecological Analysis and Synthesis, UCSB  
1996-present: Professor, Donald Bren School of Environmental Science and Mgmt, UCSB  
1994-present: Professor, Department of Geography, UC Santa Barbara.  
1989-1994: Associate Professor, Department of Geography, UC Santa Barbara.  
1983-1989: Assistant Professor, Department of Geography, UC Santa Barbara.

#### Selected Recent Professional Activity

Board of Editors, *Conservation Biology*, 1993-1999  
Principal Investigator, California Gap Analysis Project, 1990-1998  
National Research Council Committee on the Formation of the National Biological Survey, 1993  
Science Team, U.S. Forest Service Sierra Nevada Ecosystem Project, 1993-1996  
Board of Editors, *Geographical and Environmental Modeling*, 1996-2001  
Board of Editors, *Ecology*, 1999-2002  
National Research Council Committee on Restoration of the Greater Everglades Ecosystem,  
1999-2004  
Board of Trustees, The Nature Conservancy of California, since 2004  
National Research Council Committee for the Independent Scientific Review of the Everglades  
Restoration Program, since 2006

#### Research Interests

Conservation planning, landscape ecology, ecology of California rangelands and agroecosystems.

#### Research Sponsors in the past 48 months

National Science Foundation, USDA Forest Service, USDA National Research Initiative Rural Development Program, CalFed Bay-Delta Program, Resources Legacy Fund, County of Santa Barbara, U.S. Geological Survey, National Council for Science and the Environment.

#### Co-authors and collaborators, past 48 months (partial list):

Sandy Andelman, Paul Armsworth, Mark Borchert, Berry Brosi, Elizabeth Chornesky, Richard L. Church, Ken Chomitz, Gretchen Daily, Cyril Dutech, Rodney Dyer, Ross Gerrard, Dale Goble, Delphine Grivet, Craig Groves, Jon Keeley, Bruce Kendall, Jason Kreidler, William

Kuhn, Elia Machado, Bruce Mahall, Gavin McGhie, Dennis Odion, Robert Pressey, Helen Regan, Jim Reichman, Dar Roberts, J. Michael Scott, Bruce Stein, David Stoms, Claudia Tyler Victoria Sork, Peter Smouse, Victoria Apsit, Juan Fernandez, Lee Hannah, William Zielinski.

### **Selected publications**

- 1990 **Davis, F. W.** and S. Goetz. Modeling vegetation pattern using digital terrain data. *Landscape Ecology* 4: 69-80
- 1990 **Davis, F. W.**, D. Stoms, J. Scean, J. Estes and M. Scott. An information systems approach to the preservation of biological diversity. *International Journal of Geographic Information Systems* 4: 55-78.
- 1993 Scott, J. Michael, **F. W. Davis**, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, J. Ulliman and R. G. Wright. Gap analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123: 1-41.
- 1993 Callaway, R.M. and **F.W. Davis**. Vegetation dynamics, fire and the physical environment in central California. *Ecology* 74: 1567-1578.
- 1994 **Davis, F. W.**, P. A. Stine and D. M. Stoms. Remote sensing and GIS applied to phytogeographic analysis and conservation planning in southwestern California. *Journal of Vegetation Science* 5: 743-756.
- 1996 Church, R. L., D. M. Stoms, and **F. W. Davis**. Reserve selection as a maximal covering location problem. *Biological Conservation* 76: 105-112.
- 1999 **Davis, F.W.**, D.M. Stoms, and S. Andelman. Systematic reserve selection in the USA: an example from the Columbia Plateau ecoregion. *Parks* 9:31-41.
- 2001 Scott, J.M., **F. W. Davis**, G. McGhie, C. Groves. Nature reserves: do they capture the full range of America's biological diversity? *Ecological Applications* 11: 9999 – 1004.
- 2002 V. L. Sork, **F. W. Davis**, P. Smouse, V. Apsit, R. Dyer, J. Fernandez, W. Kuhn. Pollen movement in declining populations of California valley oak, *Quercus lobata*: Where have all the fathers gone? *Molecular Ecology* 11: 1657-1668.
- 2005 Goble, D., Scott J.M. and F.W. Davis. *The Endangered Species Act at 30 Volume I: Renewing the Conservation Promise*. Island Press, Washington, D.C.
- 2006 **Davis, F. W.**, C. Costello and D. Stoms 2006. Efficient Conservation in a Utility-Maximization Framework. *Ecology and Society* 11 (1): 33. [online] URL: <http://www.ecologyandsociety.org/vol11/iss1/art33/>
- 2007 Regan, H. M., **F. W. Davis**, S. J. Andelman, A. Widyanata and M. Freese. Comprehensive criteria for biodiversity evaluation in conservation planning. *Biodiversity and Conservation* 16:2715-2728.
- 2007 **Davis, F. W.**, C. Seo and W. Zielinski. Regional variation in home range scale habitat models for fisher (*Martes pennanti*) in California. *Ecological Applications* 17:2195-2213.



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### PROFESSIONAL PREPARATION

B.S. University of California, Berkeley, 1986; major- Conservation of Natural Resources

M.S. Moss Landing Marine Laboratories, CA, 1992; Marine science (Adviser: Ken Johnson)

Ph.D. University of North Carolina, Chapel Hill, 1992-1996; Marine Science (Advisor: C.H. Peterson)

Post-doc National Marine Fisheries Service, National Research Council Postdoctoral Associateship,  
Beaufort, NC, 1997-1998

Post-doc University of North Carolina, Institute of Marine Sciences, Morehead City, NC, 1998-2000

### APPOINTMENTS

Associate Professor, University of California, Santa Barbara, 2006-present

Assistant Professor, University of California, Santa Barbara, 2002-2006

Fisheries Biologist, National Marine Fisheries, Northwest Fisheries Science Center, Newport, OR 2000-2001

### GRANTS-CURRENT

Community-based Collaborative Fishery Research: Assessing Fishery Impacts of CA Marine Reserves. CA Ocean Protection Council (P.I.). 2007-2009. \$407,000.

Moorea Coral Reef LTER: Long-term dynamics of coral reef ecosystem. Moorea, French Polynesia. NSF LTER Program. (Associate Investigator). 2004-2009. \$4.2 million.

Assessing Withering Syndrome Resistance in California Black Abalone: Implications for Conservation and Restoration. California Sea Grant (Co-P.I.). 2005-2008. \$159,843.

How Abiotic Processes, Biotic Processes, and their Interactions Sustain Habitat Characteristics and Functions in River Channels and their Floodplains: An Investigation of How a Reach of the Merced River Responds to Restoration. CALFED (Co-P.I.). 2005-2008. \$1.4 million.

### PUBLICATIONS

Lenihan, H.S., S. Mills, L. S. Mullineaux, F. Micheli, C.R. Fisher, and C.H. Peterson. *In Press*. Biotic interactions at hydrothermal vents: density-dependent recruitment in mussels beds. **Deep Sea Research**.

Lenihan, H.S., M. Adjeroud, M. Kotchen, J. Hench, and T. Nakamura *In Press*. How the physical structure of coral reefs regulates coral bleaching. **Marine Ecology Progress Series**.

Halpern, B., H.S. Lenihan, et al. *In Press*. Assessing and mapping the cumulative global impact of human activities on marine ecosystems. **Science**.

Penin, L., M. Adjeroud, M. Schrimm, and H.S. Lenihan. 2007. High spatial variability in coral bleaching around Moorea (French Polynesia): patterns across locations and water depths. **Comptes Rendus Biologies** 330: 171-181

Lotze, H.K., H.S. Lenihan, B.J. Bourque, R. Bradbury, R. Cooke, M.C. Kay, S. Kidwell, M.X. Kirby, C.H. Peterson, and J.B.C. Jackson. 2006. Depletion, degradation, and recovery of estuaries and coastal seas. **Science** 312: 1806-1809

Griffiths, J., M.N. Dehtier, A. Newsom, J.E. Byers, J.J. Myers, F. Oyarzun, and H.S. Lenihan. 2006. Infaunal Responses to Recreational Clam Digging. **Marine Biology** 149: 1489-1497

Bishop, M.M., C.H. Peterson, H.C. Summerson, H.S. Lenihan, and J.H. Grabowski. 2006. Deposition and long-shore transport of dredge spoils to nourish beaches: impacts on benthic infauna of an ebb-tidal delta. **Journal of Coastal Research** 22: 530-546

Ruesink, J., H.S. Lenihan, A. Trimble, K. Heiman, F. Micheli, J.E. Byers, and M.C. Kay. 2005. Introduction of non-native oysters: ecosystem effects and restoration implications. **Annual Review of Ecology, Evolution, and Systematics** 36: 643-689

Sancho, G., C.R. Fisher, S., F. Mills, Micheli, G.A. Johnson, H.S. Lenihan, C.H. Peterson, and L.S. Mullineaux, L.S. 2005. Selective predation by the zoarcid fish *Thermarces cerberus* at hydrothermal vents. **Deep Sea Research** 52: 837-844

- Conlan, K.E., S.L. Kim, H.S. Lenihan, and J.S. Oliver. 2004. Benthic changes during 10 years of organic enrichment by McMurdo Station, Antarctica. **Marine Pollution Bulletin** 49: 43-60
- Lenihan, H.S. and C.H. Peterson. 2004. Conserving oyster reef habitat by switching from dredging and tonging to diver hand-harvesting. **Fishery Bulletin** 102: 298-305
- Lenihan, H.S., C.H. Peterson, S.L. Kim, K.E. Conlan, R. Fairey, C. McDonald, J.H. Grabowski, and J.S. Oliver. 2003. How variation in marine benthic community composition allows discrimination of multiple stressors. **Marine Ecology Progress Series** 206: 63-73
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- Peterson, C.H., J.B.C. Jackson, M.X. Kirby, H.S. Lenihan, R. Borque, R. Bradbury, R. Cooke, and S. Kidwell. 2001. Factors in the decline of coastal ecosystems- Response. **Science** 293: 1590-1591
- Lenihan, H.S., C.H. Peterson, J.E. Byers, J.H. Grabowski, G.W. Thayer, and D.R. Colby. 2001. Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. **Ecological Applications** 11: 748-764
- Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R. Bradbury, R. Cooke, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R. Warner. 2001. Historical overfishing and the collapse of marine ecosystems. **Science** 293: 629-638
- Lenihan, H.S. and F. Micheli. 2001. Soft sediment communities. *In* M. Bertness, M.E. Hay, and S.D. Gaines (editors), **Marine Community Ecology**. Sinauer Associates
- Peterson, C.H., H.C. Summerson, E. Thompson, H.S. Lenihan, J.H. Grabowski, L. Manning, F. Micheli, and G. Johnson. 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. **Bulletin of Marine Science** 66: 759-774.
- Lenihan, H.S., and F. Micheli. 2000. Biological effects of shellfish harvesting on oyster reefs: resolving a fishery conflict using ecological experimentation. **Fishery Bulletin** 98: 86-95
- Lenihan, H.S. 1999. Physical-biological coupling on oyster reefs: how habitat form influences individual performance. **Ecological Monographs** 69: 251-275
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- Lenihan, H.S., C.H. Peterson, and J.M. Allen. 1995. Does flow also have a direct effect on growth of active suspension feeders: an experimental test with oysters. **Limnology and Oceanography** 41: 1359-1366
- Lenihan, H.S., K.A. Kiest, K.E. Conlan, P.N. Slattery, B.H. Konar, and J.S. Oliver. 1995. Patterns of survival and behavior of marine invertebrates exposed to contaminated sediments from McMurdo Station, Antarctica. **Journal of Experimental Marine Biology and Ecology** 192: 233-255
- Lenihan, H.S. and J.S. Oliver. 1995. Natural and anthropogenic disturbances to marine benthic communities in Antarctica. **Ecological Applications** 5: 311-326
- Lenihan, H.S. 1992. Benthic marine pollution around McMurdo Station, Antarctica: a summary of findings. **Marine Pollution Bulletin** 25: 318-323
- Lenihan, H.S., J.S. Oliver, J.M. Oakden, and M. Stephenson. 1990. Intense and localized benthic marine pollution around McMurdo Station, Antarctica. **Marine Pollution Bulletin** 21: 422-430
- Lenihan, H.S., J.S. Oliver, and M. Stephenson. 1990. Changes in hard-bottom communities related to boat-mooring and Tributyltin (TBT) in San Diego Bay: a natural experiment. **Marine Ecology Progress Series** 60: 147-159



Biographical Sketch  
**Bradley J. Cardinale, Ph.D.**  
Department of Ecology, Evolution & Marine Biology  
University of California, Santa Barbara CA 93106

#### EDUCATION

Ph.D. in Biology, University of Maryland, May 2002  
M.S. in Fisheries and Wildlife, Michigan State University, 1996  
B.S. in Biology, Arizona State University, 1993

#### POSITIONS HELD

7/05 – present      Assistant professor, Department of Ecology, Evolution & Marine Biology,  
University of California-Santa Barbara.  
4/02 – 6/05      Postdoctoral research associate, Department of Zoology, University of  
Wisconsin-Madison.

#### HONORS & AWARDS

- Hynes Award for New Investigators. North American Benthological Society, 2003.
- Distinguished Teaching Assistant. Center for Teaching Excellence, Univ. of Maryland, 2001.
- Wildco Award for Best Oral Presentation in Basic Research. North American Benthological Society annual meeting, Keystone, Colorado, 2000.
- Wildco Award for Best Oral Presentation in Basic Research. North American Benthological Society annual meeting, San Marcos, Texas, 1997.

#### FUNDING

- National Science Foundation, DEB-0614428, \$325,000. “*Effects of algal diversity on the productivity of streams: Does diversity play a greater role in variable vs. constant environments?*” (10/06 – 09/08).
- UC MEXUS-CONACYT Collaborative Research Grant, \$25,000. “*Hotspots of biodiversity in central México: Implications and importance for habitat conservation in human-dominated watersheds.*” (07/05 – 06/06).
- Doctoral Dissertation Improvement Grant, National Science Foundation, Division of Environmental Biology, \$9225. “*Putting the relationship between species diversity and ecosystem functioning into context.*” (4/01 – 8/02).

#### PROFESSIONAL ACTIVITIES

- NCEAS (National Center for Ecological Analysis and Synthesis): Trophic structure comparisons across ecosystems. 2005-2006. Jonathan Shurin, Helmut Hillebrand (organizers).
- Long Term Ecological Research Network Science Strategic Planning Grant. 2005-2006. National Science Foundation (sponsor).
- BioMERGE (Biotic Mechanisms of Ecosystem Regulation in the Global Environment) Adaptive Synthesis Workshops II, III and IV. 2003-2007. Shahid Naeem, Daniel Bunker (organizers).
- DIVERSITAS (an international program of biodiversity science): ‘The Consequences of Changing Biodiversity - Solutions and Scenarios’. 2005-2006. Michel Loreau, Andy Hector (organizers).
- First International Conference on Aquatic Biodiversity and Ecosystem Functioning. Ascona, Switzerland. 2002. Mark Gessner, Pablo Inchausti, Lennart Persson, and Dave Raffaelli (organizers).

## 5 PUBLICATIONS MOST RELEVANT TO PROPOSED RESEARCH

1. **Cardinale, B. J.**, J. Wright, M. Cadotte, I. Carroll, A. Hector, D. Srivastava, M. Loreau, and J. Weis. 2007. Effects of plant diversity on plant biomass increase through time: A meta-analysis. *Proceedings of the National Academy of Science*, 104:18123-18128.
2. Gross, K. and **B. J. Cardinale**. 2007. Does species diversity drive ecosystem productivity or vice versa? Towards unification of the historical and contemporary paradigms. *The American Naturalist* 170: in press.
3. **Cardinale, B. J.**, D. S. Srivastava, J. E. Duffy, J. P. Wright, A. L. Downing, M. Sankaran, and C. Jousseau. 2006. Effects of biodiversity on the functioning of trophic groups and ecosystems. *Nature*, 443:989-992.
4. **Cardinale, B. J.**, H. Hillebrand, and D. Charles. 2006. Geographic patterns of algal diversity in streams predicted by a multivariate model of disturbance and community production. *Journal of Ecology*, 94:609-618.
5. Weis, J. J., **B. J. Cardinale**, and A. R. Ives. 2007. Effects of algal species richness on community biomass production change predictably through successional time. *Ecology*, 88:929-939.

## 5 OTHER SIGNIFICANT PUBLICATIONS (of 40)

6. Duffy, J. E., **B. J. Cardinale**, K. E. France, M. Loreau, P. B. McIntyre, and E. Thebault. 2007. The functional role of biodiversity in food webs: Incorporating trophic complexity. *Ecology Letters*, 10:522-538.
7. **Cardinale, B. J.**, J. J. Weis, K. J. Tilmon, A. E. Forbes, A. R. Ives. 2006. Biodiversity as both a cause and consequence of resource availability: A study of reciprocal causality in a predator-prey system. *Journal of Animal Ecology* 75:497-505.
8. **Cardinale, B. J.**, A. R. Ives, and P. Inchausti. 2004. Effects of species diversity on the primary productivity of ecosystems: extending our spatial and temporal scales of inference. *Oikos* 104:437-450.
9. Covich, A. P., M. C. Austen, F. Bärlocher, E. Chauvet, **B. J. Cardinale**, C. L. Biles, P. Inchausti, O. Dangles, M. Solan, M.O. Gessner, B. Stutzner, B. Moss, and H. Asmus. 2004. The role of biodiversity in the functioning of freshwater and marine benthic ecosystems. *BioScience* 54:767-775.
10. **Cardinale, B. J.**, M. A. Palmer, and S. L. Collins. 2002. Species diversity increases ecosystem functioning through interspecific facilitation. *Nature* 415:426-429.

**34 submitted / 8 invited talks at conferences, 24 invited seminars**

## COLLABORATORS IN LAST 5 YEARS NOT LISTED IN PUBLICATIONS

Valerie Brady (U.S. EPA)	Mike Madritch (Univ. Wisconsin-Madison)
Jason Fridley (Syracuse Univ.)	David Raffaelli (Univ. York, UK)
Andy Hector (Imperial College)	Jon Shurin (Univ. British Columbia)
Michel Loreau (McGill Univ.)	Bill Snyder (Washington State Univ.)

## ADVISORS

Dr. Thomas Burton, Michigan State University (M.S.)  
Dr. Margaret Palmer, University of Maryland (Ph.D.)  
Dr. Anthony Ives, University of Wisconsin-Madison (Post-doctoral)

CalFed (Supplement)  
T. Dunne, F. Davis, and H. Lenihan  
University of California, Santa Barbara  
Institute for Computational Earth System Science

**DETAILED BUDGET**

**7/1/08-  
5/31/09**

**SALARIES**

	Period/mos.	% Time	
1. Principal Investigator -Thomas Dunne Professor Bren School of Environmental Science & Management Summer month @ 1/9 annual rate of \$189,100 1st yr.	1	100%	21,011
2. Co-Principal Investigator - Frank Davis Professor - Bren School of Environmental Science & Management Academic period	8	2%	0
3. Co-Principal Investigator - Hunter Lenihan Assistant Professor Bren School of Environmental Science & Management Summer month @ 1/9 annual rate of \$76,300 1st yr. (Assoc II O/S)	1	100%	8,478
4. Assistant Professor - Bradley Cardinale Ecology, Evolution, and Marine Biology \$79,800 1st yr.	1	100%	8,867
5. Associate Researcher - Claudia Tyler \$5,508 /mo.	3	40%	6,610
\$5,646 /mo.	9	40%	20,326
6. Postgraduate Researcher VIII - Geomorphology & Hydrodynamics \$3,846 /mo.	7	100%	26,922
7. Postgraduate Researcher VIII - Fish Biology \$3,846 /mo.	7	100%	26,922
8. Graduate Student Researcher IV \$3,488 /mo.	3	75%	7,848
\$3,575 /mo.	8	49%	14,014
9. Undergraduate Assistants for fish biology and geomorphology \$10 /hr.			5,000
	<b>Salaries Subtotal</b>		<b>145,998</b>

**FRINGE BENEFITS**

1. Principal Investigator -Thomas Dunne \$21,011 @ 12.70%	2,668
2. Co-Principal Investigator - Hunter Lenihan \$8,478 @ 12.70%	1,077
3. Assistant Professor - Bradley Cardinale \$8,867 @ 12.70%	1,126
4. Associate Researcher - Claudia Tyler \$26,936 @ 17.00%	4,579
5. Postgraduate Researcher VIII - Geomorphology & Hydrodynamics \$26,922 @ 17.00%	4,577

6.	Postgraduate Researcher VIII - Fish Biology				
		\$26,922 @	17.00%		4,577
7.	Graduate Student Researcher IV				
		\$7,848 @	3.00%	(Summer)	235
		\$14,014 @	1.30%	(Academic)	182
8.	Undergraduate Assistants for fish biology and geomorphology				
		\$5,000 @	3.00%		150
9.	Graduate Student Health Insurance Plan*				2,324
10.	Graduate Student Tuition and Fees *				8,897
				<b>Benefits Subtotal</b>	<b>30,392</b>

**OTHER SERVICES**

1.	Construction services and surveys for fish monitoring and field experiments				10,000
2.	Preparation and publishing reports				1,000
				<b>Other Services Subtotal</b>	<b>11,000</b>

**SUPPLIES AND HARDWARE**

1.	Preparation and publishing reports				2,000
2.	LIDAR topographic data				23,000
3.	Irrigation installation and maintenance				10,000
				<b>Supplies Subtotal</b>	<b>35,000</b>

**TRAVEL**

1.	2 field trips per year to Merced, 3 people (shared transportation)				
		mileage @	\$338/trip		676
2.	Rent for communal apartment in field area for accomodation and storage				
		\$1500/mo @	months		3,000
3.	Per diem expenses for food				
		60 person-days @	\$44/day/person		2,640
4.	7 field trips per year to Merced, 3 people (sharing transportation)				
		mileage @	\$338/trip		2366
		lodging @	\$100 each		2100
		5 days per diem @	\$85/day/person		8925
				<b>Travel Subtotal</b>	<b>19,707</b>

**OTHER DIRECT COSTS**

1.	Long-distance phone, fax and project mailing costs**				145
				<b>Other Direct Costs Subtotal</b>	<b>145</b>

**TOTAL DIRECT COSTS 242,242**

**INDIRECT COSTS**

CBDA negotiated rate of 25%*** of Modified Total Direct Costs					
		231,021 @	25.0% MTDC		57,756

**Indirect Costs Subtotal 57,756**

**TOTAL COSTS 299,998**

\* Provided to all Teaching Assistants and Graduate Student Researchers employed at 25% time or more.

\*\* Costs for communication of research data to allow collaboration with research team members and with researchers related to this project.

\*\*\* This is the rate per State Agency Waiver #03R-315