Center for Water Resources
Annual Technical Report
FY 2005

Introduction

The UC Center for Water Resources Center administratively is a special program within the University of California Division of Agriculture and Natural Resources. As a multiple campus research unit, it has commitments to faculty and students at all 10 UC campuses and to corporative personnel in each of the 58 counties. The Center fulfills its missions in advancing water resources research, student training, and information transfer through a competitive grant program that is supported by federal grants and state matching funds. The funded research projects address critical issues in four broad areas of water sciences and technologies: hydrology, climatology and hydraulics; aquatic eco-systems; water quality; and policy, management, law, and institution framework with additional state funds and endowments earmarked for activities in salinity and drainage, water conservation and management, and international water policies. The Water Resources Center Archive has a rich special collection of technical literature and documents on water resources development in California. It serves the State in the capacity in data repository and information dissemination. In addition, the Center organizes the annual Salinity Drainage Conference and the Biennial Groundwater Conference both are co-sponsored by public agencies and are ideal continuing education for water professionals in the State. Contact: cwres@ucr.edu or http://waterresources.ucr.edu

Research Program

The UC Center for Water Resources has funded 28 projects for a total of $801,000.00 with nearly every UC Campus Participating.

Dynamics of Point and Non-Point Source Fecal Pollution from an Urban Watershed in Southern California

Basic Information

Title:	Dynamics of Point and Non-Point Source Fecal Pollution from an Urban Watershed in Southern California
Project Number:	2003CA50G
Start Date:	9/1/2003
End Date:	8/31/2006
Funding Source:	104G
Congressional District:	48
Research Category:	None
Focus Category:	Ecology, Surface Water, Water Quality
Descriptors:	None
Principal Investigators:	Stanley B. Grant, Patricia Ann Holden, Brett franklin Sanders

Publication

1. Ahn, Jong Ho; Stanley Grant; Cristiane Surbeck; Paul DiGiacomo; Nikolay Nezlin; Sunny Jiang, 2005, Coastal water quality impact of stormwater runoff from an urban watershed in southern California, Environmental Science and Technology, 39, 5940-5953.
2. Surbeck, Cristiane; Sunny Jian; Jong Ho Ahn; Stanley Grant, 2006, Flow fingerprinting fecal pollution and suspended solids in stormwater runoff from an urban coastal watershed, Environmental Science and Technology, in press.
3. Brooks, Dan. 2005. Fecal pollution and microbial community composition and diversity in an urban river during two large rainstorms in southern California. MS Degree Report. Department of Mechanical and Environmental Engineering. University of California, Santa Barbara, CA. 28 pp.
4. Grant, Stanley; Jong Ho Ahn; Paul DiGiacomo; Nikolay Nezlin; Sunny Jiang ; Cristiane Surbeck, 2005, Impact of storm water runoff on Coastal Water Quality, in the National Meeting of The American Chemical Society, San Diego, CA.
5. Surbeck, Cristiane; Stanley Grant; Jong Ho Ahn; Sunny Jiang, 2006, Fecal pollution and suspended particle sin stormwater runoff from an urban coastal watershed, in ACS
6. Surbeck, Cristiane; Stanley Grant; Jong Ho Ahn, 2005, Storm water runoff from an urban watershed in southern California: top-down approach for characterizing and modeling pollutant loading rates, in EWRI 2005: Impacts of Global Climate Change, ASCE Press, Reston, VA, NA.

7. Brooks, Daniel, Stanley Grant; Patricia A. Holden. 2005. Progression of riverine bacterial community composition and diversity during two large rainstorms. American Society for Microbiology, 105th General Meeting, June 5th - 9th, 2005. Atlanta, GA.

This research project is focused on the fate and transport of microorganisms and suspended particles in surface waters from an urban coastal watershed along an inland-to-ocean transect (creeks, rivers, estuaries, surf zone, offshore).

Problem. Recently, surface water runoff has emerged as the primary source of pollutant loading to the urban ocean due to changes in civil infrastructure, such as damming and development. Surface waters in southern California are negatively impacted by microorganisms and suspended particles, consequently failing many total maximum daily load (TMDL) requirements and potentially affecting the health of recreational swimmers. Therefore, the sources of pollutants in urban runoff must be quantified as part of assessing pollutant loads, and there is a need to understand the fate and transport of pollutants in a watershed system in order to reduce the impact through the development and deployment of best management practices (BMPs).

Research Objectives. The objective is to elucidate the origins and fluvial transport of fecal indicator bacteria, human pathogenic viruses, and suspended particles along an inland-to-ocean transect in the Santa Ana River watershed, southern California, during dry weather and episodic storm events, and to identify coastal water quality impact from a highly urbanized coastal watershed system. This research includes the following specific goals:

- To characterize the concentrations of fecal indicator bacteria and suspended sediment in storm water runoff from the Santa Ana River.
- To understand the origin and transport mechanism of suspended particles through the characteristics of particle size spectra eroded from an urban watershed.
- To assess coastal water quality impact of storm water runoff and the correlation between in-situ measurements and remote sensing.
- To assess the impact of urban runoff and treated wastewater in the growth and die-off mechanisms of fecal indicator bacteria.
- To assess microbial community changes in storm water runoff in the Santa Ana River as indicators of fecal pollution and runoff origins

Methodology.

- High frequency sampling of stormwater runoff at three sites in the Santa Ana River watershed over three storms. Measurements on runoff samples included: fecal indicator bacteria (total coliform, *E. coli*, and enterococci), fecal indicator virus (F^+ coliphage), human pathogenic virus (human adenovirus and human enterovirus by nested polymerase chain reaction, PCR), suspended particles (mass and size distribution), and microbial community composition by analysis of terminal restriction fragment length polymorphisms (TRFLPs) of particle-associated and free-living eubacteria.
- Merging of satellite sensing of runoff plumes with shipboard measurements of runoff plumes, and in situ sensor data. Measurements included: MODIS satellite data (true color images), NEOCO in situ sensor at Newport Pier (1/4 min^{-1}, salinity, temperature, chlorophyll), fecal indicator bacteria in surf zone (conducted by Orange County Sanitation District, OCSD), offshore (UCI and Bight 03), human pathogenic virus, suspended particles.
- Dry-weather transect sampling of stretch of Cucamonga Creek. Measurements include: fecal indicator bacteria, dissolved organic carbon, nitrate, ammonium, phosphorus, dissolved oxygen, pH, salinity and conductivity.
- Microcosm studies using different combinations of Cucamonga Creek baseflow, sterilized baseflow, treated wastewater discharge, sterilized treated wastewater discharge, and nutrient broth. Sampling of microcosms over time and measuring fecal indicator bacteria.

Principal Findings. Principal findings are the following:

a. Within-watershed stormwater studies:

- Concentrations of fecal indicator bacteria and fecal indicator viruses increase sharply during the rising limb of the storm hydrographs and do not fall with the falling limb of the storm hydrographs.
- Concentrations of suspended particles follow the shape of the storm hydrographs.
- Human adenovirus and human enterovirus results were negative (below detection limits using PCR and nested PCR), except for one positive result of adenovirus during the early part of a storm, downstream of the treated discharge of a tertiary wastewater treatment plant.
- Bacterial communities were both particle-associated and free-living in storm runoff. Whether the two fractions were similar depended on the site.
- Bacterial communities differed by site and were particularly distinct in the ocean. They also varied between storms within a site, but when one site was sampled during the course of a hydrograph no temporal variations in microbial communities were observed.

b. Coastal water quality impacts:

- Storm water runoff impacts coastal ocean water quality, both in the surf zone and offshore, with water quality in the surf zone frequently exceeding marine bathing standards by >500%.
- F^+ coliphage, human adenoviruses and enteroviruses detected just offshore of the Santa Ana River outlet.
- Turbidity plumes generated by the Santa Ana River spread out over a very large area (exceeding 100 km^2).
- Bacteria and viruses appear to be associated with particles smaller than 53 microns, or they are not particle associated. This results was confirmed both by culture-dependent and culture-independent microbiological methods.

Significance.

a. Within-watershed stormwater studies:

- Fecal indicator bacteria appear to be ubiquitous across the urban landscape and are washed off into receiving water bodies during storms.
- Traditional best management practices (BMPs) for treating stormwater pollutants may not be effective for treating bacterial pollutants.
- Flow fingerprints—or changes in the concentration of stormwater constituents with volumetric flow rate in the river—appear to be a useful analytical tool for determining sources of pollutants in stormwater runoff from urban watershseds.
- Community fingerprints appear to be site-specific which implies that microbes may be tracers for runoff water quality from various, integrated sources upstream.

b. Coastal ocean studies:

- Turbidity detected by MODIS satellite sensors does not necessarily correlate with water quality, as measured by fecal indicator bacteria, fecal indicator viruses, and human pathogenic viruses.
- Coastal impact of storm water runoff depends on prevailing ocean currents and waves, within-plume processing of particles and pathogens, and the timing, magnitude, and nature of runoff discharged from the river over the course of a storm.

Distribution and toxicity of sediment-associated pesticides in the Sacramento River watershed.

Basic Information

Title:	Distribution and toxicity of sediment-associated pesticides in the Sacramento River watershed.
Project Number:	2003CA57G
Start Date:	9/30/2003
End Date:	9/29/2006
Funding Source:	104G
Congressional District:	9th
Research Category:	Not Applicable
Focus Category:	Agriculture, Non Point Pollution, Sediments
Descriptors:	
Principal Investigators:	Donald Paul Weston, Chris Ingersoll, Michael j Lydy

Publication

1. You J. and M.J. Lydy. 2006. Determination of pyrethroid, organophosphate and organochlorine pesticides in water by headspace solid-phase microextraction. International Journal of Environmental Analytical Chemistry. 86(6): 381-389.
2. Amweg, E.L., D.P. Weston, C.S. Johnson, J. You and M.J. Lydy. (in press) Effect of piperonyl butoxide on permethrin toxicity in the amphipod Hyalella azetca. Environmental Toxicology and Chemistry.
3. Amweg, E.L., D.P. Weston, J. You and M.J. Lydy. 2006. Pyrethroid insecticides and sediment toxicity in urban creeks from California and Tennessee, USA. Environmental Science and Technology. 40: 1700-1706.
4. Weston, D.P., E.L. Amweg, A. Mekebri, R.S. Ogle and M.J. Lydy. (in review) Aquatic effects of aerial spraying for mosquito control over an urban area. Environmental Science and Technology.

Distribution and toxicity of sediment-associated pesticides in the Sacramento River watershed (WRIP Award #03HQGR0120).

Problem and Research Objectives

The proposed work is an extension of our past studies in which we have proven the analytical feasibility of sediment analysis for pyrethroids have shown them present in most sediment samples from agriculture-affected water bodies, and have shown pyrethroid-related toxicity to benthic invertebrates in many locations. The study involves far more work on pyrethroids, and particularly on more basic aspects of their toxicology. This study has the following objectives:

1) Conduct bioaccumulation and toxicokinetics studies that examine how pyrethroids are processed by benthic invertebrates.
2) Determine the potential enhancement of pyrethroid toxicity by piperonyl butoxide (PBO), a synergist included in some pesticide formulations and known to be present in surface waters.
3) Examine possible interactions between pyrethroids and organochlorines that may modify the expected independent toxicity of the compounds.
4) Collect sediment from urban creeks and analyze them for pyrethroids and toxicity. Analyze native benthic invertebrates for tissue pyrethroid concentrations.
5) Run chronic toxicity tests on selected sediment samples collected as part of the PRISM project. Dr. Chris Ingersoll, a USGS Scientist located at the Columbia, MO laboratory, will conduct this testing.
6) Measure changes in bioavailability (toxicity tests) and aqueous desorption rates (Tenax beads) of pyrethroids in field-collected soils over time.

Bioaccumulation and toxicokinetics

Methods - Toxicokinetics is the study of the rate processes involved in uptake, distribution, metabolism and elimination of a toxic chemical in an organism. This information is critical when judging the potential for toxicity and bioaccumulation of chemicals, as well as the potential for trophic transfer of toxic substances to predators. This component of the project will determine toxicokinetic parameters such as sediment uptake clearance coefficients (k_s), elimination rate constants for both parent compound (k_{ep}) and metabolites (k_{em}), the biotransformation rate (k_m), biological half life ($t_{1/2}$) and bioaccumulation factors (BAF). Two invertebrate species that differ widely in biotransformation capabilities were initially intended to be used: Chironomus tentans and Lumbriculus variegates.

Findings and status – Toxicokinetic studies have been completed with Chironomus for the pyrethroid, permethrin, and work with lambda-cyhalothrin is in progress. Rather than using Lumbriculus we instead have worked with Chironomus and DDT, contrasting the toxicokinetics of a pesticide that is biotransformed (pyrethroids) with one that is not (DDT). We have also added a component to examine the temperature dependency of the toxicokinetics, since pyrethroids have the unusual trait of being more toxic at colder temperatures. We have found that the reason for this temperature-dependency lies in the inhibition of pyrethroid biotransformation. The enzymatic activity that would ordinarily detoxify the pyrethroids is dramatically inhibited at low temperatures, leading to the observed increase in toxicity. A publication on this work is now in preparation, with submittal expected in shortly.

PBO synergy

Methods - Piperonyl butoxide (PBO) is a synergist used to enhance the insecticidal properties of pyrethroid insecticides. The function of PBO is to inhibit metabolic degradation of the insecticide by the target pest species. With metabolic detoxification inhibited or completely stopped, the toxic potency of the pyrethroid is increased. PBO is included in many pyrethroid pesticide formulations, and residues of the compound are detectable in surface waters of California. The demonstration of PBO in surface waters raises the possibility that PBO may be having the same synergistic effect on aquatic non-target species as on the pest for which was initially applied, and suggests that literature estimates of pyrethroid toxicity may underestimate the risks since they do not include the possibility of a co-occurring synergist.

Findings and status – We have demonstrated the synergy of PBO and pyrethroids in the laboratory, using permethrin and bifenthrin. Field studies in urban areas and at a pond that had been sprayed for mosquitoes using a PBO-containing product have documented the presence of PBO in the water, but at concentrations far too low to cause synergy. We believe the absence of environmental synergy is the norm. However, a mosquito control application over Sacramento provided an unexpected and unique opportunity to test this hypothesis under worst-case conditions. Due to an outbreak of West Nile Virus, the entire metropolitan area of Sacramento was sprayed from the air for three successive nights. We found PBO in urban creeks at concentrations 100-fold greater than our previous studies. These same creeks are known to contain pyrethroids from general urban use, and the PBO in the water from the mosquito control effort was in sufficient concentration to approximately double the toxicity of the pyrethroids already in the creeks. Our study had the surprising conclusion that the greatest impact of the spraying was not the insecticide itself, but the interaction of the PBO synergist with pyrethroids pre-existing in creek sediments. One paper on the PBO work is in press and a second is in review.

Interactions between pyrethroids and organochlorines

Methods - Our understanding of interactions of pesticides in mixtures is generally limited and restricts our ability to predict impacts of environmental contamination. Little if any research has been conducted examining interactions among pyrethroid insecticides or between pyrethroids and organochlorine pesticides. There is significant potential for interactions as both pesticide groups are neurotoxins with similar modes of action. The objective of this study component is to investigate, for selected species, potential interactions among pyrethroids and among pyrethroids and organochlorines, and classify these interactions as additive, synergistic or antagonistic.

Findings and status – Work has recently begun and will be completed this summer.

Urban creek sampling

Methods – Our prior work with pyrethroids has focused on agriculture-dominated water bodies. However, urban use of pyrethroids in California is approximately twice that of agricultural use. Despite this, there has been no previous monitoring for pyrethroids in urban water bodies in the U.S.

Findings and status – We had initially proposed using USGS funding to sample three sites in the San Francisco Bay area. Instead, we actually sampled six, and took samples on 2-3 occasions at each one. With matching funds we sampled Sacramento area creeks on four occasions. Briefly, this work has shown pyrethroids are widespread in urban creeks, and in fact, were detectable in

every one of our samples. The sediments in nearly all Sacramento creeks are acutely toxic to our tests organism, Hyalella azteca, due to pyrethroids. In the San Francisco Bay area pyrethroids were the primary toxicant in some creeks, but were not in sufficient concentration to explain the toxicity in most of them. One paper on this work has been published and another is in preparation. Our initial plans to look at pyrethroid tissue levels in resident macroinvertebrates in the creeks failed to materialize due to lack of sufficient biomass.

Chronic toxicity testing

Methods – Dr. Chris Ingersoll of USGS had intended to do chronic toxicity testing of our urban sediments to supplement the acute testing we had planned.

Findings and status – Dr. Ingersoll was not able to perform the chronic tests because of the demands of other projects in his laboratory.

Changes in pyrethroid bioavailability over time

Methods - USGS support will be used to measure relative changes in bioavailability and aqueous desorption rates of pyrethroids in field-collected soils as they age after the initial pesticide application. Acute toxicity tests will be used as the measure of bioavailability, while desorption rates will be determined using Tenax beads. Soil will be taken from agricultural sites at 7, 30, 120, and 270 days post-application.

Findings and status – We tracked pyrethroid bioavailability over time at three farms (pear orchard, tomato, and rice). Work is complete and data analysis is in progress.

Institutional Re-arrangements: forging smart use water policy coalitions at the intersection of geo-technical engineering with urban open space

Basic Information

Title:	Institutional Re-arrangements: forging smart use water policy coalitions at the intersection of geo-technical engineering with urban open space
Project Number:	2004CA110G
Start Date:	9/1/2004
End Date:	8/31/2006
Funding Source:	104G
Congressional District:	48
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Hydrology, Recreation
Descriptors:	None
Principal Investigators:	Helen Ingram

Publication

WRIP Annual Report
For Research Project #04QGR0155

"Institutional Re-arrangements: Forging 'Smart Use' water policy coalitions at the intersection of geo-technical engineering with urban open space"

Principal Investigator Helen Ingram, Ph.D.
University of California, Irvine

RESEARCH PROGRAM

1. Updated basic project information summary

   This project is an investigation into the political coalitions which drive the creation of new or re-engineered urban watershed recreation districts. We are considering four urban areas – Denver, Colorado; Los Angeles, California; San Jose, California; and Tempe/Phoenix, Arizona – and looking specifically at the revitalization and restoration of their rivers, the South Platte, Los Angeles, Guadalupe, and Salt Rivers, respectively. We are interested in how groups of actors come together to advocate for both environmental restoration and human recreation projects in these large-scale river renewal projects.

   The research project involves interviews with coalition members in each of the four cities. In addition, we have acquired and analyzed project documents and correspondence between the various actors and groups involved, as well as media accounts and organizational literature.

2. Problem and Research Objectives, Methodology and Principal Findings, Significance

   The problem is a classic implementation gap between the best available hydrology and ecology recommendations for watershed protection, and the urban political and development culture of major American cities. We are interested in how this gap is bridged, i.e. how coalitions of actors come together to create urban spaces that meet both environmental and social goals.

   Our research objectives are to provide a better understanding of where innovations in urban water management might gain a foothold in local political arenas; to document the key institutional mechanisms for incorporating environmental objectives into ambitious riverfront renewal schemes; and to clarify the processes of policy learning and institutional change that enable ecological imperatives and citizen values to affect the outcome of local government projects.

We use a qualitative research methodology, relying heavily on ethnographic field interviews with agency officials, non-profit activists, politicians, and community leaders in each city. Each interview followed a standard format of open-ended questions, and was tape recorded and transcribed for analysis. We supplement this data with media surveys for each site, as well as the collection of agency and organizational policy documents, membership correspondence, notices, meeting minutes, and other project-related text records. In addition, we have attended public forums and task force meetings related to river revitalization efforts, as participant observers. These field notes have also been recorded, transcribed, and included in the analysis.

This data enables findings that remain as true as possible to the actual political climate where innovations in geo-technical engineering, urban hydrology, and environmental restoration technologies must be accepted and implemented. We strive to represent and understand the *real* (the organizational challenges of local administrative patterns), in order to guide and enable the *possible* (the utilization of far-sighted hydrological modeling and ecological restoration technologies).

3. We are in final stages of data analysis and expect to be able to publish some of our preliminary findings within the next six months. There have not yet been any publications associated with this research project.

   We contend that the significance of this research continues to be very great. The benefits of this type of study to the field of urban water resources planning were highlighted by the devastation wrought by Hurricanes Katrina and Rita in September 2005. Past practices of the U.S. Army Corps of Engineers – which the urban park coalitions are engaged in transforming, in each city being studied – are now more topical and highly scrutinized than ever. We are confident that this study offers a new and highly relevant perspective on how urban watersheds can be better managed and protected, for the benefit of the local region's hydrology, ecology and economy, but especially for the benefit and protection of a city's many residents.

INFORMATION TRANSFER PROGRAM

1. Information transfer activities at this point have been limited to conference presentations based on this research.

   The first, made at the national academic planning conference, the Association of Collegiate Schools of Planning, October 27-31, 2005, in Kansas City, Missouri, was entitled, "Social Ecology Hybrid: Urban Watershed Park Coalitions."

   The second, made at the fifteenth annual Greening Conference (an association of Southern California colleges and universities), January 28, 2006, in Los Angeles,

California, was entitled, “Coalitions, Cooperation, and Institutional Change: the Urban Watershed Park.”

The support of the National Institutes for Water Resources, the United States Geological Survey, and the University of California Center for Water Resources at UC Riverside was acknowledged at both conferences.

2. As stated above, we expect to be able to publish some of our preliminary findings within the next six months.

Do Constructed Flow-Through Wetlands Improve Water Quality in the San Joaquin River?

Basic Information

Title:	Do Constructed Flow-Through Wetlands Improve Water Quality in the San Joaquin River?
Project Number:	2005CA123B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Wetlands, None, None
Descriptors:	None
Principal Investigators:	Anthony T. O-Geen

Publication

1. OGeen, A.T., J.J. Maynard, and R.A. Dahlgren, In press. Efficacy of Constructed Wetlands to Mitigate Non-point Source Pollution in the San Joaquin Valley, California, USA. Water Science and Technology.
2. Maynard, J.J., A.T. OGeen and R.A. Dahlgren, 2005. Using Constructed Wetlands to Remove Water Quality Contaminants in Agricultural Return Flows. California Plant and Soil Science Conference, Modesto CA.
3. Maynard, J.J., A.T. OGeen and R.A. Dahlgren, 2004. Monitoring Carbon and Nutrient Dynamics of Constructed Wetlands in the San Joaquin Valley, California. In Annual Abstracts. Soil Science Soc. Am., Seattle WA.
4. OGeen, A.T., J.J. Maynard, and R.A. Dahlgren, 2004. Monitoring the Ability of Constructed Wetlands to Mitigate Non-Point Source Pollution in the Central Valley. 3rd Biennial CALFED Bay-Delta Program Since Conference Abstracts, Sacramento, CA
5. OGeen, A.T., E. Van Nieuwenhuyse and R.A. Dahlgren, 2005 Strategies for Attenuating Hypoxia in the Lower San Joaquin River, California World Water & Environmental Resources Congress. Anchorage, AK
6. Maynard, J.J., A.T. OGeen and R.A. Dahlgren, 2005. Spatial Investigation of Bio-Available Phosphorus in Submerged Wetland Soils, Western Society of Soil Science Ashland, OR

7. Brauer, N., Maynard, J.J., A.T. OGeen and R.A. Dahlgren, 2005, Mineralogical Characterization of Seasonally Submerged Wetland Soils Western Society of Soil Science Ashland, OR.
8. OGeen, A.T., J.J. Maynard, and R.A. Dahlgren, 2005. Efficacy of Constructed Wetlands to Mitigate Non-point Source Pollution in the San Joaquin Valley, California, USA. Diffuse Pollution Specialist Conference. Johannesburg, South Africa.

Title: Do Constructed Flow-Through Wetlands Improve Water Quality in the San Joaquin River?

Principal Investigator: Anthony T. O'Geen
Dept. of Land, Air & Water Resources, UC Davis
Email: atogeen@ucdavis.edu
Phone: 530-752-2155
Fax: 530-752-1552

RESEARCH PROGRAM:

1. Project information summary.

The primary goal of this study is to evaluate the efficacy of using constructed wetlands (CW) to sequester organic carbon. Two CWs were monitored during the 2004 and 2005 irrigation season (April-Sept.), a recently constructed CW (now 2yrs old) (W-1) and 12-year-old CW (W-2). The initial stage of this project encompassed baseline sampling of seasonally submerged soils and identification of appropriate strategies for water quality and flow monitoring. Soil samples were analyzed for C, N, P and particle size. In 2005, we retrofitted all input and output locations with flow meters and now have the capability to monitor variation in flow and calculate loads of carbon and nutrients that enter and exit these systems. Input/output waters from the CW were collected on a weekly basis and analyzed for the following constituents: total nitrogen (TN), total phosphorus (TP), dissolved organic carbon (DOC), particulate organic carbon (POC), total suspended solids (TSS), volatile suspended solids (VSS), and chlorophyll-a (a measure of algal biomass). In 2005, we supplemented this sampling strategy with high resolution monitoring using autosamplers to better understand temporal variability in input/output waters. Carbon, nutrient and sediment retention efficiency was evaluated from input/output concentration data. After comparing the initial soil sampling with sediment from the collection plates it was discovered that CWs have a great potential to store carbon. After receiving tail water in 2004, the average soil organic carbon content of seasonally submerged soils increased from 10.9 g kg^{-1} to 50.2 g kg^{-1} at W-1 and from 12.2 g kg^{-1} to 125.2 g kg^{-1} at W-2. This information will be incorporated into a GIS along with volumetric sedimentation rates to calculate a more accurate carbon accumulation rates within each CW on an aerial basis. First year results (2004) indicate that W-2 was more efficient at removing POC and contaminants. Average POC retention, indicated by VSS, was 75% in W-2 and 66% in W-1. Chlorophyll-a (a bio-indicator of algae) tended to be higher at W-1 compared to W-2, especially in the inputs. Initially, output concentration of chlorophyll-a increased 15 fold in W-2, however over time, as emergent vegetation established, chlorophyll-a decreased to 35% of input levels. While W-1 was generally a sink for DOC, W-2 was often a source of DOC possibly due to leaching of DOC from vegetation and litter. Average TN removal efficiency was 44% for W-2 compared to 15.5% in W-1. After an initial release of P due to establishment of reducing conditions in the wetland sediments, average P removal efficiency was 71% at W-2 compared to 19% at W-1. CWs were most effective at removing TSS with average removal efficiency of 84 and 97% for W-1 and W-2, respectively. These trends were slightly different in 2005, although much of the data still needs to be processed. For example, W-2 became a source of chlorophyll-a in 2005, while W-1 showed no differences between input and output. W-2 was a source of DOC roughly 50% of the irrigation season and W-1 was a sink for DOC over 70% of the season. CWs are clearly effective at capturing sediment and nutrients removed from irrigated farmland. Our results demonstrate that CWs act as sinks for POC, but the mechanisms that control algae production and DOC export still need to be understood.

2. Problem and Research Objectives, Methodology and Principal Findings and Significance for your project.

Objectives

The primary objective of this study is to understand the evolution of carbon, sediment, and nutrient flow within a spatial and temporal context using a chronosequence of seasonally submerged soils of constructed, flow-through wetlands in the San Joaquin Valley. This will allow us to evaluate the potential of constructed wetlands (CW) for sequestering organic carbon in California irrigated agriculture.

Specific objectives are to:

1. Examine the spatial relationships between seasonally submerged soil properties, hydraulic flowpath, water quality, macrophyte, phytoplankton, periphyton NPP, and soil organic matter pools.
2. Examine source and input/output budgets for particulate organic carbon, dissolved organic carbon, biological oxygen demand (BOD), major nutrients (TN, TP, soluble-reactive PO_4, NH_4, NO_3, dissolved Si), chlorophyll-a, and total suspended solids (TSS) in inflow/outflow waters.

Methodology

The two CWs were monitored during the 2004 and 2005 irrigation seasons (April-Sept.), a 2-year-old CW (W-1) and 12-year-old CW (W-2). We also identified, instrumented and surveyed a third wetland (W-3) of identical design and age to W-2, however a breach in the system rendered it un-usable during the 2005 season. For all sites, soil, biomass and sedimentation samples were collected and analyzed for particle size, C, N and P and used to develop nutrient and carbon budgets. CW soils were sampled after the wetland was constructed and before it received water for W-1 and at the onset of the project for W-2. Next, sediment plates (over 50 per site) were placed throughout the CW in order to collect sediment each irrigation season and determine sedimentation rates and compare properties of each year's sediment with that of the original soil properties.

We monitored input/output waters collecting samples on a weekly basis in 2004 and 2005. Water samples were analyzed for several constituents, including total nitrogen (TN), total phosphorus (TP), dissolved organic carbon (DOC), particulate organic carbon (POC), total suspended solids (TSS), volatile suspended solids (VSS), and chlorophyll-a (a measure of algal biomass). This season (2005) we attempted to identify the sampling approach that best approximates the actual variability in constituents, which is governed by concentration and flow. Autosamplers were set up at sampling locations to collect samples testing a variety of sampling approaches, every 2-hrs for a day and 6-hrs over a week. Over 1500 water samples were analyzed for the 2005 irrigation season.

A great deal of time and effort was devoted to the design and testing of a flow monitoring system for input/output waters this season. The system was tested in 2004 and is now fully operational at each CW. Area flow velocity meters were installed at input locations and weirs with pressure transducers were installed at output locations. Input/output flow volumes will allow us to develop reliable input/output budgets for all water quality constituents.

We also installed over 50 redox probes at each site. Probes were placed at 2.5, 5.0 and 10 cm in order to identify the thickness of the oxidative layer. These data will also allow us to determine if methanogenesis occurs through the course of the season. These data have not been processed to date.

Sediment plates were harvested in the spring of 2005 representing sediment accumulation over the 2004 irrigation season. We have just begun to harvest the sediment plates for the 2005 irrigation season. Soil properties from the sediment plates such as total sediment, mineralogy, SOC, N, phosphorus fractions and P sorption index were measured for W-2 and we are in the process of completing this for W-1. These data are being used with GIS and geostatistical software to develop spatial relationships within and between CW soil properties.

Principal Findings

The CW soils are particularly efficient at trapping sediment and phosphorus and sequestering SOC. A great deal of characterization data have been summarized for W-2. Soils (collected in 2004 before wet-up) and sediment plate material collected after the 2004 irrigation season were used for determination of net sedimentation rate, poorly crystalline and crystalline iron oxides, SOC, total N and P sorption index. Output and input locations were retrofitted with flow measurement sensors in 2005. Auto- samplers allowed us to experiment with various monitoring frequencies. Over 1500 water samples were collected.

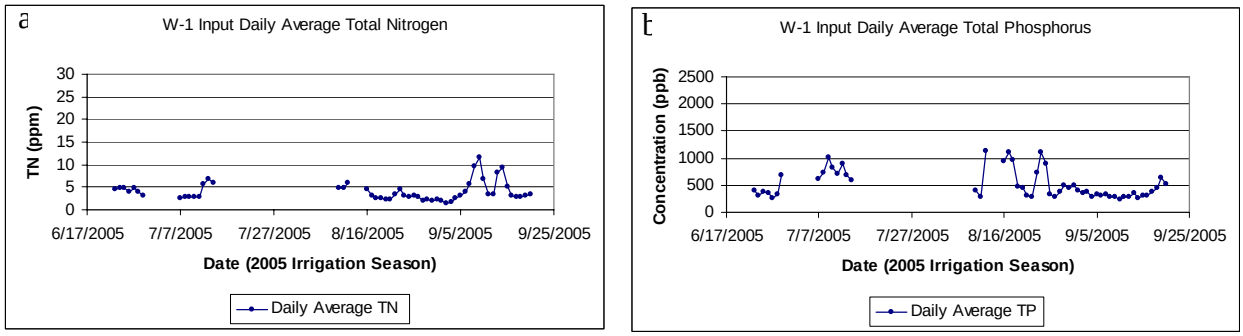

Figure 1. Variation in total nitrogen (a) and total phosphorus (b) at input locations in W-1 determined by high resolution sampling.

Daily averaged concentration of total N and P at W-1 were calculated to understand the variability of input water quality entering the wetlands. These data indicate that a relatively constant total N concentration enters the CW throughout the irrigation season, with a few sharp increases in September (Fig. 1a). Sharp changes in total P occurred throughout the season (Fig 1b).

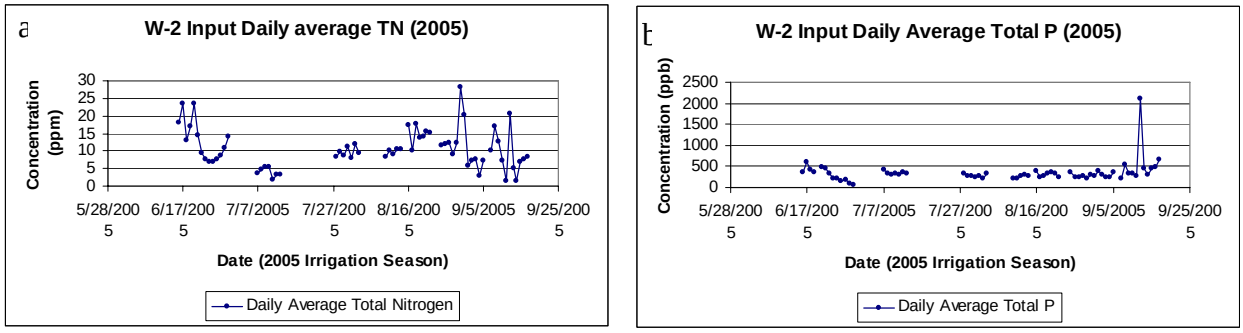

Figure 2. Variation in total nitrogen (a) and total phosphorus (b) at input locations in W-2 determined by high resolution sampling.

Daily averaged input concentration of total N was higher and more variable for W-2 compared to W-1 (Fig 1a and 2a). This is likely due to the fact that more acres of irrigated land with diverse crops drain into W-2 vs W-1. In contrast, the input concentrations of total P tended to be lower and more constant in W-2 (Figures (1b & 2b).

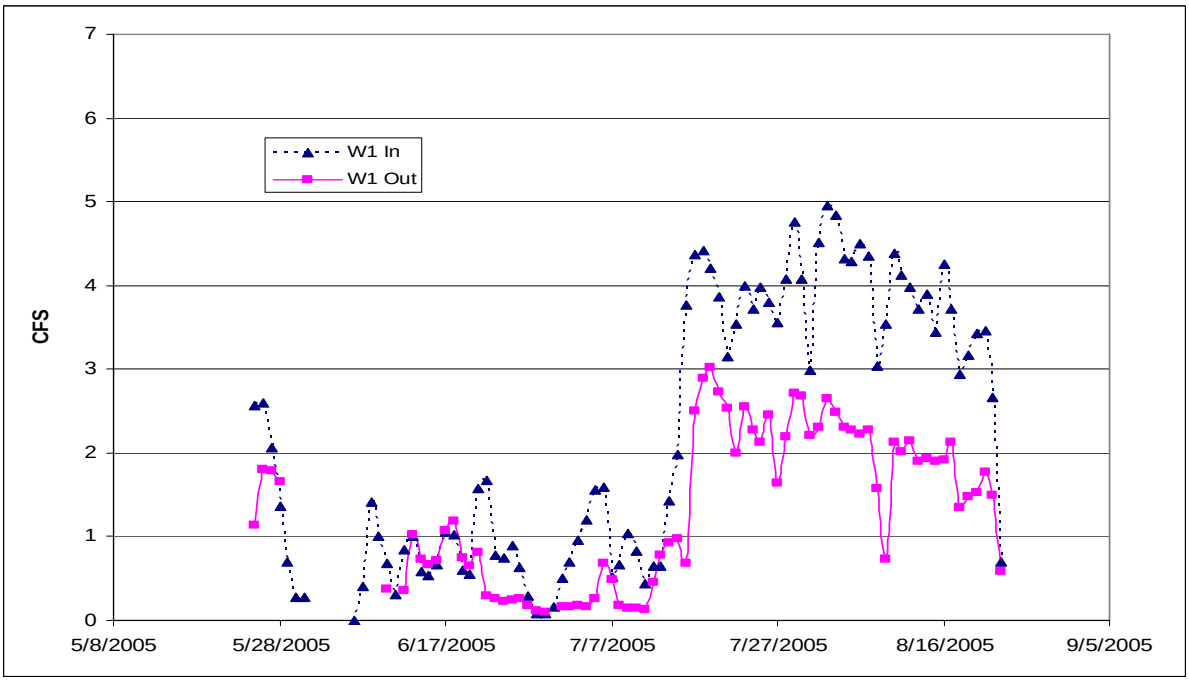

Figure 3. Input and output hydrograph for W-1.

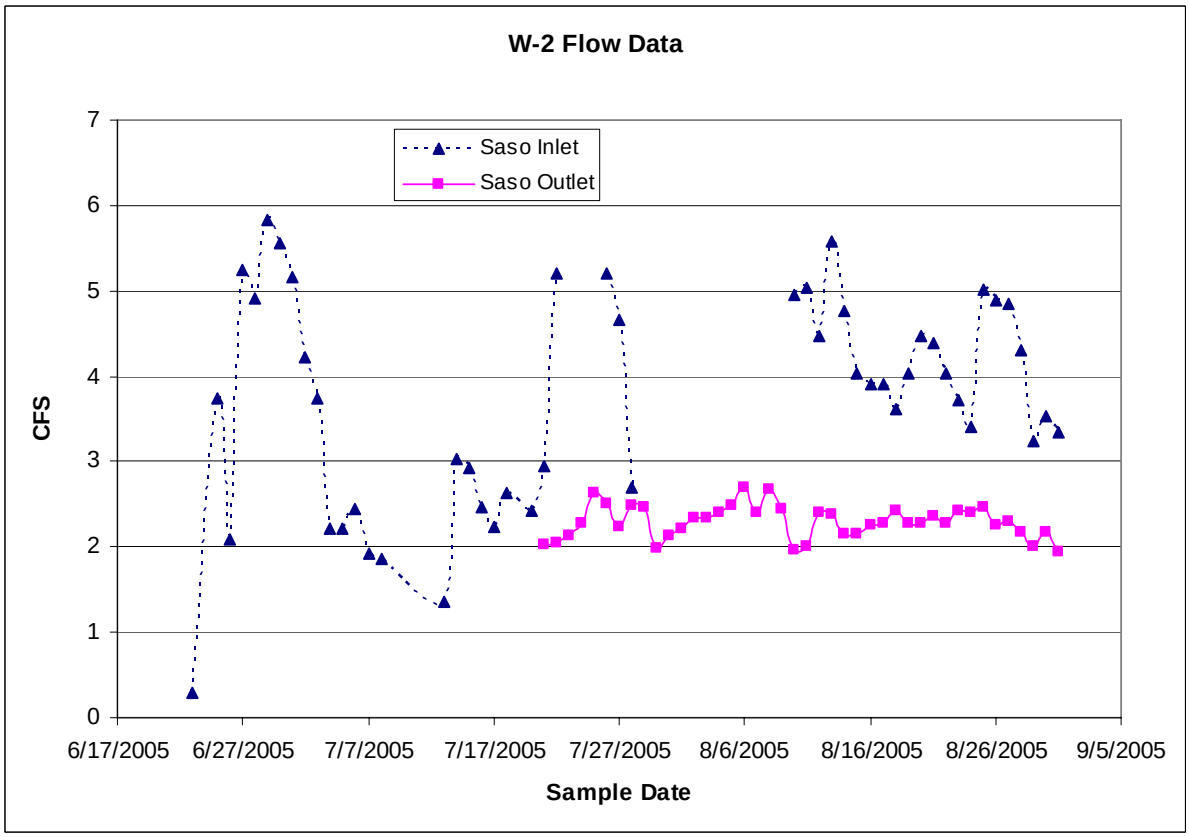

Figure 4. Input and output hydrograph for W-2.

Flow data at input and output locations for W-1 and W-2 provides a perspective on the variability of tailwater entering the CWs. It also was used to calculate constituent loads entering and leaving the wetland. Load is calculated by multiplying the concentration of a constituent at a given time interval by the corresponding flow rate. In general, flow rates ranged from 1 to 6 cfs but varied significantly throughout the irrigation season (Figs

3 & 4). Information on flow and hydraulic residence time will be used in the future to identify the best flow regimes that maximize residence time, hence contaminant removal, but also minimize algal growth.

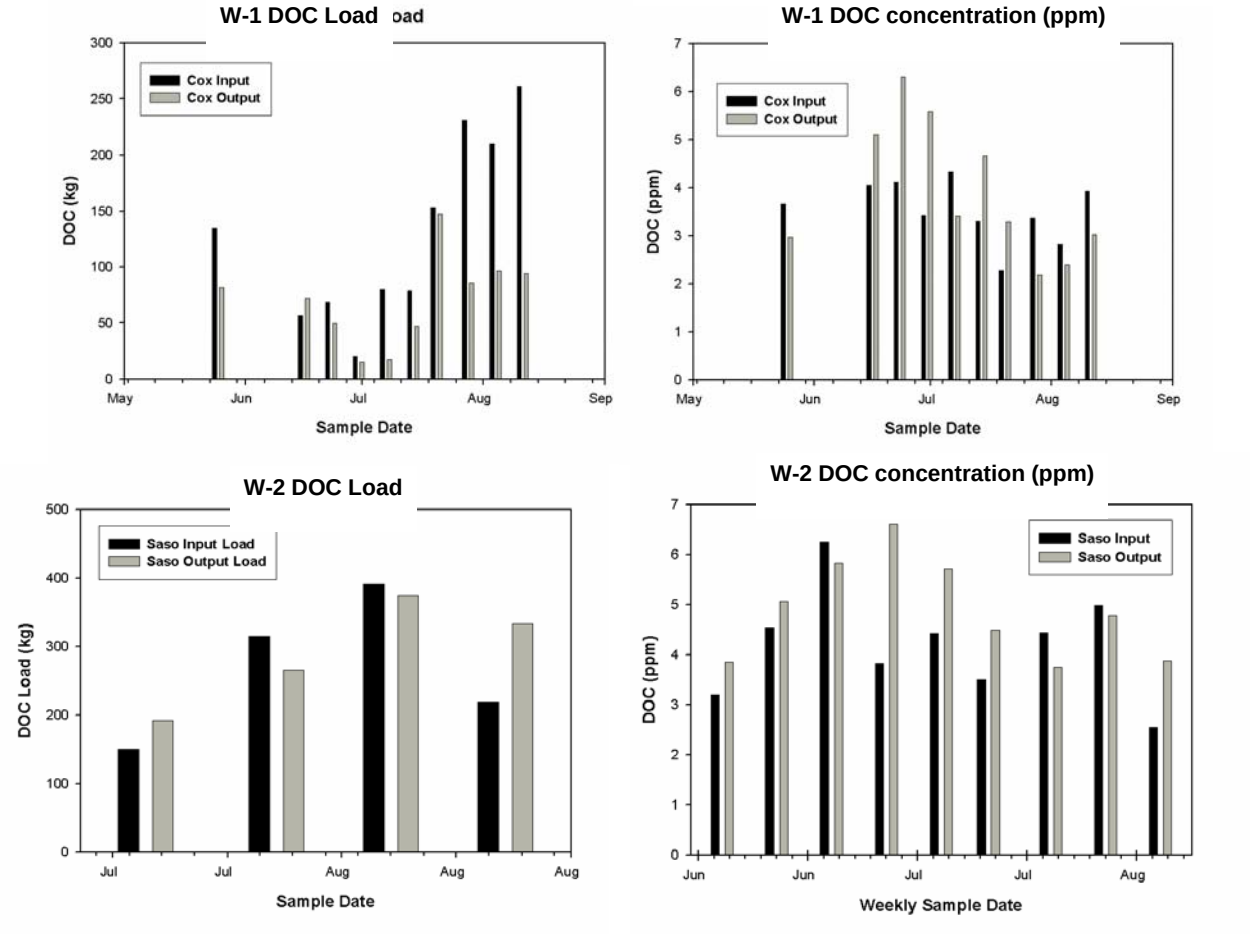

Figure 5. Comparison of dissolved organic carbon loads and concentration at W-1 andW-2.

The trends in DOC concentration at W-1 and W-2 indicate that CWs are a source of DOC approximately 50% of the time. In contrast, at W-1, DOC loads indicate that the CW was a sink for DOC 70% of the time. At W-2, input and output loads appear to be equal most of the time with the exception of August when it was a source of DOC (Fig. 5).

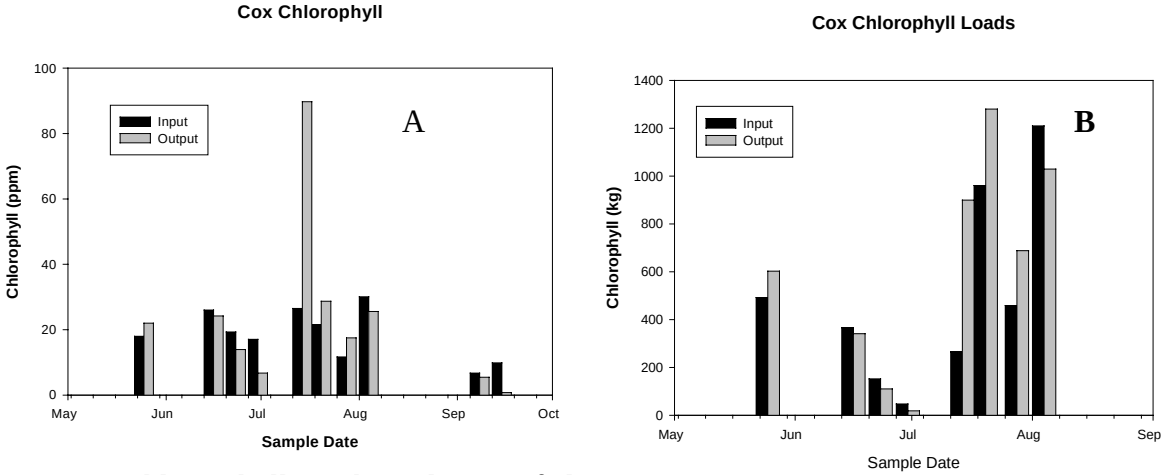

Figure 6. Chlororphyll-a (a bioindicator of algal growth) concentration (A) and load (B) at CW -1 in 2005.

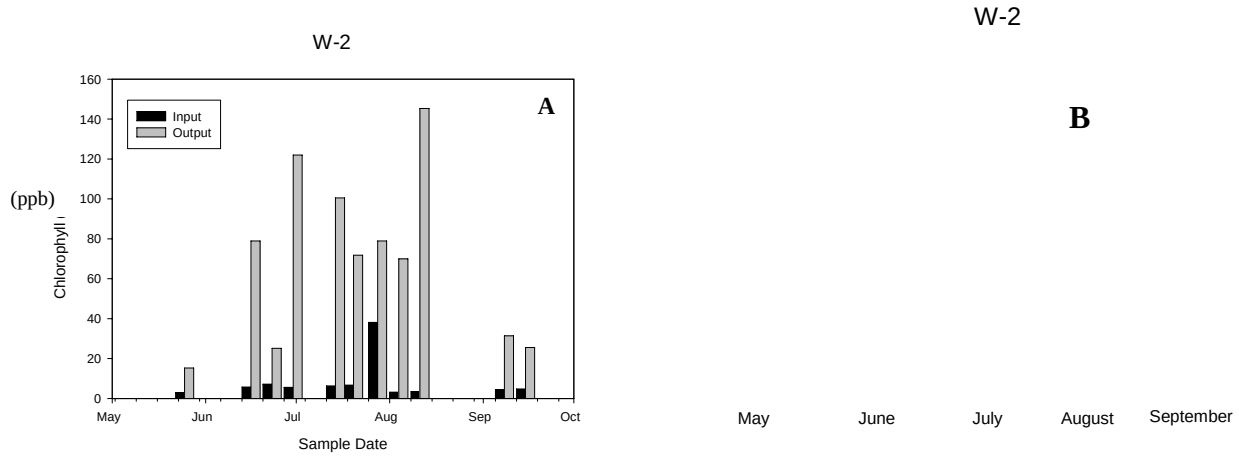

Figure 7. Chlorophyll-a (a bioindicator of algal growth) concentration (A) and load (B) at CW -2 in 2005.

CW-1 was neither a source nor a sink for chlorophyll-a when looking at concentrations or weekly loads (6 A & B). In contrast, at CW-2 both concentration and loads of chlorophyll-a indicate that it was a source of algae (Fig 7 A & B). These results were much different than the 2004 season, which indicated that input and outputs were roughly equal.

The effects of CW design (volume, shape and configuration of input/outputs) on hydrologic flow path and residence time may play an important role in carbon and nutrient capture. SOC levels were greatest near the output and along the inlet-flowpath just beyond the active depositional area because these areas were less affected by deposition. C:N ratios in the 0-5 cm soil depth across the W-2 appear to be systematic and may indicate differences in source of SOC such as topsoil settling at the input, POC settling along the flowpath or detritus accumulating from decomposing plant litter.

These systems appear to sequester carbon rapidly on an annual basis, however, dry periods in early spring may result in oxidation of existing organic matter. Future work will attempt to document the amount of carbon lost during these dry periods.

The presence of carbon and hydraulic residence time appears to play a major role in nutrient capture in CWs. Removal of N from the water column occurs through denitrification and plant uptake. P removal from the water column occurs through plant uptake and sorption to mineral particles. Organic carbon content appears to play a role in the mineralogy of the submerged soils hence the P retention capacity. Removal of sediment and POC from the water column occurs through deposition.

In 2004, it was found that W-2 was more efficient at trapping carbon and nutrients because it is older and larger with a greater hydraulic residence time. W-2 also had a more established plant canopy, which can water residence time by decreasing water velocity (Braskerud, 2002). Thus, conditions that optimize the degree of denitrification, plant nutrient uptake, sorption and sedimentation are more prevalent in W-2 compared to W-1. In 2005 this vegetative canopy did not emerge possibly because flood waters remained throughout the winter and spring, hence seeds did not germinate. The absence of a plant canopy in W-2 appears to result in greater export of algae over the 2005 season compared to W-1. Furthermore, the aging affect of W-1 appears to improve its ability to filter materials from tailwater. This hypothesis will be explored further explored once the complete data set is processed.

Results for DOC loads suggest that the mineral dominated CW systems in the Central Valley are a not significant source of DOC (Fig. 5). At W-1, DOC loads indicate that the CW was a sink for DOC 70% of the time. At W-2, input and output loads appear to be equal most of the time with the exception of August when it was a sink for DOC (Fig. 5).

The conversion of flood plain agroecosystems to flow-through wetlands is becoming a popular land-use practice nation wide, yet little information exists to document how these systems function in California. This project directly addresses the needs of the Kearney mission. Information gained from this research and monitoring program will allow us to identify factors that may improve the functionality of CWs as carbon sinks and water purifiers. This information will also provide a basis to recommend a monitoring protocol that will allow farmers to meet the agricultural waivers monitoring requirements in a scientifically sound and cost-effective manner. There is evidence that carbon contained in CW soils may play an important role in the ability of these soils to remove P and N. This will be investigated further in 2006 along with a detailed carbon budget for the soils and sediment. Constructed wetlands have the potential to be excellent organic carbon and contaminant sinks and represent the last opportunity for treatment before tailwaters are re-circulated back to the SJR.

Estuarine Landscape Modeling of Suisun Bay

Basic Information

Title:	Estuarine Landscape Modeling of Suisun Bay
Project Number:	2005CA124B
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Principal Investigators:	David H. Schoellhamer, Bassam Younis

Publication

1. Ganju, N.K., and D.H. Schoellhamer, in press, Annual sediment flux estimates in a tidal strait using surrogate measurements, Estuarine, Coastal and Shelf Science.
2. McKee, L., N.K. Ganju, and D.H. Schoellhamer, 2006, Estimates of suspended sediment entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California, Journal of Hydrology, 323, p. 335-352.
3. Ganju, N.K., and D.H. Schoellhamer, Lateral displacement of the estuarine turbidity maximum in a tidal strait: submitted for Proceedings of the INTERCOH2005 conference, Saga, Japan.
4. Schoellhamer, D.H., N.K. Ganju, P.R. Mineart, and M.A. Lionberger, Sensitivity and spin up times of cohesive sediment transport models used to simulate bathymetric change: submitted for Proceedings of the INTERCOH2005 conference, Saga, Japan.

Introduction and Problem Statement

California's delicate balance between water supply and ecosystem preservation is under increasing pressure from a growing population and habitat loss. The locus of many of these issues is San Francisco Bay, where freshwater from the Sacramento/San Joaquin Delta meets saline water from the Pacific Ocean. Suisun Bay is the furthest landward subembayment of San Francisco Bay, and is therefore most responsive to freshwater flow. Water withdrawals from the Delta adversely impact the estuarine ecosystem and habitats. Increasing the quality of habitat in Suisun Bay, however, would decrease the ecosystem stress caused by freshwater flow diversions. Current goals of ecosystem restoration include the creation and maintenance of beneficial wetlands and shallow-water habitat (Goals Project 1999).

Geomorphic evolution of estuarine habitats and landscapes over decadal timescales (>10 years) is sensitive to sediment supply from the watershed as well as estuarine hydrodynamics. Sediment supply to the Bay is an ongoing issue, beginning with the drastic input of sediment during the hydraulic mining period of the late 19th century (Gilbert 1917). Today sediment supply is declining due to reduction of the hydraulic mining sediment pulse, reservoir storage, and land use practices (Wright and Schoellhamer in press). Future climate change, land use practices, and sea level rise are some of the many factors that may alter sediment supply and threaten ecologically beneficial estuarine habitats (Scavia et al. 2002, Pont et al. 2002). Hydrodynamics are directly modulated by the varying morphology of the Bay (and vice-versa), so there is a feedback between hydrodynamics and geomorphology.

Objectives

The specific objectives of the research were as follows:

1. Develop a tidal timescale hydrodynamic/sediment transport model of Suisun Bay based on existing public-domain software.
2. Implement idealized boundary conditions for the seaward boundary of the domain, due to the lack historical data for hindcasting simulations.
3. Calibrate and validate the complete model with reference to sediment flux data at the landward and seaward boundaries of Suisun Bay from 1997-1998 and 2002-2004 (McKee et al. 2006; Ganju and Schoellhamer in press).
4. Evaluate the accuracy of a time-stepping procedure which simulates hydrologic seasons as two-week periods, and extrapolates the results for the entire water year.
5. Apply the idealized boundary conditions and time-stepping procedure for hindcasting simulations based on the historical geomorphic data from Cappiella et al. (1999).

Methods

Site description

Our study area is Suisun Bay, the most landward subembayment of northern San Francisco Bay. The Sacramento and San Joaquin Rivers deliver freshwater to Suisun Bay, primarily during the winter rainy season and during the spring snowmelt and reservoir releases. Precipitation is negligible during late spring and summer. Suisun Bay is a partially mixed estuary that has extensive areas of shallow water that are less than 2 m deep at mean lower-low water. Shallow estuarine environments such as Suisun Bay are ecologically significant because a large fraction of the biota depends on these areas for shelter and nourishment (Cloern et al. 1985, Caffrey et al. 1998). Wetlands, which usually form on shallow fringes of the Bay, provide habitat for species and communities not found elsewhere within the Bay (Goals Project 1999). Channels in Suisun Bay are about 9-11 m deep. Carquinez Strait is a narrow channel about 18 m deep that connects Suisun Bay to San Pablo Bay, to the rest of San Francisco Bay, and to the Pacific Ocean. Tides are mixed diurnal and semidiurnal and the tidal range varies from about 0.6 m during the weakest neap tides to 1.8 m during the strongest spring tides. Freshwater inflow typically first encounters saltwater in the lower rivers, Suisun Bay, and Carquinez Strait. The salinity range in this area is about 0-25 and depends on freshwater inflow.

Suspended and bed sediment in Suisun Bay is predominately fine and cohesive, except for sandy bed sediment in some of the deeper channels (Conomos and Peterson 1977). The typical suspended-sediment concentration (SSC) range in northern San Francisco Bay is about 10-300 mg/L and sometimes up to about 1,000 mg/L in an estuarine turbidity maximum (ETM). In Suisun Bay, ETMs are located near sills and sometimes near a salinity of 2, depending on tidal phase and the spring/neap tidal cycle (Schoellhamer and Burau 1998, Schoellhamer 2001a). Accumulations of suspended sediment, nutrients, phytoplankton, zooplankton, larvae, and juvenile fish are found in ETMs (Peterson and others 1975, Arthur and Ball 1979, Kimmerer 1992, Jassby and Powell 1994, Schoellhamer and Burau 1998). The location of a bottom salinity of 2 is used as a habitat indicator to regulate freshwater flow to the Bay because it is believed to be an easily measured indicator of the location of the ETM and a salinity preferred by many estuarine species (Jassby et al., 1995).

An annual cycle of sediment delivery and redistribution begins with large influx of sediment during winter (delivery), primarily from the Central Valley (Goodwin and Denton 1991, McKee et al. 2006). Much of this new sediment deposits in San Pablo and Suisun Bays. Stronger westerly winds during spring and summer cause wind-wave resuspension of bottom sediment in these shallow waters and increase SSC (Ruhl and Schoellhamer 2004). The ability of wind to increase SSC is greatest early in the spring, when unconsolidated fine sediments easily can be resuspended. As the fine sediments are winnowed from the bed, however, the remaining sediments become progressively coarser and less erodible (Conomos and Peterson 1977; Krone 1979; Nichols and Thompson 1985; Ruhl and Schoellhamer 2004). Thus, tides and wind redistribute the annual pulse of new sediment throughout the Bay. Since 1850, alterations in the watershed and estuary have changed the bathymetry of Suisun Bay (Cappiella et al. 1999).

Model development

The Regional Oceanic Modeling System (Shchepetkin and McWilliams, 2005) is a public-domain hydrodynamic model with an optional sediment transport module. There are several advantages that ROMS has over other available models: 1) it is free, public-domain software (which is tens of thousands dollars cheaper than most models); 2) it is improved and expanded amongst hundreds of researchers continuously; and 3) it is part of a community-based sediment transport initiative within the U.S. Geological Survey.

ROMS is a split-mode model: the barotropic, depth-integrated equations are solved on a shorter (fast) time step (due to barotropic propagation speed) while the baroclinic terms are solved at a longer (slow) time step. The grid features of ROMS are: an Arakawa “C” grid (Fig. 5), orthogonal curvilinear horizontal coordinates (Fig. 6), and stretched, terrain-following vertical coordinate. Boundary conditions for momentum/tracers on the four edges of the grid can be clamped (fixed), gradient (zero-derivative), radiation (allow disturbances to propagate away), or wall (zero-flux). In all cases, ROMS has adaptive capabilities, in order to switch from active conditions for inward fluxes and passive conditions for outward fluxes. Discretization options for momentum/tracers range from the 2nd order to 4th order (in space). With regards to turbulence, at least four common two-equation closures (k-epsilon, k-kl, k-omega, and gen) can be specified with the generic length scale implementation provided in the model. Sediment transport in the form of both suspended and bed load (Meyer-Peter Muller version) has been implemented in the latest version of ROMS. Further details of the model can be found at http://marine.rutgers.edu/po/index.php?model=roms.

Idealization of landward boundary conditions: flow, salt, sediment

Net freshwater flow into Suisun Bay is a combination of flows through the Sacramento River, San Joaquin River, the ephemeral Yolo Bypass, minor tributaries, and exports by the federal and state water projects. Because these separate inputs and outputs are not explicitly modeled, the net flow is the parameter of interest. The DAYFLOW program (California Department of Water Resources) balances these inputs and outputs, to yield a daily value of flow past Mallard Island. This value is imposed at the landward boundary of the domain. Conceptually, this ignores the within-Delta transfer of water (and therefore sediment). However, the model will be calibrated to fluxes at the Mallard Island cross-section, so actual sediment retention within the Delta system will be accurately represented (though possible sediment exports by the water projects will be ignored). Salinity at the landward boundary is specified as zero. Periods prior to 1929 require construction of

daily hydrographs from monthly and yearly data, as daily data were not available. This method is discussed below.

Daily sediment loads past Freeport on the Sacramento River and Vernalis on the San Joaquin River were obtained from the U.S. Geological Survey. For modeling purposes, the suspended-sediment concentration is specified as a boundary condition, therefore the loads are divided by the DAYFLOW value to yield the appropriate landward boundary SSC. All boundary conditions are spread equally across the cells on the landward boundary, both vertically and laterally.

Idealization of seaward boundary conditions: tides, velocities, salt, sediment

Because the final geomorphic model will be used for simulations spanning the 19th and 20th centuries (when detailed data at the seaward boundary were not always available), idealizations are necessary in terms of tidal height, velocity, salinity, and SSC. Tidal harmonics provide an appropriate initial estimate of historic tidal elevations and velocities. A tidal harmonic predictor was developed from current meter deployments in San Francisco Bay (J. Gartner, writ.. comm.). The predictor provides tidal elevations and velocities at the west end of Carquinez Strait, which is the seaward boundary of the modeled domain. While these values are imposed on the seaward boundary of the model, the actual boundary condition is not strictly clamped, and allows the tidal elevation and velocities to adjust to net outflow (from freshwater flow). Nonetheless, meteorological forcings such as wind and barometric pressure are not represented in the tidal record. The tidal elevation and depth-averaged velocity are applied uniformly in a lateral sense at the seaward boundary, while the 3D velocity field is solved with a gradient condition.

For salinity, the method of Warner et al. (2005) can be used, which utilizes a deterministic function based on near-bottom longitudinal salinity profiles. Data from 358 longitudinal cruises between 1969-2005 of the R/V Polaris were processed to determine this relationship. Within the model code, the salinity gradient is calculated as a function of freshwater flow. This salinity gradient is applied on flood tides, at the first interior point of the domain, to calculate the flood tide salinity. This function was shown to work adequately in prior simulations (Ganju and Schoellhamer, 2005).

Sediment boundary conditions are substantially more difficult, as SSC at the seaward boundary responds to freshwater flow, tidal energy, wind-wave resuspension in San Pablo Bay. Schoellhamer (2001b) constructed synthetic SSC time-series as a means of testing spectral analysis routines; these time-series combined fluctuations in SSC due to seasonal variability of winds, spring-neap tidal energy, and tidal advection. Because flood-tide SSC is the parameter of interest, the measured flood-tide SSC at Carquinez Bridge was averaged on a daily basis. The pattern for water years 2002, 2003, and 2004 showed a similar pattern: a seasonal pattern related to wind-wave resuspension was superimposed on a spring-neap pattern that had greatest variability during high freshwater-flow periods and the least variability at the beginning and end of the water year (when sediment input is at a minimum). Therefore two signals were superimposed to recreate a synthetic time-series of SSC: a seasonal wind-wave signal that peaks in the summer, and a spring-neap signal that is a function of tidal energy (obtained from tidal harmonics). The time-series is then modulated by mean yearly SSC and a random fluctuation that is 10% of the SSC value. The mean yearly SSC at sites Car and PSP is linearly related to total sediment input from the watershed during the water year. This relationship suggests that despite significant tidal and atmospheric forcing, the net sediment input does affect baseline and average SSC throughout the Bay.

Calibration to 2002-2004 fluxes

Calibration of the seaward suspended-sediment concentration boundary condition, sediment properties (i.e. bed shear strength, settling velocity, erosion rate), and Delta configuration will be accomplished by simulating hydrodynamics and sediment transport during water years 2002-2004. Landward boundary conditions and the remaining seaward boundary conditions are specified as outlined above. Calibration goals will consist of simulating the correct net flux between Suisun Bay and the Delta (Mallard Island cross-section), and the correct net flux between Suisun Bay and Carquinez Strait (Benicia Bridge cross-section) within the error bounds of the flux measurements of McKee et al. (2006) and Ganju and Schoellhamer (in press).

Validation to 1997-1998 fluxes

Validation of the calibrated model will be accomplished using flux data from water years 1997-1998. This period contains peak freshwater flows that are 5 times greater than the 2002-2004 period, and average yearly cumulative flow is 3 times larger. Therefore we will calibrate to a relatively dry period, and the mechanics of the model will be validated during a much wetter period. This will ensure that the model is not suited to dry periods only. Again, validation will be quantified in reference to simulating the correct net flux between Suisun Bay and the Delta (Mallard Island cross-section), and the correct net flux between Suisun Bay and Carquinez Strait (Benicia Bridge cross-section) within the error bounds of the flux measurements of McKee et al. (2006) and Ganju and Schoellhamer (in press).

Formulation of time-stepping procedure

Analysis of model results suggests that fluxes over selected two-week periods can be extrapolated individually to represent seasonal dynamics accurately. This procedure was tested for all five modeled water years. Four two-week periods were selected to represent 1) fall conditions (low freshwater flow and reduced wind-waves), 2) winter conditions (high freshwater flow with episodic wind-waves), 3) spring conditions (decreasing freshwater flows and increasing wind-waves), and 4) summer conditions (low freshwater flow and steady diurnal wind-waves). The two-week period contains tidal variability due to the 14-day spring-neap cycle, which is critical for sediment transport processes. The model was then run for each two-week period, and the fluxes were extrapolated for the season by weighting the results to account for one-quarter of a year. The bed changes corresponding to the period were also extrapolated to account for one-quarter of a year. The estimated fluxes by this method compare well to the actual fluxes, while the bed change is also modeled accurately.

Principal Findings and Significance

Calibration to 2002-2004 fluxes

Model results compared well with sediment flux estimates as computed by Ganju and Schoellhamer (in press). The seasonal pattern of sediment flux was represented well, with export during high flows and import during the summer low-flow season. The net sediment import for 2002-2004 was estimated at 1.17 Mt/y by Ganju and Schoellhamer (in press), while the model results show a net export of 0.10 Mt/y.

Validation to 1997-1998 fluxes

Model results compared well with sediment flux estimates as computed by Ganju and Schoellhamer (in press). The seasonal pattern of sediment flux was again represented well, with export during high flows and import during the summer low-flow season. The net sediment export for 1997-1998 was estimated at 21.3 Mt/y by Ganju and Schoellhamer (in press), while the model results show a net export of only 1 Mt/y. This discrepancy is largely due to the large predicted export in water year 1998. The model results do not accurately represent the predicted sediment fluxes, though model improvements are being implemented to correct this flaw.

Formulation of time-stepping procedure

Four two-week periods were selected for each water year, and the flux results for those periods were extrapolated to represent the entire year. The average error for all five water years for this procedure was less than 15%. Considering the 85% reduction in computational time, this is an adequate way to increase computational efficiency.

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INFORMATION TRANSFER PROGRAM: Provide a brief description of information transfer activities supported with section 104 and required matching funds during the reporting period.

1. Provide a brief description of the information transfer activity for your project.

   Information transfer has encompassed poster presentations, oral presentations, and seminars at multiple forums. Primary goals were receiving feedback on methods and goals, while informing associated researchers of our intentions and possible opportunities for collaboration. Through these efforts, collaboration has commenced with USGS researchers spanning disciplines (climatology, hydrology, aquatic biology, remote sensing, benthic ecologists, etc.), primarily through the CALFED-funded CASCaDE project.

An Economic Analysis of Groundwater Nitrate Pollution Control in Dairy-Intensive Watersheds

Basic Information

Title:	An Economic Analysis of Groundwater Nitrate Pollution Control in Dairy-Intensive Watersheds
Project Number:	2005CA126B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	44
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Groundwater, Nitrate Contamination
Descriptors:	None
Principal Investigators:	Kenneth A. Baerenklau

Publication

1. Baerenklau, K.A. and N. Nergis. 2006. Controlling Dairy Nitrogen Emissions: A Dynamic Analysis of Herd Adjustment, Ground Water Discharges, and Air Emissions. Submitted to American Journal of Agricultural Economics. 49 manuscript pages.

Research Program

The objective of this research program is to develop a mathematical model for assessing the costs of different groundwater nitrate pollution control alternatives in dairy-intensive watersheds, and for designing policies that achieve nitrate standards cost-effectively.

Our modeling approach builds upon previous agricultural economics literature that has recognized the importance of accounting for delayed effects of pollution control policies when assessing the economic efficiency of policy alternatives. Simply put, a longer time lag between the initiation of a source control policy and the realization of reduced damages at a receptor point tends to favor less stringent source control efforts.

In the case of dairy farms, there are three main sources of delay. First, the dynamic nature of managing a dairy herd implies a farmer's optimal response to changing operating conditions will not be instantaneous. Rather, there will be a transition from one herd profile to another. Second, dairies apply organic nitrogen which must be mineralized before it can be leached, and this process takes time. And third, nitrogen leachate must be transported from source to receptor before it causes damage.

Determining the optimal balance between source control and receptor treatment efforts requires accounting for these dynamic processes. Therefore we are modeling each process in a single mathematical framework that allows us to simulate the economic and environmental effects of different nitrate pollution control alternatives. Our model includes: farm-level decision-making, herd and crop production, waste generation and reuse, and fate and transport mechanisms.

To-date we have completed the first three components and now have a working model that predicts the time path of nitrogen emissions to both groundwater and air for a representative California dairy. Our simulations clarify the importance of dynamic elements and demonstrate three main results: (1) dairies are unresponsive to pollution charges unless they are relatively large and financially burdensome for farmers; (2) regulations aimed at controlling only nitrate leaching will cause significant increases in ammonia emissions; and (3) mitigating both nitrogen problems with emissions taxes involves substantial reductions in both herd size and farm profit.

These findings are the basis for a technical presentation to be given at the Annual Meeting of the American Agricultural Economics Association in July 2006, and for a manuscript that currently is under submission at the *American Journal of Agricultural Economics*:

Baerenklau, K.A. and N. Nergis. "Controlling Dairy Nitrogen Emissions: A Dynamic Analysis of Herd Adjustment, Ground Water Discharges, and Air Emissions." Date submitted: April 2006. 49 manuscript pages.

Information Transfer Program

As stated above, these findings are the basis for a presentation to be given at the Annual Meeting of the American Agricultural Economics Association in July 2006, and for a manuscript that has been submitted to the *American Journal of Agricultural Economics*:

Baerenklau, K.A. and N. Nergis. “Controlling Dairy Nitrogen Emissions: A Dynamic Analysis of Herd Adjustment, Ground Water Discharges, and Air Emissions.” Date submitted: April 2006. 49 manuscript pages.

Imperial Valley Agriculture and Water: A Regional Economic Analysis

Basic Information

Title:	Imperial Valley Agriculture and Water: A Regional Economic Analysis
Project Number:	2005CA127B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	44
Research Category:	Social Sciences
Focus Category:	Management and Planning, Water Quantity, None
Descriptors:	None
Principal Investigators:	Kurt Schwabe

Publication

1. Update the basic project information summary.

   It is the objective of this research to evaluate the ability of growers in the Imperial Valley to meet both impending reductions in allowable Colorado River water usage and possible restrictions on drainage effluent necessary for inflow into the Salton Sea. Also evaluated will be the impact of changes in agricultural labor and income, arising from these reductions and restrictions, on regional economic income and productivity using a regional multiplier model. To date, the crop-water production functions have been estimated for the five major crops and irrigation systems in the Imperial Valley. Additionally, drainage-water production functions for each crop-irrigation system have also been estimated. Price and cost data for each cropping system (crop type and irrigation system) have been calculated. Finally, a regional economic multiplier model has been investigated—IMPLAN- and various links between the regional agricultural production model and the regional economic multiplier model have been identified (labor and income).

2. Include Problem and Research Objectives, Methodology and Principal Findings and Significance for your project.

   The objectives of this research, we intend to evaluate issues associated with potential reductions in the quantity or quality of the drainage water entering the Salton Sea from agriculture in the Imperial Valley by building a regional agricultural production model that accurately represents regional cropping activities, irrigation choices, and water issues. The conceptual and theoretical model behind these efforts was presented by the graduate student I have working on this project as his Ph.D. proposal (of which he passed and now has advanced to candidacy). By developing a detailed regional mathematical programming model of Imperial Valley agricultural production, we can evaluate the impacts associated with alternative strategies that meet these commitments on agricultural productivity and sustainability. Furthermore, by linking this agricultural production model to a comprehensive regional model of economic activity (using what is referred to as social accounting matrix multiplier analysis, or SAM), the impacts on regional economic activity can also be explored and highlighted. Given that agriculture is the largest industry within the region, including the impacts of alternative agricultural management strategies on the region as a whole can provide a more comprehensive analysis than agricultural production models alone, and can better identify more efficient alternatives and their distributional consequences. Finally, through establishing a relationship between agricultural runoff from the Valley and inflows into the Salton Sea, the implications of these various strategies on characteristics of the Salton Sea can be explored. We are currently refining our estimation of the evapotranspiration, yield, deep percolation and runoff as functions of applied water. We have also obtained the IMPLAIN software and data on Imperial County to be used in the SAM analysis. Efforts include investigating how one might go about replacing the generic “agricultural industries” estimates in the current IMPLAN model with what will be are more accurate and useful estimates from our regional agricultural production model. Development of these models will allow us to evaluate the impacts of alternative management strategies on regional agriculture, employment, income, and the environment.

3. Provide publication citations associated with the research project.

   n.a.

4. You have the option of providing introductory text regarding your overall research program.

Under the 1922 Colorado River Compact, 7.5 million acre-feet (ac-ft) of Colorado River water was allocated to the lower basin states of Nevada (300,000 ac-ft), Arizona (2.8 million ac-ft), and California (4.4 million ac-ft). Until the mid-1990s, though, California's average use was more in the neighborhood of 5.2 million ac-ft. Increased demands for water in Nevada and Arizona resulted in California being mandated to reduce its share down to its legally designated amount. While California's appropriative water use rights indicate that Southern California urban suppliers and users could be required to bear the brunt of these reductions, attention shifted towards "enticing" the agricultural sector, mostly in the Imperial Valley, to accept responsibility. The current agreement, referred to as the Quantification Settlement Agreement and signed by representatives from local, state, and federal agencies,[1] consists of commitments associated with water conservation measures, water transfers, and groundwater banking and conjunctive use measures. The state of California was given 15 years to achieve these commitments, many of which rely upon agricultural growers in the region reducing their long-term historical average water use by nearly 30% (Western Water 2001, p. 8), and one that includes a controversial 200,000 ac-ft transfer of water from the Imperial Irrigation District to the San Diego County Water Authority.

It is the objective of this research to evaluate the ability of growers in the Imperial Valley to meet these commitments. By developing a detailed regional mathematical programming model of Imperial Valley agricultural production, we can evaluate the impacts associated with alternative strategies that meet these commitments on agricultural productivity and sustainability. Furthermore, by linking this agricultural production model to a comprehensive regional model of economic activity (using what is referred to as social accounting matrix multiplier analysis, or SAM), the impacts on regional economic activity (e.g., employment, income, profits) can also be explored and highlighted. Given that agriculture is perhaps the largest industry within the region, including the impacts of alternative agricultural management strategies on the region as a whole can provide a more comprehensive analysis than agricultural production models alone, and can better identify more efficient alternatives and their distributional consequences. Finally, through establishing a relationship between agricultural runoff from the Valley and inflows into the Salton Sea, the implications of these various management strategies on the volume, surface area, and depth of the Salton Sea can be explored. Indeed, particular constraints on required inflows into the Salton Sea can be included in the model so as to mimic conditions associated various proposed restoration plans for preserving the Salton Sea. Alternatively, the economic impacts from such restoration plan alternatives (from inflow requirements) on both agricultural productivity and regional economic activity can be evaluated.

[1] These groups include the Imperial Irrigation District (IID), the Coachella Valley Irrigation District (CVID), San Diego County Water Authority (SDCWA), the Metropolitan Water District (MWD), the U.S. Department of Interior (DOI), and the State of California.

California-2100: Assessing Future Water Resources over California

Basic Information

Title:	California-2100: Assessing Future Water Resources over California
Project Number:	2005CA129B
Start Date:	7/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, None
Descriptors:	None
Principal Investigators:	Bryan C. Weare

Publication

1. Lara M. Kueppers, Mark A. Snyder, Lisa C. Sloan, Dan Cayan Jiming Jin, Hideki Kanamaru, Masao Kanamitsu, Norman L. Miller, Mary Tyree, Hui Du, and Bryan Weare, 2006. Multi-model comparison of the climate response to land-use change in the western United States. Global and Planetary Change. Submitted.
2. Weare, Bryan C., 2005, Global climate change in the past century: Focus on California in Climate Change: Challenges And Solutions For California Agricultural Landscapes, California Energy Commission, CEC-500-2005-189-SF

Problem and Research Objectives

This project implemented the initial phase of California-2100 (Cal21), which is aimed at making and evaluating high resolution estimates of climate change over California out to the year 2100. The initial WRC component of this project has been focused on evaluating how well regional climate models reproduce the variations of important components of the water budget for California, and estimating the climatic effects of the increases over the past century in irrigation in California on regional climate.

Methodology

The utilized regional model is the widely used MM5 running at 30km grid spacing and having 45 levels (Chen and Dudhia, 2001). The outer boundaries, which are placed in the central Pacific Ocean and Midwestern United States are from the ERA-40 reanalysis (Uppala et al., 2005). Currently, we have made more than eight runs for the period 1 August, 1995- 30 September, 1996. Initial statistical comparisons of the output of these model runs have been made with the Climate Research Unit's (CRU) surface climatology (Mitchell and Jones, 2005) and other observations for the California region.

Principal Findings

Six present-day MM5 runs with slightly different parameterizations of rainfall and the planetary boundary layer have been run. In general these simulate well the observed patterns of variation of precipitation and surface temperature. However, the surface temperatures are approximately two degrees Centigrade colder than the CRU nearly everywhere. Preliminary studies show that this is related to an excess of high thin cloud generated in the model.

To properly simulate the effects of irrigation MM5 was modified to include irrigation water which is added every 10 days during warm months at about the observed rate of approximately one meter per season. In the primary experiment all of the present day irrigated and urban areas are replaced by scrub land. The preliminary results indicate that the climate of an irrigated California has lower maximum and largely unchanged minimum temperatures. These changes are associated with significantly higher soil moisture and latent heat fluxes and lower sensible heat fluxes.

Significance

These results help interpret the observed trends in surface temperatures over California in the past century (Christy et al. 2006). Observed downward trends of maximum temperature are associated the expected changes resulting from the known 10-fold increase in irrigation in the same period. The observed upward trend in minimum temperature can be attributed to the influence of greenhouse gas induced global warming and a lack of effect of increased irrigation.

References

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Mitchell, T.D. and Jones, P.D., 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. International Journal of Climatology, 25: 693-712.

Uppala, S. M. and coauthors, 2005: The ERA-40 re-analysis. *Q. J. R. Meteorol. Soc*., **131**, 2961- 3012.

Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions

Basic Information

Title:	Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions
Project Number:	2005CA137G
Start Date:	9/1/2005
End Date:	8/31/2008
Funding Source:	104G
Congressional District:	30
Research Category:	Ground-water Flow and Transport
Focus Category:	Nitrate Contamination, Management and Planning, Models
Descriptors:	None
Principal Investigators:	William W-G. Yeh

Publication

1. Tu, M-Y, F. T-C. Tsai and W. W-G. Yeh, 2005, "Optimization of Water Distribution and Water Quality by Hybrid Genetic Algorithm," Journal of Water Resources Planning and Management, ASCE, 131 (6): 431-440.

PROJECT TITLE: Model Development for Conjunctive Use Planning and Aquifer Protection in Semi-arid Regions

AGREEMENT NO.: 05HQGR0161

PRINCEPAL INVESTIGATOR: William W-G. Yeh

Contact Information:

William W-G. Yeh, Professor and Chair
5732B Boelter Hall
Department of Civil and Environmental Engineering
University of California, Los Angeles, CA 90095-1593
Phone: (310) 825-2300
Fax: (310) 825-7581
Email: williamy@seas.ucla.edu

RESEARCH PROGRAM

Project summary:

In the semi-arid region of the Southwestern U.S., population and economic growth are making increasing demands on the water supply. For example, almost 40% of the water supply in Southern California is from groundwater. To protect groundwater from over-pumping and contamination, there is a critical need to develop surface water and groundwater management tools that can be used to predict water level variations and solute concentrations in the aquifer under different management scenarios. By controlling the total water resources of a region, conjunctive use planning can increase the efficiency, reliability, and cost-effectiveness of water use, particularly in river basins with spatial and temporal imbalances in water demand and natural supplies.

Typical of Southern California, the Warren Basin, located in San Bernardino County, has seen sustained population growth and increased water demands since the 1950's. Since groundwater is the only local source of water supply available, water levels experienced a steady decline of up to 300 ft in some areas between 1956 and 1994. In 1995, the Hi-Desert Water District (HDWD) implemented a recharge program using imported State Water Project (SWP) water and two recharge pond sites. As a consequence, water levels rose up to 200 ft in some areas. However, nitrate concentrations increased drastically, from a baseline level of approximately $10\,mg/l$ to values in excess of $100\,mg/l$. A study conducted by the USGS showed that the increase in nitrate concentrations is due to entrainment of seepage from septic tanks and irrigation, previously stored in the unsaturated zone, by the artificially elevated water table.

The goal of this research is to develop a decision support system (DSS) for sustainable groundwater management, including conjunctive use planning of surface water and groundwater, and aquifer protection. The proposed DSS will encompass a management framework that links simulation to optimization. We will use the geological information and historical data collected by the USGS for the Warren Basin for the development of the simulation model. The developed simulation model will be linked to an optimization model for conjunctive use planning and aquifer protection. Additionally, we will develop algorithms for parameter structure identification, model reliability analysis, data sufficiency evaluation and monitoring network design.

Currently, we have completed the development and calibration of a flow and transport simulation model for the Warren Basin. Geological information for the Basin, and historical water level and nitrate concentration observations are provided by the Water Resources Division of the USGS.

Award No. 04HQAG0001 Spatially Explicit Modeling and Monitoring of Hydroclimatic Extremes: Reducing the Threat to Food Security in the Developing World

Basic Information

Title:	Award No. 04HQAG0001 Spatially Explicit Modeling and Monitoring of Hydroclimatic Extremes: Reducing the Threat to Food Security in the Developing World
Project Number:	2005CA187S
Start Date:	10/1/2003
End Date:	9/30/2006
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

Publication

1. Funk, C. and Brown,. M., 2006, A maximum-to-minimum technique for making projections of NDVI in semi-arid Africa for food security early warning, Int. J. of Remote Sensing. 101. 249-256.
2. Verdin J., Funk C., Senay, G., Choularton, R., 2005. Climate Science and Famine Early Warning, Philosophical Transactions of the Royal Meteorological Society, B. 360. 2155-2168.
3. Husak, Gregory. Methods for Statistical Evaluation of African Precipitation. Ph. D. Dissertation, Geography, University of California, Santa Barbara, Santa Barbara, CA.
4. Freund, Jeremy, Aids for Estimating Crop Area and Production in Kenya: A Multi-Temporal Remote Sensing Approach, M.A. Thesis, Geography, University of California, Santa Barbara, Santa Barbara, CA.
5. Funk, Chris, Jeremy Freund, Mike Budde, Elijah Mukhala and Tamuka Magadzire, 2006, Analysis of MODIS -NDVI for 2000 through 2006. FEWS NET Report. ftp://hollywood.geog.ucsb.edu/pub/AnalysisOfMODIS_NDVIforZimbabwe_JTF4.zip. 8 pages.
6. Funk, C. and J. Michaelsen, 2004: A simplified diagnostic model of orographic rainfall for enhancing satellite-based rainfall estimates in data poor regions, Journal of Applied Meteorology, V43. October,

2004
7. Funk, C., J. Michaelsen, J. Verdin, G. Artan, G. Husak, G. Senay, H. Gadain, and T. Magadazire, 2003: The Collaborative Historical African Rainfall Model: Description and Evaluation. International Journal of Climatology, 23, 47-66

1. Project Information Summary

The UCSB Climate Hazard Group combines the efforts of researchers in Santa Barbara, Washington, Nairobi, Niamey, Harare and Guatemala City. Scientists at the UCSB, with guidance from the National Center for EROS, focus on developing new techniques for modeling and monitoring drought and flood events. Field scientists apply these tools and techniques while providing training and information to institutions in their regions. The CHG research focus is "geospatial hydroclimatology", with an emphasis on the early detection and forecasting of hydroclimatic hazards. We perform basic research into the climatic processes that govern drought and flood hazards in food insecure countries. We develop techniques, algorithms, and modeling applications that can exploit the tremendous potential benefits of remote sensing and other geospatial data.

2.a. Problem and Research Objectives

Drought and famine are slow onset disasters that present a variety of early climatic and socioeconomic signs that dire conditions could evolve. Nonetheless, the drought of the early 1970s was responsible for 100,000 deaths in the Sahel and 200,000 deaths in Ethiopia, and was soon followed by drought in 1983-1985 that saw deaths in Ethiopia estimated from 400,000 to 1 million. These large-scale famines shocked the world and pointed up the tragic lack of timely information that might serve to head off human suffering of huge proportions. Collaboration between the CHG and our USGS collaborators seeks to provide new science and science applications that help policy makers mitigate the potential impact of drought. Our research objectives can be broadly organized into three overlapping categories: i) improved hydro-meteorological monitoring techniques, ii) applications of remote sensing to crop monitoring, and iii) the analysis of multi-year drought patterns, including climate change.

2.b. Methodology

While CHG members come from a number of geographic sub-disciplines, our methods can almost always be categorized as ‘empirical earth science’, and typically synthesize data from a range of satellite and non-satellite sources. Truly geographic in context, the analyses performed typically involve human and climate components.

2.c. Principle Findings and Significance

CHG collaboration with the USGS has continued now for eight years, and several key research milestones have been achieved. First, our initial objective of providing improved precipitation estimates and standardized precipitation indices has been largely accomplished. These methods allow the effective merger of long period of record gridded precipitation archives with new short period of record satellite observations. This makes the timely detection of drought in data sparse Africa much easier. We have also demonstrated that mid-season short lag precipitation forecasts may be linked with satellite rainfall observations to provide effective crop production projections. These projections, for example, provided advance warning of the 2002/03 ENSO-related drought in Southern Africa. Funding from a NASA CAN proposal will allow us to operationalize these techniques during 2006/07.

A second, newer component of CHG research involves the use of satellite data to estimate crop-related areal parameters at district and national scales. MODIS NDVI is being used to approximate crop production, and ETM+ data is used to evaluate cropped area. A Zimbabwe analysis showcased the combination of all these tools in February of 2006. The political context involves Robert Mugabe’s destructive farm policy, and the dubious nature of crop production figures provided by the Zimbabwe Ministry of Agriculture. Remote sensing analysis carried out at the CHG and National Center for EROS identified dramatic reductions in both crop area and production. An independent analysis of enhanced rainfall data suggested only a modest reduction in crop production, with the difference ascribable to failed farm policies.

A third category of CHG research involves the analysis of low frequency climate variations in East Africa. This work has uncovered dramatic declines in Africa's most food insecure nation, Ethiopia. These tendencies towards reduced rainfall are indicative of decreases across much of the Horn of Africa, and are quite likely related to global warming and increasing sea surface temperatures in the Indian Ocean. This research suggests that warming in the tropical oceans may be decreasing the transport of moisture from over the oceans into food insecure Africa.

2.d. Significance

This work has made substantial advances in early warning science. The improved rainfall estimate techniques should benefit all the myriad scientific and social applications requiring good estimates of precipitation. The remote sensing applications should help unlock the largely untapped reservoir of information contained in the MODIS and ETM+ archives. Scientifically, our work has explored some of the links between oceanic heating/precipitation anomalies and moisture transports. These interactions are central to the ocean/atmosphere heat engine that drives the entire atmospheric circulation. Our early identification of the long term drying tendency in Ethiopia is valuable, and the potential link to global warming is possibly quite important. We are slowly working towards a hydrologic flux monitoring system for the tropics and sub-tropics. In its ideal such a system would be able to provide accurate measures of the key hydrologic fluxes into and out of the atmosphere. Routine monitoring combined with a long period of record, meteorological forecast and climate change evaluations would provide a detailed framework for both hydrologic science and effective drought and flood early warning.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	3	0	14	23
Masters	3	5	0	4	12
Ph.D.	9	10	0	17	36
Post-Doc.	2	4	0	1	7
Total	20	22	0	36	78

Notable Awards and Achievements

2003CA50G:

Ph.D. student Cristiane Surbeck received an EPA STAR Fellowship for 2005-2008 based on the work conducted under the NWIR grant.

2003CA57G:

Two graduate students in Dr. Lydys laboratory (Andrew Trimble, doctoral student; Amanda Harwood, Masters student) have received EPA STAR graduate fellowships to continue this research. These fellowships will begin August 2006 and are the result in part due to USGS/NIWR funding.

Due in large part to the urban creek findings from this study, as well as our agricultural findings from prior work, the California Department of Pesticide Regulation (DPR) has announced their intent to put pyrethroid pesticides in to the process known as re-evaluation. It is extremely rare for DPR to put pesticides in re-evaluation based on water quality data, but our studies provided strong evidence of agricultural and urban aquatic toxicity due to the pyrethroids. Under re-evaluation, DPR will require the registrants to provide additional data on sources, potential mitigation practices, and environmental fate and effects of pyrethroids so that the State of California can manage them more effectively.

We have received two supplemental awards as a result of this study, both from the Sacramento River Watershed Program. The first award of $23,000 provided for sampling at an additional farm site in connection with our studies on changes in pyrethroid bioavailability over time, as described above. The second award, for $91,000, provided for the development of procedures to identify when pyrethroids are the causative agent for mortality when observed in sediment toxicity tests (i.e., Toxicity Identification Evaluation). The PBO studies described above will be very helpful in developing these procedures.

205CA123B:

Two students working on this project received awards for best poster presentation.

2005CA187S: In 2005 research into drought in the Greater Horn was highlighted in an open letter on global warming by the British Royal Society to the G8 ministers in 2005. In 2005 the most recent 5-year FEWS NET work plan was expanded to explicitly provide support for multi-disciplinary research into the impact of low frequency climate/social patterns on food security. In 2006 the Zimbabwe production/cropped area assessment received special commendation from the director of FEWS NET.

Publications from Prior Projects