California Department of Water Resources
2004 Water Use Efficiency Proposal
Section B: Research and Development; Demonstration and Technical Assistance

Title: **Development of Strategies to Enhance Water Use Efficiency and Quality Using Field Studies and Modeling at the regional scale**

Relevance and Importance

The loss of the agricultural discharge waiver in January 2004 and the concurrent shift toward Total Maximum Daily Load (TMDL) monitoring have challenged farmers to provide more effective management of irrigation and winter runoff. Because the Central Valley alone contains 77% of California's irrigated agriculture (CASS, 2004), the state's geography ensures that virtually all Delta waters are affected by agricultural areas before entering the Delta and being redistributed for public use. Balancing the needs of agricultural activities with public and environmental uses of surface water flows requires a broad assessment of the role that agriculture plays in affecting overall environmental quality. The only way to reconcile adverse affects of agricultural practices with Delta water quality and quantity water is to link watershed pollution management with field-scale management practices. Unless this effort is grounded in a scientific approach to this issue, it is unlikely that objectives for enhancing water use efficiency and NPS reduction will be achieved, even with significant public investment. This project addresses several objectives relevant to CALFED's mission: NPS pollution monitoring and reduction, improved water use efficiency, increased groundwater recharge and storage, and adoption of long-term, economically sound strategies linking agricultural quality and natural capital.

In California, the Sacramento River Basin and Yolo Bypass carry a combined 20 million acre-feet of the Delta's 27 million acre-feet (MAF) of annual inflows (Figure 1). Because these catchments are drained by extensive networks of streams and irrigation canals originating within intensively farmed areas, recent data suggest that sediment, nutrient, and pesticide loads from small feeder branches may be having a larger impact than loads entering the estuary from large rivers (Thompson and Gunther, 2004). Intensive agricultural practices have been shown to adversely affect overall soil quality, leading to decreased hydraulic conductivity, water retention and infiltration (Abdul-Baki, 1998, Hynes, 1980; Joyce et al. 2002). Water penetration problems continue to increase in severity in most irrigated farmlands in the arid and semi-arid California, increasing flood risk. Most importantly, production driven cropping practices in the Central Valley typically lead to bare soils during winter, which increase runoff and sediment loads that have been shown to be responsible for the majority of N and P exported from a watershed (Sims, 1994). The accompanying erosion of topsoil and reduction in soil organic matter significantly affects the ability of agricultural systems to buffer these negative effects on environmental quality.

Despite these impacts, the degree to which specific agricultural activities influence both water quality and availability across watersheds is uncertain. Non point source pollution is difficult to quantify. There is virtually no information linking the influence of management practices on the quality and quantity of surface runoff at the field or landscape scale. In addition, little information exists characterizing ambient levels of dissolved nutrients required to maintain aquatic trophic food web integrity and net primary production (NPP), or the impact of nutrient

load reductions on these systems. While Phase II monitoring efforts currently undertaken by Regional Water Quality Control Boards and various coalition groups are an essential first step, these efforts must be complemented by a quantitative understanding of the relationship between farm practices and runoff water quality and quantity.

Systems-based studies at the field and regional scale are urgently needed to develop practical and economically viable conservation practices in irrigated agriculture for the immediate and long-term management of surface water resources. Strategies that reduce runoff from farm fields, including increasing water use efficiency, must be evaluated in terms of their ability to reduce NPS pollution loading, while balancing the need for safe drinking water and overall ecosystem health. To do so, it is urgent to address the links among water quality, soil conservation, and agricultural practices. Six essential ecosystem services have been attributed to healthy soil: buffering and moderation of the hydrologic cycle, physical support of plants, retention and delivery of nutrients to plants, disposal of wastes and dead organic matter, renewal of soil fertility, and regulation of the major nutrient cycles (Daily et al., 1997). Because agriculture is dependent on these overlapping functions, agricultural productivity is inherently linked to environmental quality. As farming activities intensify, marginal trade-offs occur between the value derived from agricultural productivity and the degree to which that productivity can be maintained by the underlying ecosystem functions that support it. In this context, water quality protection cannot rely solely on alternative inputs and spatially diffuse monitoring efforts; we must also focus on the potential of an integrated set of farming practices to improve environmental quality.

The profitability of farming in the U.S. has decreased as globalization has proceeded while the costs of material inputs, particularly energy, have increased (Blank, 1998 and 2000). For example, prices received by growers have decreased by 8 per cent in the last decade while prices for farm inputs have increased by 21 per cent. Fuel, machinery and labor costs have increased at an even greater rate, with fuel prices more than 50 per cent higher than they were in 1990 and machinery and labor costs up one third (NASS, 2000). In order to remain profitable, farmers have had to continuously adopt new technologies that increase production efficiency, increase yield or both. Those who cannot keep pace are likely to leave agriculture hastening losses of open space, wildlife habitat, and biodiversity, especially if the land is urbanized (Medvitz, 1999; Blank, 2000; Sanders, 2000). In order to preserve the public commons and the accompanying natural capital, changes implemented by farmers to protect water quality must be effective. In response to these challenges, there is a growing interest among growers, researchers, extension personnel, government agencies and commodity groups to develop best management practices that promote sustainable farming systems.

The only way to solve NPS pollution problems in the long term is to link regional pollution prevention to field-scale management practices using mechanisms that encourage voluntary adoption by growers. A framework of similar strategies has been developed by regional coalition groups, resource conservation districts, and some growers, but the effects of newly adopted practices must be understood quantitatively. This proposal will augment those efforts by directly addressing the complex interactions between soil conditions, microclimate, field configuration, and monitoring protocols. Overall, this project will determine the potential of alternative management strategies that promote watershed health and the economic sustainability of agriculture. Specifically, the aim is to address how best management practices (BMPs) may assist growers in meeting local water management strategies that satisfy regional watershed improvement plans. Only when costs and benefits are adequately understood can

rational decisions be made about what kinds of farming systems are most likely to contribute to improved water quality in the Bay-Delta ecosystem, and what might be necessary to facilitate the large-scale adoption of these systems.

Technical/scientific merit, Feasibility

Project Plan

The primary technical goal of this proposal is to investigate agricultural practices as a means of controlling overland runoff quality and quantity. Fundamentally, soil physical, chemical and biological properties buffer the hydrologic cycle. Any realistic attempt to improve environmental quality in agricultural systems must therefore focus on the complex interactions between specific soil characteristics and the nature of the land use. As mentioned above, the majority of agricultural land in the Central Valley is left fallow or unmanaged during winter, when runoff is most likely to occur. Winter fallowed soil is vulnerable to the kinetic energy of raindrops that destroy stable aggregates, decreasing infiltration and potentially leading to the release soil particles into the runoff flow stream (Box and Bruce, 1996). These erosive forces result in the formation of soil seals that induce high-energy runoff responsible for the majority of nutrient and residual pesticide exports. By implementing management practices that shield bare soil and promote infiltration through increased field residence times, agricultural discharges can be significantly minimized and their overall quality improved. Specifically, conservation strategies employing a combination of conservation tillage (CT) and/or cover crops (CC) have proven potential to reduce runoff and sediment losses during periods of overland flow. Equally important are physical changes in field configuration and drainage management, which show much promise for trapping water and enhance infiltration. However, much information is needed before these strategies will be widely adopted. Specifically, it is critical to determine how these strategies are affected by micro-scale soil physical properties, such as texture and organic matter content, and field-scale water movement, determined by furrow configuration and hydrologic residence time. Ultimately, the convergence of environmental and agricultural quality lays in the refinement of economically viable, conservation-based management practices suitable for diverse locations across the Central Valley. Therefore, we propose to evaluate the benefits of these practices in terms of runoff quantity and quality, farm profitability, and the long-term value of sustained soil health.

Conservation tillage (CT) generally refers to practices that establish crops in a previous crop's residue, which is purposely left on the soil surface to minimize costs through reduced tillage operations. Fewer and less intensive tillage operations result in slower decomposition of above- and below-ground crop biomass. This effectively creates physical resistance to overland flow in the short term, and leads to increases in surface organic matter levels over several cropping seasons. Combined, the results are decreased erosion and increased infiltration by maintaining soil structure and protecting bare soil. Hence, CT is inherently a system of soil and water conservation, which has the potential to decrease runoff quantity and sediment loads while increasing profits (Carter and Berg, 1991; Sojka and Carter, 1994). In addition, CT systems improve irrigation water use efficiency by increasing water holding capacity, reduce dust emissions, and provide more and higher-quality wildlife habitat (Dimmick and Minser, 1988; Seta et al., 1993; Reeves, 1997; Reicosky, 1998). Numerous studies in the Midwest and other parts of the country have shown the benefits of conservation tillage (Franzluebbers et al., 1995; Smolik et al., 1995; Paustian et al., 1997; Lal et al., 1998;), and initial studies in California

suggests that CT systems have a greater ability to retain N inputs than conventional tillage systems (Horwath et al., unpublished). Despite these potential benefits, CT is currently being used on less than 5% of California's irrigated farmlands (CTIC, 1999; Mitchell, 1999). Few studies exist examining CT in furrow irrigated fields, particularly in the arid and semi-arid western U.S. (Ashraf, 1999), and none have yet addressed implementing CT in low-input and or organic systems. Maintaining clear furrows for irrigation uniformity and intensive intercrop tilling to achieve a "clean" field also prevents growers from realizing the full benefits of CT systems, including improved water management (Mitchell et al., 2000).

Winter cover cropping (CC) also offers enormous potential for managing runoff. Similar to CT, CC canopies prevent the destruction of soil aggregates by shielding bare soil and absorbing the kinetic energy of raindrops. In addition, the extensive root systems of some cover crops are highly effective in loosening and aerating the soil throughout the rainy season, in some cases extending the soil-loosening effects of a sub soiling tillage treatment, and even performing like a "biological plow" by penetrating compacted soils (Henderson, 1989). Cover crops may also decrease NPS pollutions by enhancing soil nutrient cycling and long-term aggregate stability through increased microbial biomass and soil organic matter, as well as by reducing reliance on highly soluble synthetic fertilizers (Kabir and Koide, 2000, 2002). In California, research at UC Davis has shown that legume cover crops can be incorporated into a tomato rotation to improve plant nutrient uptake, sequester soil C, promote greater biological activity, and reduce root disease severity with little or no significant reduction in tomato yields (Poudel et al., 2001). Preliminary data from agricultural runoff monitoring at a Yolo County ranch show significant reductions in NPS pollution were achieved through the use of a cover crop, with no loss in tomato yields (CALFED Grant **#ERP-02-P36)**. The results support the hypothesis that first-year plantings of winter cover crops greatly enhance infiltration and reduce sediment transport. However, the availability of cover crop N inputs to the following crop is highly dependant on form and timing, and further information is needed to determine if NPS pollution reductions can be achieved at other sites and cropping systems while maintaining comparable yields. Other studies have revealed that CC systems have higher support higher infiltration of winter runoff compared to a conventional winter-fallowed system (Mitchell et al. 2000). This may contribute to greater groundwater recharge, but it may dependent on the water demands of the CC. Additionally, it is unclear whether the higher infiltration under CC compensates for the loss of water due to higher evapotranspiration from the CC, compared to a fallow field.

In addition to CT and CC approaches, alternative irrigation strategies such as sub-surface drip irrigation (SDI) may have promise to increase water use efficiency. SDI has been lauded for many reasons both economic and environmental, among them increasing harvest yield through efficient fertilizer delivery (fertigation) (Radin et al., 1992), and decreasing weeds and subsequent herbicide use (Ogbuchiekwe et al., 2001; Patterson et al., 1990) and most of all saving irrigation water use (Batchelor et al., 1996). In our preliminary studies, SDI was shown to have similar yield compared to furrow irrigation systems (Table 1).

In anticipation of the urgent need to integrate Delta ecosystem health with Central Valley agricultural viability, we propose the implementation of the first large scale, long term, replicated field trials examining the effects of agriculture practices on the quality and quanity of agricultural runoff. The overarching primary goal of the proposal is to understand the factors affecting the fate of irrigation and winter precipitation runoff. The secondary goal

Table 1. Tomato fruit yield in FI and SDI under either CT (conservation) or ST (standard) tillage.

System	Yield (tons/ha)
FI-ST	69.9
FI-CT	60.1
SDI-ST	65.4
SDI-CT	67.7

is to examining the effectiveness of subsurface drip irrigation on water use efficiency and agricultural productivity as an alternative to traditional furrow irrigation.

The goals of this project have their roots in over a decade of work on sustainability initiatives at UC Davis, including over a year of intensive runoff investigations in response to the current regulatory climate. Our preliminary runoff work confers two notable benefits to this proposal: first, it capitalizes on state-of-the-art runoff monitoring resources and expertise, and second, it allows for refinement of theoretical concepts between runoff parameters and land use characteristics. To date, our results support a striking connection between land management practices and runoff (Table 1). Data from the 2003-2004 winter runoff season show an enormous potential for CT and CC to reduce winter runoff, control sediment loading, and mitigate agro-chemical pollution. For example, the cumulative rainy season runoff in

Table 2. Runoff values from CC and non-cover cropped (NCC) from a Yolo County farm fields in 2003-04 rain season

	Cover cropped	Non cover cropped
Total precipitation discharged as runoff (%)	0.9	16.3
Average Suspended solid concentrations (g L^{-1})	0.58	2.14
Average runoff velocity (m s^{-1})	0.24	0.58

2003-2004 was approximately twenty-fold greater from a winter fallow field (6,123m^3) than runoff from a legume/oats CC field (321m^3). Average suspended solids were approximately 400% and runoff velocity was 100% greater in winter fallow field than the CC field. Detailed results from the same Yolo County ranch during an intense early storm event (December, 29th, 2003) and late storm event (February 25, 2004) highlight similar trends in nutrient losses (Table 2). In winter fallow field runoff, total suspended solids (TSS), phosphate (PO_4-P), dissolved organic phosphorus (DOP), nitrate (NO_3-N), ammonium (NH_4-N) and dissolved organic nitrogen (DON) loads were consistently higher than that of CC (Table 2.). Importantly, the loading potential of the winter fallow field runoff was much higher among all dissolved constituents due to significantly higher discharge quantities observed throughout the season under that management system (Table 2). Overall, however, nutrient concentrations in runoff from both systems were low. A comparative analysis of residual pesticides is pending, but initial results indicate pebulate and chlorothalinil residues in the parts per trillion ranges in the runoff.

Table 3. Comparisons of CC and NCC fields for several water constituents of concern

		TSS		PO_4-P		DOP		NO_3-N		NH_4-N		DON		DOC	
		Load*	Conc.#	Loa	Con	Load	Conc	Load	Conc.	Load	Conc.	Load	Con	Load	Conc.
Early	**CC**	2.00	2233	0.04	0.03	0.00	0.00	0.38	0.31	0.04	0.03	0.08	0.79	2.00	2.13
	NC	35.0	3742	0.39	0.04	0.09	0.01	3.00	0.38	0.25	0.04	6.60	0.83	16.0	1.93
Late storm	**CC**	1.60	517	0.06	0.02	0.00	0.008	0.17	0.05	0.33	0.12	3.66	1.3	10.8	4.0
	NCC	156	3897	1.3	0.04	0.00	0.002	5.30	0.21	5.90	0.17	42	1.3	81	2.9

*Load: Kg storm event^{-1} acre^{-1}
#Concentration: ml Kg^{-1}

In conjunction with the current policy shift toward ambient water quality standards, these striking results provide a strong incentive to expand current farm-scale investigations, and necessitate a rethinking of agricultural monitoring methodologies. To achieve efficient NPS pollution reductions, conceptual models must be developed that correlate water inputs and load reductions with innovative agricultural management practices. Our experience has determined that significant technical difficulties accompany winter and summer season farm-scale monitoring, providing an even greater incentive to focus on preventative solutions which avoid watershed level TMDL violations. Extending these models into the realm of ambient water quality standards and monitoring protocols requires qualitative scientific information, and creates an excellent opportunity to assist growers while simultaneously improving Delta inflows. Above all, the current regulatory climate offers an unique opportunity to disseminate valuable information to growers in a manner that allows for self-evaluation and self-selection of site-specific and economically feasible water conservation strategies.

In this study we will test the following five hypotheses:

1. **Different factors influence soil-water relations and runoff quality in conventional, low-input and organic farming systems.**
   A. Organic and low-input systems have more water storage and less runoff than conventional farming systems.
   B. Organic and low-input systems need less irrigation during crop growing season
2. **CT and/or CC enhance infiltration and ground water recharge.**
   A. Infiltration rate and groundwater recharge is higher under CT and or CC systems than under a conventional furrow irrigated system.
3. **The effectiveness of CT and CC will depend mainly on ratio of precipitation to evapotranspiration, with soil type and cropping system secondary influences in the Central Valley.**
   A. Evapotranspiration depend on the crop and soil type more than quanity of precipitation or irrigation water.

4. **Implementation of CT and CC will favorably influence energy budgets associated with agronomic operations and irrigation water management.**
    A. Greater winter recharge will save costs by decreasing overall summer irrigation operations.
    B. More water will be available for summer pumping of irrigation water.
    C. Increased groundwater recharge will increase summer surface water availability off the farm.
5. **Drip irrigation provides effective water savings**
    A. Less evaporation and economic water use
    B. Less pesticide use
    C. More efficient fertilizer delivery will decrease NPS pollution potential in runoff.

The specific project objectives are:

- Create the first field scale runoff research facility in California for quantification of interactions between farm management practices, furrow length and runoff volume and quality;
- Determine the potential of CT and CC practices on farm-level water savings and achieving TMDL targets across various precipitation/evaporation regimes in the Central Valley;
- Determine how runoff quantity and quality are affected by different soil cover and furrow lengths (factors affecting retention times);
- Determine the influence of furrow configuration on soil water content, infiltration rate and runoff control;
- Develop physically based hydrological models relevant to grower, watershed, and regional water policy entities that correlate watershed water quality parameters with specific agricultural management practices by utilizing UC Davis dedicated runoff plots;
- Develop a GIS technology to improve farm-level water use efficiency;
- Determine the water saving, nutrient management and potential benefits and costs of drip irrigation as compared to furrow irrigation;
- Develop economically feasible farm-level conservation strategies that improve water efficiency and maintain farm productivity in irrigated row crop systems using the economic and hydrologic models;
- Investigate and compare annual field water balances for the conventional, low-input and organic furrow irrigated systems in terms of storage capacity, infiltration and ground water recharge.
- Create a comprehensive grower workbook for use in evaluating farm water resources and implementing suitable water conservation practices;

Feasibility

The multidisciplinary team of investigators proposing this project has a long and successful history of working together, having developed and maintained the ongoing Sustainable Agricultural Farming System (SAFS) and Long-term Research on Agricultural Systems (LTRAS) Projects for last 16 years. These studies fostered long-term, farmer-participatory, multidisciplinary, replicated field trial comparing organic, low-input, and conventional farming systems. The farmers and farm advisors participated in every stage of

research, from planning and design to interpretation and dissemination of results, making the results of the research more relevant to the farming community.

The SAFS project has developed a highly successful outreach structure, with a mailing list of over 1500. The project has hosted several hundred visiting scholars, government ministers and other officials, and farmers, from all parts of the globe, and was featured on national and international television and radio shows. Annual field days are attended by between 80-150 growers, farm advisors, extension specialists, resource conservationists, and others. Over a hundred peer-reviewed publications has result from the SAFS research, as well as numerous articles in technical and popular media, posters and presentations at professional meetings, extension bulletins, and newsletters. The project has a highly visible profile in agricultural and research communities, and among governmental and nongovernmental organizations.

A Two-Tiered Research Approach

This proposal takes a two-tiered approach to investigating agricultural water use efficiency and runoff quality and quantity, based substantially on our current efforts on UC Davis study plots (Researcher-Managed-Studies) and grower fields (Grower-Managed-Studies). Most farm management practices are applied at the field scale, but most research aimed at influencing farm management practices is done using small plots. In many cases this has been successful, but in the instance of field and farm runoff, the issue of scale is a significant determinant of the behavior of the system.

Two issues are involved: (1) the quantification of the relationship between varying combinations of new and traditional farm management practices on runoff, and (2) how to carry out research which accounts for the effects of scale on runoff from these varying combinations. The relation of physical parameters to in-field management is difficult to predict, and farm-based research is not by itself sufficient to analyze a range of practices in a systematic way. Each farm is unique, and represents a limited number of possible management approaches. To assemble sufficient numbers of observations, a large, likely unmanageable number of farm locations would be needed. The cost of such a program would be excessive. Instead, a predictive model is needed to portray the response encountered under different environmental, physical and management conditions.

SAFS and LTRAS researchers have been highly successful in establishing a resource base – cooperative growers notwithstanding – for the exploration of relationships between environmental and agricultural quality in California's Central Valley. To fully utilize this base, these Researcher-Managed studies will be complemented with Grower-Managed Studies located in agriculturally distinct sites – a two-tiered approach. Establishing research sites on farm fields and research plots will allow for predictive model development and testing, and provide a rational framework for the integration of results at both scales. In turn, this will increase the likelihood of adoption of effective runoff control strategies at diverse locations throughout the Central Valley. Sound public policy solutions can also be based on this work and established with less cost and in a shorter period of time.

Field Site Characterization and Experimental Design

The proposal will utilize highly controlled research-managed plots housed at UC Davis Russell Ranch Research Facility (lat. 38° 32'N, long. 121° 47'W, 18 m elevation, 28 acres) and at grower-managed fields in the lower Sacramento and the upper San Joaquin Valleys (lat. 38°

41″N long. 121° 48″W 21 to lat. 37° 41″N long. 119° 45″W 43, covering Stanislaus, Yolo, Sacramento, and Solano counties).

Despite clear successes, numerous questions have arisen from the first two years of runoff monitoring in systems using CT and CC. When examining the landscape response to water inputs and resulting discharge, the complexity of interactions between cropping cycles, field operations, water use efficiency, and scale, has necessitated the subdivision of research questions to achieve optimal efficiency and usefulness of results. As such, three **Researcher-Managed-Studies** will be conducted at the Russell Ranch Research facility:

- Core Long-Term Research Plots

  These plots will be used to investigate water storage, infiltration, groundwater recharge, runoff quantity and quality in different farming systems. The experiment will be composed of a one-acre split-plot design with three replications. The main plots will be used to compare three cropping systems of corn/tomato rotations each with different management practices – conventional, low-input, and organic farming systems. Each of the farming systems has been subdivided into standard tillage (ST) and CT systems. The CT sub-plots will use permanent beds and minimal disturbance of the soil and the ST sub-plots will use tillage practices standard to the area (i.e., ripping, disking, listing, and planting). The organic and low-input farming systems will be CC, and the conventional system will remain fallow during winter.

- Dedicated Runoff Plots

  All flow data gathered at the Russell Ranch facility to date indicate a strong need for large plots that account for scale and field configuration, to address the concentration time of runoff – i.e., the time it takes for water to travel from the furthest point of the field to the primary drain. This diversity in physical environment (e.g., furrow length, runoff distance, furrow diversions, etc.,) is critical to understanding the relationship between flow velocities and discharge rates, and will be addressed on Dedicated Runoff plots. The design of the experiment will be 4x3 factorial with 4 lengths of furrow (e.g. 3/4, 1/2, 1/4 mile) and 3 cultural practices (e.g. CC, CT and winter fallow). Horticultural crops used in the SAFS Core Long Term plots will be grown, allowing for inference across a range of experimental scales. Comparisons will also be made with perennial forage crops in treatments which are thought to reduce runoff most consistently. We hypothesize that runoff distance and drainage area are not correlated and therefore, length and orientation of furrows may be used to dictate the field configuration to reduce runoff.

- Companion Plots

  The primary function of the Companion plots is to provide a means for testing new management strategies that may later be incorporated into the Core Long Term plots. The nature of the Core plots requires operations to remain precise and consistent, while the Companion plots allow for continuous refinement of operations and introduction of novel strategies without disturbing the overall integrity of the Core plots. Currently, the Companion plots are being used to test alternative irrigation methods to achieve water conservation and precision application of chemicals for row crops. These plots are also a significant outreach vehicle for demonstrating the most progressive alternative techniques to interested growers.

The experimental design of the Companion plots will be a split-split-plot design with four replications. The field trial will contain the main treatments of sub-surface drip irrigation (SDI) and furrow irrigation (FI) subplot treatments of CT and ST and sub-subplot treatments of CC and NCC during winter. All plots will be chemically managed with practices typical to the area, i.e. fertilizers and pesticides. The drip system will be fertigated while the FI will have the fertilizer side dressed to six inches in depth. Both systems will receive the exact same type and amount of fertilizer to avoid confounding factors associated with fertilizer effects. Crop rotation will be processing tomato followed by corn, safflower, wheat or other suitable crops for the region. Normally the SDI plots will be irrigated approximately 3 times per week while the FI plots will be irrigated approximately every 9 days in accordance with standard practices being developed by UC Cooperative Extension.

In the Grower-Managed-Studies, up to five Central Valley grower sites will be selected along a north-south transect representing precipitation regimes ranging from 11″ to 22″ to account for intensity and frequency of rain events and evaportranspiration regimes (Figure 2). Each grower location will represent a distinct combination of microclimate, cultural practices, soil types, moisture regimes, and irrigated row-cropping systems. The focus of summer crop selection will be on irrigated row-crop fields in any combination of corn, tomato, wheat, and sunflower. Winter cover crop treatments will consist of several legume mixture or legume/cereal combination systems. Each complete grower site will consist of a control (bare soil in winter) and a treatment utilizing a winter CC or a CT-based system (defined as a minimum 30% residue cover). As data is gathered, more growers may be added in the following years whose site characteristics are conducive to stated objectives.

Readiness to proceed

Combined with LTRAS operational infrastructure, the SAFS project has the experience and stakeholder support that allow rapid implementation. Our proposal integrates over a year's worth of extensive agricultural runoff monitoring and data analyses previously funded by **CALFED (Grant #ERP-02-P36)** and fourteen years of sustainable agriculture research, providing an exceptionally solid foundation to expand water quality investigations. Wherever appropriate, project implementation will capitalize on accumulated SAFS resources, including water monitoring equipment and laboratory research facilities. In addition, the proposal will tap well-established cooperative relationships between growers, farm advisors, extension personnel and SAFS researchers.

Environmental Compliance

There are no permits (e.g. CEQA and NEPA) required to conduct this project. Researcher-Managed studies will take place at the UC Davis Russell Ranch Research Facility, and will comply with all local, county, state and federal laws. Grower-managed research sites in Northern California are operated on established private agricultural fields by experienced growers with a history of collaboration with UC Davis.

Submittal List and Schedule

Task	Submittal list	Estimated completion date	Projected cost
1.0 1.1 1.2 1.3	**Project Administration** Contact summary form Progress report Expenditure projection	 Within 3 months of agreement Quarterly (Jan., Apr., July, Oct.) Mid-Jun and Mid-Dec. in each yr	**$124,148**
2.0 2.1 2.2 2.3 2.4 2.5 2.6	**Site selection and experimental design** Grower's fields selection List of growers selected Landowner agreement UC Davis research field established Final experimental design Install runoff drainage and measurement systems	 1/12/06 1/15/06 1/20/06 1/30/06 3/15/06 4/03/06 and annually thereafter	**$368,781**
3.0 3.1 3.2	**Water flow monitoring and sampling** Water flow measurement Water sampling	 Continuous during all overland flow events	**$100,326**
4.0 4.1 4.2 4.3	**Runoff quality analyses** Sediment analyses Nutrients analyses Pesticides analyses	 Continuous during water sampling periods	**$345,045**
5.0 5.1 5.2 5.3	**Soil sampling, water balance monitoring and analyses** Soil sampling Infiltration, water content, ET Soil analyses	 Continuous throughout Continuous throughout Immediately following sampling	**$134,128**
6.0 6.1 6.2 6.3 6.4 6.5 6.6 6.7	**Data entry and analyses** Soil, plant and water data entry Crop yield data entry Water quality and flow data management GIS data management Economic data management Advanced statistical analyses	 Daily 9/30/06 and annually thereafter Continuous throughout Continuous throughout Continuous throughout Continuous throughout	**$74,264**
7.0 7.1 7.2	**Physical based modeling** Data gathering and management Soil hydraulic and BMPs optimize	 Continuous throughout End of each growing season	**$80,541**
8.0 8.1 8.2	**GIS Application to hydrology** Data analyses Create a model	 Continuous throughout	**$81,159**
9.0 9.1 9.2 9.3	**Economic Assessment** Data gathering and management Cost-benefit analyses Economic model	 Continuous throughout Continuous throughout 2nd and 3rd of the project	**$130,378**

10.0	**Outreach and reporting**		**$240,631**
10.1	Newsletter production	12/10/06 and quarterly thereafter	
10.2	Stakeholder presentations	At least twice per year	
10.3	Annual field day	6/30/06 and annually thereafter	
10.4	Website development	12/10/06, then quarterly	
10.6	Manual for irrigated water use	12/09/08	
10.7	Draft Project Report	12/10/08	
	Final Project Report	12/20/08	

Monitoring and Assessment

Flow monitoring and sampling

Overland flow at all sites will be monitored, measured, and collected by ISCO 6712 autosamplers (Isco, Inc., Lincoln, NE). During runoff events, minute-by-minute flow and precipitation measurements will be taken using ISCO Model 750 Area-Velocity Modules and ISCO Model 674 Rain Gauges, both of which are fully integrated into the autosamplers. Runoff samples will be taken when field discharge reaches a specified rate, signaling an internal datalogger to commence a preprogrammed sampling protocol. Samples will be collected from the field within 24 hours of sampling and transported to UC Davis for analysis of a suite of water quality indicators. This protocol has been refined by the SAFS research team, and provides a reliable, convenient, highly precise means of monitoring rain-induced runoff in which flow rates and water quality indicators can be correlated with rain intensity and concentration time. A list of water quality constituents and their respective analytical methods is provided on Appendix 2.

Runoff quality analyses

A list of water quality constituents and their respective analytical methods is provided in Appendix 3. Nitrate, NH_4, dissolved organic P, dissolved organic N and dissolved organic C content of the runoff will be analyzed using methods described by Horwath et al. (1995), which meet EPA quality assurance standard. Pesticides will be analyzed using methods described by Crepeau et al. (1999) and Munch et al. (1990). Pesticides will be identified and quantified using either GC or GC/MS (for higher pesticide concentrations) depending on minimum detection limits. The identification of the pesticides will be confirmed by comparison of retention times and characteristic masses, respectively, to those of a calibration standard.

Soil sampling, water balance monitoring and analyses

Soil physical properties will be measured include soil texture, pH, EC, SOM, soil aggregate stability, and water-holding capacity with standard methods. Soil water content will be measured with time domain reflectometry (TDR) to observed soil water dynamics over the length of irrigated furrow. The mass balance equation of Young (1997) will be used to estimate irrigation management and BMPs effects on groundwater recharge. Infiltration will be determined using the two-point method as described by Walker and Skogerboe (1987). During the summer cropping season, evapotraspiration (ET) will be estimated weekly using reference values provided by CIMIS weather station located within 100 meters of the SAFS main experimental site. During the winter, transpiration and evaporation will be quantified using one 20-ft. weighing lysimeter and one 20-ft floating lysimeter in different farming systems. The lysimeter

data will be compared with results of a field-validated ET model (Hsiao and Henderson, 1985) that uses soil wetness and canopy cover as input parameters for calculating E and T. Crop canopy will be measured weekly using a LICOR 1600 Line Sensor and a Dycam AGCAM digital camera (Chatsworth, CA) that uses IR and red band ratio to determine % canopy cover.

Data entry and management

All flow data will be downloaded from autosamplers and managed in a dedicated flow monitoring database (Flowlink, ISCO, Inc.), allowing for versatile, easily interpretable and rapidly retrievable quantity/quality relationships. All quality data will be recorded on paper as it is synthesized, then entered into spreadsheets and stored electronically at UC Davis. Digital backup copies will be made monthly and stored in separate locations. Quality, quantity, discharge velocity, discharge rate values collected from the controlled university research plots and grower fields also will be incorporated in a GIS database. Analyses will be conducted through statistical exploration of relationships between components. Temporal trajectories of variables, and relationships between responses and various input or other factors, will be analyzed using linear and nonlinear regression, principal components analysis and simulations. Core data, in concert with Flowlink and GIS databases, will be used to describe the a real extent of BMPs vs. conventional scenarios. This will allow us to define the spatial distribution of flux boundaries for the vadose zone and ground water models. Vector GIS coverage will be developed for soil water retention, infiltration, groundwater recharge and water demands under BMPs and conventional farming systems.

This is a non-proprietary project, and all data will be made available, upon request and with reasonable cause, to the general public, cooperating institutions and private individuals. Biannual project progress reports will be submitted to the Department of Water Resources (DWR). The outcome of the studies will be disseminated to the growers in the form of a Grower Workbook. Periodic updates will be made available to policy makers, watershed groups and commodity groups through annual field days, newsletters, field tours, peer-reviewed articles, conferences, and a website (http://safs.ucdavis.edu/). We will also work closely with local and regional watershed groups to increase the dispersion of our results at their meeting and use of their outreach mechanisms.

Physical based modeling

The outcomes of the data analyses will allow us to assess how different management practices influence water balance, water storage, infiltration and runoff. MIKESHE physical based models will be executed for this study. The MIKESHE model is used for the simulation of all major hydrological processes occurring in the land phase of hydrological cycle (Refsgaard and Storm, 1995). It solves the one-dimensional Richard's equation for the vadose zone and three-dimensional equation for ground water. A finite difference solution of the partial differential equations, describing the process of unsaturated and saturated flow, interception and evaporation, is used for water movement modeling. The model considers almost all hydrologic components that may influence on soil water storage. We intend on applying and refining these models by determining relationships obtained from our core long-term research, dedicated runoff and companion plots and validating them using farm water shed scale data to understand the physical and management aspects that influence the fate of runoff and overall water use efficiency.

GIS Application to hydrology

A GIS will be used to organize data from the small scale (core long-term research plots, dedicated runoff plots) to the larger farm scale. The data organization and extrapolation of scales will be used to describe the area extent of BMPs vs. conventional and their influence on the landscape. This will allow us to define the spatial distribution of flux boundaries for the physical based models. Vector GIS coverage will be developed for soil water retention, infiltration, groundwater recharge and water demands under BMPs and conventional farming systems. The overall intention of the GIS exercise is the address the efficacy of BMPs to influence runoff and water use efficiency and to extend the results of our simulation efforts.

Economic assessment

To examine these tradeoffs at the farm level, an economic analysis of each system will be conducted using the Budget Planner computer program developed at the University of California (Klonsky and Cary, 1990) which will simulate the economic performance of a hypothetical 810 ha farm. Gross returns for the organic systems will be calculated two ways, with conventional prices and organic premium prices to ascertain the dependence of the economic viability of the organic system on price premiums.

Further economic analysis will be conducted with the water budget model with an economic model to determine optimum ground water pumping rates and BMPs. The system will optimized to maximize the total net return from agricultural production within sub-regions subject to pertinent production and resources constraints on water and land. The agricultural production function will describe the tradeoffs between increased water supply reliability in future periods with current return. Consequently the total return on capital investment will be measured. The resource constraints will be dependent upon total availability and allocation of surface and ground water sources. Farm behavior will be keyed to the cell or sub-region as defined by the GIS procedures.

The economic model and hydrologic model will be developed in parallel and from a common database and regional specification. Given this commonality, results from the model can be displayed using GIS.

Expectations and Potential Constraints

We expect greater runoff retention and control and increased water quality under CC and CT systems. The main constraint to the feasibility of the project relates to monitoring landscape responses in extreme weather conditions. During 10- or 25-year storm events, such as would be expected during a strong El Nino year, it is likely that possible that runoff could become so heavy that it would overtop furrows and overwhelm the automated sampling systems, or wash out the main drainage ditches. In a drought year it is possible that not enough winter runoff would occur for measurement and sampling of it to take place. Weather conditions also affect equipment needs, as timing of operations is critical to the success of farming. In a study involving multiple sites with geographically distant locations whose planting dates will depend on local weather conditions, more equipment is necessary than for a study with only one research site, and at times it may not be readily available. In addition, though we plan on looking at a diverse precipitation gradient and soil conditions, it is not possible to cover all physical conditions that may affect the behavior of water on the landscape. We anticipate our physically based modeling effort to fill some of these gaps and identify future research needs.

We expect the result of the GIS and physical based model to show the tradeoffs between water use, runoff, and groundwater recharge that would occur with large-scale adoption of BMPs. We would expect that these tradeoffs would be different for different sets of weather conditions. We would also expect that the system could be optimally managed by focusing BMPs on certain soil types and fields of a certain geometric configuration (i.e. short vs. long furrows, wide vs. narrow fields).

Qualifications of the applicants and cooperators

As noted above, SAFS and LTRAS have a well-established and reputable history investigating the biological and economic viability of sustainable management practices. The researchers involved in our long-term projects represent many disciplines. Space restrictions of the proposal preclude a detailed list of each participant's qualifications; however this information is available in text form at both the SAFS website (http://safs.ucdavis.edu/) and LTRAS (http://LTRAS.ucdavis.edu). The details about the qualifications, the division of work, and responsibilities of each applicant and staff member is given in appendix 1.

Outreach, community involvement, acceptance and opposition

The impacts of the loss of the agriculture waiver cannot be understated, and it provides an exceptional opportunity to catalyze watershed-level integration of sustainable agriculture efforts. This project will utilize UC Davis' established position as a leader in grower-driven sustainable agriculture research to educate stakeholder groups on the feasibility of implementing BMPs that address concerns raised by the loss of the agricultural discharge waiver. Our intent is to fine tune, select or combines the necessary practices needed to bring different agricultural landscapes and cropping systems into compliance with water quality plans and regulations in both local and regional basis. In order to provide a wide range of growers with accessible information on runoff control, and provide a measurement system so that growers can gauge how they are doing in terms of implementing sustainable water conservation practices, we propose to develop a comprehensive Grower's Workbook to Water Conservation and Farm Level TMDL Compliance. The Workbook will take a farm level approach to sustainable water management, and is designed to:

- Provide a roadmap from conventional farming to sustainable farming.
- Provide educational material for implementing specific water conservation techniques.
- Provide growers a way to measure the level of adoption of sustainable water conservation practices on their farms and a way to track improvements.
- Document the level of sustainable farming adoption in the district.

The Workbook will provide growers with information to:

- Assist in measuring the level of adoption of sustainable farming practices.
- Identify areas of water quality concern on their farms.
- Determine which of these areas they would like to improve upon.
- Develop action plans to address these concerns.
- Implement these action plans.

In addition to the Workbook, the outcome of the studies will be disseminated to policy makers, watershed groups and commodity groups through our annual field days, newsletters, field tours, peer-reviewed articles, conferences, and a website. In keeping with the SAFS research paradigm, we will continue working closely with growers, local watershed groups, environmental and commodity groups, farm advisors, and extension personnel to adapt research objectives and disseminate results throughout the state of California. Our proposal has been endorsed by the Central Valley Regional Water Quality Control Board (CVRWQCB), Yolo County Flood Control and Water Conservation District (YCFCWCD), and the Yolo County Farm Bureau because of their interest to received accurate scientific information about NPS pollutants in the proposed project. They emphasized that the outcome of the project would extremely help growers to meet water quantity and quality objectives in most cost and environmental manner. Our proposal was opposed by the Tomato Grower's Association and Tomato Research Institute due to concerns that they may face additional regulatory issues from the state.

Innovation

For over a decade, the SAFS and LTRAS projects at UC Davis have demonstrated the effectiveness of developing relevant and economically viable sustainable agriculture strategies. Our current investigations into runoff monitoring combined with our ongoing efforts to promote sustainable agriculture practices make us well-equipped to inform growers and policy makers about appropriate water conservation strategies. We believe there is significant potential for development of BMPs that improve environmental quality while keeping farming operations profitable and sustainable. However, the relation of physical parameters to in-field management is difficult to predict and therefore an integrated landscape and regional approach is needed to effectively address the influence agricultural practices on water quality. To increase irrigation efficiency and reduce runoff and NPS pollution loads, improved management practices and their site-specific interactions must be understood and quantified Applying universal, formulaic approaches to NPS management in diverse locations without quantitative understanding of the factors controlling runoff is unlikely to achieve public policy goals for reduced NPS pollution from farms that the goal of our studies is to understand, refine, select and combine the practices needed to bring different agricultural landscapes and cropping systems into compliance with water quality plans and regulations.

Very large-scale experimental work at the LTRAS/SAFS site can be linked to a network of on-farm trials located around the valley through empirical measurement, GIS/GPS techniques, simulation modeling and site-specific management. This innovative approach will provides a quantitative basis for assessment and prediction of runoff from an array of farm conditions beyond those measured. It will measurably increase the rate at which effective NPS reduction can occur, improve the economic efficiency of NPS management, and help lead to desirable policy outcomes. A farm scale research facility is needed for the core measurements required for this innovative approach. There are several advantages to be derived from this facility:

- Hypothesis testing addressing causes of runoff, the effects of differing farming practices on runoff volume and NPS pollutant content can be made.
- A precise ability to control the farming practices and
- The effects of field length on runoff volume and NPS content can be quantified

Benefits and Costs

Farm Profitability

Potential economic benefits derived from adoption of CT and/or CC strategies are numerous, and have been addressed in previous sections.

CT by definition reduces the number of preplant operations and thereby reduces the amount of fuel, labor and equipment needed to produce a crop. Further cost savings may be realized in terms of reduced fertilizer applications, and water conservation. The aggregate impacts on weed populations and yield are not clear and may either increase or decrease as a result of the adoption of CT.

With CT practices, the use of CC increases both the number of field operations and their costs, compared to the use of synthetic fertilizers. For the crops included in this study, typically five preplant operations occur before planting. Using a CC adds three to four passes: planting, mowing and disking one or two times. The cost of ground preparation, excluding the CC, ranges from $35 to $55 per acre, about two hours of operation time, which accounts for from 10 to 33 per cent of cultural costs (not including harvest). The cost of the CC adds from $35 - $55 per acre compared to about $20 per acre to apply synthetic fertilizers.

Other important implications relate to constraints on the timing of operations. One problem with the use of CC in field crop production in California is the need to cut and incorporate the CC and make beds in the early spring. Weather often interferes with these operations, leading to late planting and forcing operations to be performed under suboptimal moisture conditions. A decrease in the number of preplant operations would relieve these timing constraints and reduce production risk. Weeds may be encouraged.

The farming operations related to each of the farming systems will be recorded with respect to date, equipment use and material use. All costs of materials and equipment will be obtained by local input suppliers. Yields and prices received will be recorded. Hours of operation and labor hours will be calculated using the Budget Planner model, since the actual hours per acre in the trial plots cannot be extrapolated to a farm scale operation because of the relatively higher number of turns required in a field trial.

As stated above, CT will most likely have differing effects on the energy efficiency of the three farming systems. Pre-plant tillage operations will be greatly reduced, but cover-cropping will add some operations. Over time, effects on soil tilth of cover-cropping could reduce the horsepower needed to draw implements through soil.

Energy Efficiency

Most studies of energy flow in agroecosystems have concentrated on the efficiency of humanly-supplied energy use in production of saleable biomass (see, for example, Giampietro, 1993; Livingston, 1995). This approach has provided much useful information about the degree to which conventional agriculture is dependent upon fossil fuel inputs. It does not, however, take into account the portion of energy flow that is devoted to stabilizing biosphere function. This is an area of agroecosystem research that needs attention.

In this study, energy flow will be partitioned into inputs or costs, and outputs or benefits. Energy inputs or costs will be taken to be only those energy inputs which humans supply or induce to occur. Biomass will be considered to be an energy benefit, and will be further

partitioned into that which would be saleable and that which would stabilize biosphere function. Saleable benefits, in this agroecosystem, would include tomato fruit and cereal grain. Benefits that would stabilize biosphere function would include soil organic matter, plant residues, and root systems. Ratios will be taken of the energy value (benefits) of total, saleable, and stabilizing biomass to the energy costs of producing the biomass. These ratios will then use as a basis of comparison of the different management systems.

Budget Justification

The total cost of the proposed project is estimated at $1,692,673. The faculty of Agriculture and Environmental Sciences has contributed $50,000 to the project for the development of an area to install runoff drainage, setup of the experiment and other measurement system at UC Davis Russell Ranch study field. Each of the 11 Principal Investigators from SAFS at UC Davis will be devoting approximately 5% of his or her time to the project, for a total of $213,263 during the study period. Applicants are sharing 17% of the total cost of the project and are requesting for 83% of the cost of the budget i.e. $1,421,980 to the Agricultural Water Use Efficiency Programs at the Department of Water Resources. An in-kind service will be provided by the individual growers participating in the project by providing land, labor and other facilities. The detailed budget justification showed below:

(i) **Personnel.** A) Funds are requested for 50% of Outreach Coordinator salary ($22,500/yr) for three years. She will work on the publication of the Irrigation Manual for the growers; additionally she will maintain project website and audiovisual library, coordinate annual field days and farm tours, produce three newsletters and at least two trade journal articles per year, coordinate the hosting and mentoring of students from the FARMS program. B) Funds are requested for full time Assistant Specialist salary ($36096/yr) for three year. He will be responsible to setup experiment, install autosamplers, collects water samples download data and analyses. C) Funds are also requested for 50% of two Junior Specialists salaries ($16,554/yr) for 3 yrs. One of them will work on the pesticides analyses and other will work on the core experimental setup, equipment maintenance, irrigation coordination etc. d) Funds requested for a fulltime postdoc ($36,405/yr) for two years. He/she will be responsible to work on the hydrology based modeling and GIS application in hydrology and help in preparation of irrigation manual. E) Funds requested for 50% salary ($25,450/yr) of Research Manager for 3 yrs. He will be primary responsibility for managing the project, Duties such as employee supervision, data management, budget management, report production, meeting facilitation, and acting as liaison to funding agencies. F) Funds are also for two instate fulltime graduate students. Salary for each student $34956/yr, at 46%, 720 hrs/yr for 3 yrs (4% benefits 25% Indirect Costs and $28221 for 3 yrs of student fees). One of the students will responsible for economic analyses and economic modeling and other will be responsible for water use efficiency, runoff and water quality research. Two student assistant funds are requested ($8/hr) for three yrs. Student Assistant will help Assistant Specialist, Graduate students and Postdoc in their fields and lab works.

(ii) **Benefits:** Benefits are calculated at 17% of academic salaries and at 4% of graduate student's salaries.

(iii) **Office equipment.** Two laptops ($2000/each) are requested for the modeling and data entry and analyses.

(iv) **Laboratory supplies**: Funds are requested for the nutrients and sediments lab at $11000/yr for a total of $33,000 for three yrs. and $8000/yr for a total of $24,000 for 3 yrs for pesticides lab.

(v) **Other supplies**: Funds are requested for outreach, office, computer and meeting supplies a total of $11,760.

(vi) **Travel expenses:** Funds are requested for travel to the national and international conferences a total of $6000 ($2000/yr) for 3 yrs.

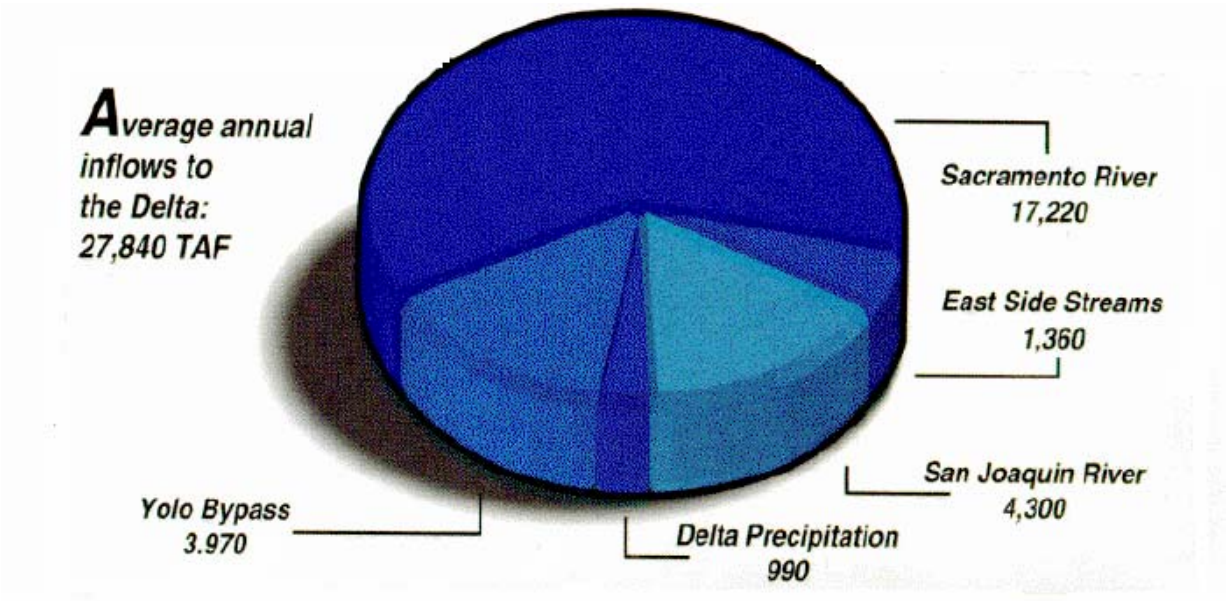
(vii) **Equipment purchase and rental**: The equipments funds ($127,245 for 3 yrs) are requested for six autosamplers for runoff and flow monitoring, 6 rain gauges for each runoff measurement stations, 3 engine and pump stations, water distribution and pipe fitting, water metering and filtration systems, laser leveling of the fields, equipments and tractor rentals, Van rental for extension and research works and equipments maintenance.

(viii) **Materials/Installation/Implementation**: Funds are requested for field operations, seeds, fertilizers, pesticides, district water costs etc. at $35,000/yr for 3 yrs.

(ix) **Report preparation**: Funds requested for report preparation ($54,838 for 3 yrs). This includes publishing an Irrigation Manual for the growers ($20,000), Newsletter printing and mailing, scientific manuscripts printing costs, speakers for the Field Days and preparation for the draft and final reports to the Department of Water Resources.

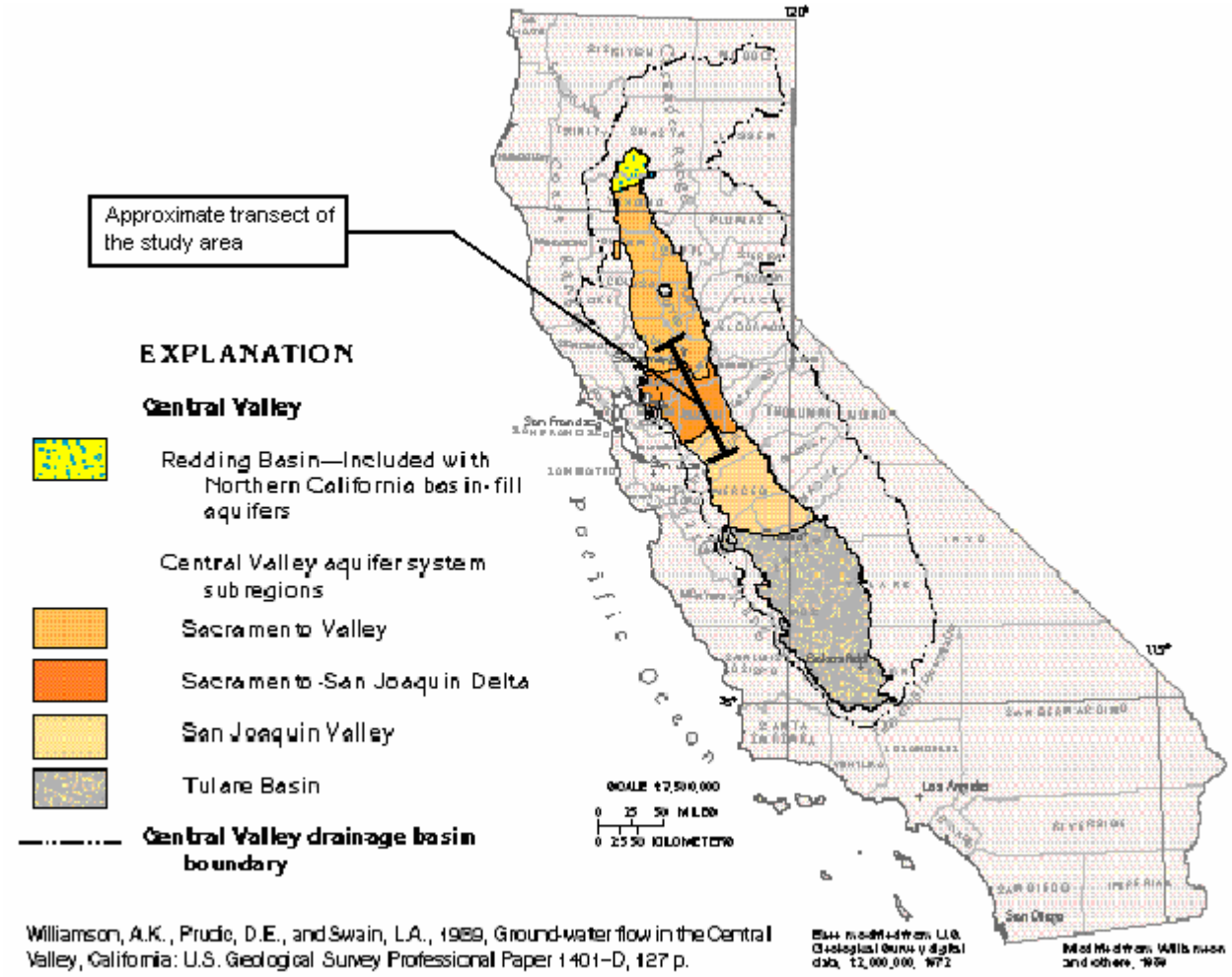
(x) **Overhead** i. e. I**ndirect** Costs is 25% of a modified total direct cost. This indirect cost rate is based on the waiver established between the State of California and the Regents of the University of California on May 9, 2003.

Figure 1. Average annual inflows to the Delta



All values in thousands acre-feet (TAF)

Figure 2. The Central Valley aquifer that is divided into sub-regions on the basis of surface-water



Appendix 1. Qualifications of applicants and division of work

Participant	Current title and research/work experience	Responsibilities
All participants	See below	Will give presentations of research results at professional and other meetings, collaborate in producing research publications, participate in field days, and participate in radio, newspaper, magazine, and television interviews as requested.
William R. Horwath, Ph.D. (530) 754-6029 wrhorwath@ucdavis.edu	Professor of Soil Biogeochemistry, Department of Land, Air and Water Resources. His research emphasizes the fate of nutrients in agricultural systems. His research programs deal with both plant nutrient use efficiency and movement of nutrients from agricultural land. In his studies on plant nutrients, he emphasizes the role of soil organic matter and fertilizers in supplying nutrients to crops. In addition, the factors controlling the availability and movement of nutrients are examined. Dr. Horwath has studied riparian systems and the movement of nitrogen, phosphorus and pesticides from adjoining agricultural land. Currently is involved in studies determining the fate of nitrate nitrogen in orchards and row crops and nitrate contamination from dairy operations.	Will supervise measurement of sediment and nutrient content of runoff from all sites. He will supervise a graduate student who will directly involve in sampling soil and water, analyzing samples and collecting data in this project. Will also supervised a laboratory assistant who will process and analyze samples. He will also monitor soil nutrient content and mineralization and organic matter dynamics.
Wes W. Wallender, Ph.D. (530) 752-0688 wwwallender@ucdavis.edu	Professor at the University of California, Davis in the Departments of Land, Air and Water Resources (Hydrology Program) and Biological and Agricultural Engineering. Has published more than 50 journal articles on surface irrigation hydraulic modeling. In 1992-3 was Director of the University of California Salinity/Drainage Research Program where he administered the development, interpretation, and dissemination of research knowledge addressing critical environmental problems on salinity, drainage, selenium, and other toxic elements in the San Joaquin Valley.	Will supervise hydrological measurements (runoff, infiltration) and modeling at the SAFS site and at growers' fields in different Counties. He will supervise a Project Scientist who will collect data and assist with modeling efforts.
Karen Klonsky, Ph.D. (530) 752-3563 klonsky@primal.ucdavis.edu	Extension Specialist in the Department of Agricultural and Resource Economics at the University of California - Davis for the past 20 years. She is also Associate Director of the Agricultural Issues Center, University of California. Dr. Klonsky has conducted extensive research on the economic feasibility of alternative farming practices in California with an emphasis on organic farming.	Will analyze the economic feasibility and sustainability of the farming systems under study. She will also supervise a graduate student who will help conduct the ecological-economic cost-benefit analysis.
Jeffrey P. Mitchell, Ph.D. (559) 646-6565 mitchell@uckac.edu	Cooperative Extension Specialist in the Department of Vegetable Crops and Weed Science at the University of California, Davis. Has published over 45 peer-reviewed publications in a variety of fields including crop physiology, soil quality, cover crop practices and conservation tillage. Since 1996, has served as the University of California's Division of Agriculture and Natural Resources Conservation Tillage Workgroup Chair. His current research focuses on conservation tillage production systems, improving production efficiencies in terms of profitability, energy and water use and long-term soil resource quality and carbon sequestration.	Will supervise conservation tillage operations and soil quality and hydrological data collection in growers' fields in Stanislaus County. He will supervise CT equipment transport and maintenance. He will directly supervise one assistant who will collect data to analyze soil quality and soil-water relations in growers' fields.
Howard Ferris, Ph.D. (530) 752-8432 hferris@ucdavis.edu	Professor of Nematology. Holds graduate degrees in Nematology and Plant Pathology. His research interests, relative to the current project, are the exploration of structure and function in soil food webs. He is enthusiastic about the potential of nematode faunal analysis as a bioindicator tool for studying food web dynamics and processes. In recent and ongoing research he has explored the response of nematode functional guilds to food web enrichment and perturbation. In studies on the biology and management of detritivore nematodes, he has contributed to the design of crop management alternatives that increase rates of nitogen mineralization in soil.	Will monitor the soil food web as it relates to soil nutrient mineralization and organic matter dynamics and consequent nurient runoff, and determine how management practices affect these relationships.
Kate Scow, Ph.D. (530) 752-4632 kmscow@ucdavis.edu	Professor and soil microbial ecologist in the Dept. of Land, Air and Water Resources. She earned a BS in Biology from Antioch College and both an MS and PhD in Soil Science at Cornell University. Her lab's research concerns the fate and transport of organic chemicals in soils and water; biodegradation of contaminants; and understanding the responses of soil microbial communities to pollution. She has also been involved in the Sustainable Agricultural Farming Systems Project studying how agricultural management practices influence microbial communities and processes.	Will supervise measurement of pesticide content of runoff from all sites. She will supervise a lab assistant who will process and analyze samples. Dr. Scow will also monitor soil microbial populations and diversity and their relationships to nutrient mineralization and organic matter dynamics and consequent nutrient runoff.

Continued

Participant	Current title and research/work experience	Responsibilities
Steven R. Temple, Ph.D. (530) 752-2023 srtemple@ucdavis.edu	Agronomist and Grain Legume Specialist, UC Davis. Professional career spans 28 years of applied research and extension activities in grain and cover crop legume breeding and agronomy, cropping systems, international ag development, and sustainable ag research and education. Developed and released more than 50 dry bean varieties, emphasizing host-plant resistance to insects, diseases, and nematodes, as a means to sustain high yields without dependence on chemical inputs. Extensive experience in various forms of participatory and on-farm research and extension, and in multidisciplinary, team research and education projects.	Will provide guidance for all agronomic operations and monitor crop yields, productivity, and pest predation, as well as evaluate specific cover crops for use in these systems.
Steve Kaffka Ph.D. (530) 752-8108, srkaffka@ucdavis.edu	Director of the Center for Integrated Farming Systems (the Russell Ranch facilites) and Extension Specialist –in the Department of Plant Sciences at the University of California, Davis. His professional interest in investigates ways to improve crop production efficiency and environmental quality relative to crop production. Works at the commodity, farming systems and water shed scales.	Provides overall management and direction for the Russell Ranch facilities. Will supervise all farming operations at the Russell ranch research facilities, and keeping records of prices and amounts of all farming inputs, yields, and prices received for crops. Will devote time to participation and planning of outreach activities and provide technical assistance to growers interested in CT.
Louise Jackson, Ph.D. (530) 754-9116 lejackson@ucdavis.edu	Professor and Cooperative Extension Specialist in Agricultural Ecology. Her research and education program spans the continuum from basic research in soil biology and plant ecophysiology to working with farmers to improve soil management practices. Areas of expertise are: soil microbial nitrogen cycling; root biology; plant water relations and nutrient uptake; arbuscular mycorrhizae; ecosystem-level nitrogen and water budgets; and organic and conventional vegetable production. Has worked in the Central Valley tomato production systems since 1988, and has published numerous scientific articles on soil microbial ecology, soil nitrogen dynamics, and plant nitrogen use in these systems.	Will monitor plant water relations and nutrient uptake, particularly concentrating on N dynamics, and will develop system-level N, C, and water budgets.
Lynn Epstein, Ph.D. (530) 752-5026 lepstein@ucdavis.edu	Professor, Plant Pathology. Interested in the development, implementation, and monitoring of sustainable disease and pest control. In addition to working on particular disease problems, she is involved in studies that use the California Pesticide Use Reports to monitor the impact of Integrated Pest Management Programs on pesticide use.	Will monitor plant diseases and identify relationships between management practices and disease levels
W. Thomas Lanini, Ph.D. (530) 752-4476 wtlanini@ucdavis.edu	Extension Weed Ecologist, UC Davis. His research over the past 15 years has focused on low-input weed control. The approaches on which he has conducted research include biological control, mulches, cultivation, selective water placement (buried drip irrigation), as well as reduced rate herbicide treatments. Most recently, he has been focusing on precision weed control, applying herbicides only where they are needed and at rates appropriate for the species and density of weeds.	Will supervise monitoring of weed populations and biomass, and develop and test new approaches to weed management in the alternative systems.
Shrini Upadhyaya, Ph.D. (530) 752-8770 skupadhyaya@ucdavis.edu	Professor, Biological and Agricultural Engineering. Research career spans 30 years of work in development of systems for in-situ measurements of spatial variability in soil physical and chemical properties, with the goal of development of precision agriculture. Has published numerous research articles on and developed technology for in situ measurement of soil tilth, compaction, moisture content, infiltration, spatial variability, nitrate content, and others.	Will supervise collection of soil compaction and tilth data. Will supervise a student who will test and utilize new methods for collecting this data.
Zahangir Kabir, Ph.D (530) 754-6497 kabir@ucdavis.edu	Research Manager, Sustainable Agriculture Farming Systems Project. Ph.D. in Soil Science, McGill University, Canada. Primary interest is in sustainable and organic crop production; with the objective of understanding and implementing economically viable and environmentally benign methods, without disregarding essential aspects of crop production (such as crop yield and quality necessary to meet increasing market demand as well as grower profitability). These areas of research included cover cropping, crop rotation, biofumigation, conservation tillage, nutrient management, microbial inoculum and weed management.	Will have primary responsibility for managing the project, Duties such as employee supervision, data management, budget management, report production, meeting facilitation, and acting as liaison to funding agencies. He will integrate and synthesize research results from the various disciplines represented on the project; coordinate the input of data. He will devote to outreach activities such as giving presentations of integrated research results to the watershed groups, workshops and conferences...
Samuel Prentice (530) 752-2023 seprentice@ucdavis.edu	Project Supervisor, Department of Land, Air and Water Resources, SAFS Water Quality Project. Prentice primary research interests are in the general fields of hydrology, geomorphology, and water resources	Will be responsible for analyzing rainfall and runoff data and developing linear and nonlinear models. He will also be responsible for writing trade journal articles, peer-reviewed manuscripts and reports.

Continued

Participant	Current title and research/work experience	Responsibilities
Lyra Halprin (530) 752-8664 lhalprin@ucdavis.edu	Senior Public Information Officer Sustainable Agriculture Research & Education Program (SAREP)	Will maintain project website and audiovisual library, coordinate annual field days and farm tours, produce three newsletters and at least two trade journal articles per year, coordinate the hosting and mentoring of students from the FARMS program, produce popular media articles as requested, coordinate living laboratory and mentoring for K-12 and university courses in agricultural and environmental sciences, develop interpretive poster displays for use at conferences, trade fairs, and visitors' centers, develop extension bulletins and other extension materials such as an audiotutorial PowerPoint presentation.
James Cannon 530-754-8555 jhcannon@ucdavis.edu	Computer Resource Specialist II, SAREP	SAFS Web site creation/maintenance including posting newsletters, PowerPoint presentation, and other information; assist with mailing database for newsletters
Bruce Rominger (530) 662-5787 brrominger@ucdavis.edu	Grower-collaborator. Farms organically and conventionally.	Will participate in planning and design of research as well as interpretation and dissemination of results. Will participate in field/demonstration days, offer farm tours, participate on grower panel presentations, and give individual research presentations. Has offered land for demonstration trials.
Scott Park (530)682-5695 parkfarm@syix.com	Grower-collaborator. Has farmed 1100 acres organically and conventionally for over 20 years.	Same.
Ed Sills (916) 655-3391 esills@ns.net	Grower-collaborator. Grows organically on 2000 acres in Sutter County.	Same
Frank Muller	Grower-collaborator Grows sustainable and conventionally on 2700 acres in Yolo/Sacramento counties	Same
Tony Turkovich (530) 795-2090 tturk@bigvalley.net	Grower-collaborator. Grows organically and conventionally in Yolo County.	Same
James Durst (530) 787-3390 jdurst@onemain.com	Grower-collaborator. Grows organically on 600 acres in Yolo County.	Same
Gene Miyao (530) 666-8143 FAX 666-8732 emmiyao@ucdavis.edu	Vegetable Crops farm advisor, UC Cooperative Extension, Yolo/Solano Counties	Will participate in planning and design of research as well as interpretation and dissemination of results. Will participate in field/demonstration days, offer farm tours, participate in panel presentations, and give individual research presentations.
Kent Brittan (530) 666-8143 klbrittan@ucdavis.edu	Field Crop farm advisor, University of California Cooperative Extension. Yolo, Solano, and Sacramento Counties.	Same

Appendix 2.

Measurements

Table 1 summarizes the methods, reporting units and sample types used in this study. With the exception of precipitation, all water samples represent agricultural runoff collected via automated samplers (ISCO Model 6712 Autosampler, Lincoln, NE). Precipitation will be collected via a rain gauge.

Table 1. Analyte with Corresponding Units and Methods.

Analyte	Units	Method of Analysis
Ammonia	mg N/L	Manual phenate method (*Standard Methods*, 20th ed., APHA/AWWA/AWF, method 4500-NH_3 F.)
Carbon, organic	mg/L	UV-persulfate oxidation Phoenix 8000 (Teledyne-Tekmar, Mason, OH)
Electrical conductivity	µS/cm	Model 220 conductivity meter (Denver Instr. Co., Arvada, CO)
Nitrate + Nitrite	mg N/L	Automated FIA cadmium reduction QuikChem Method 12-107-04-1-B (Lachat Instruments, Milwaukee, WI)
Nitrogen, total	mg N/L	Persulfate digestion (*Standard Methods*, 4500-N C.)
Phosphate, ortho	mg P/L	Manual ascorbic acid method (*Standard Methods*, 4500-P E.)
pH	pH units	Model 220 pH meter (Denver Instr. Co., Arvada, CO)
Phosphorus, total	mg P/L	Persulfate digestion (*Standard Methods*, 4500-P B.)
Total suspended solids	g/L	0.45 micron filtration and drying at 103-105°C
Turbidity	NTU	Micro 100 turbidimeter (HF Scientific, Ft. Myers, FL)
Precipitation	mm	Rain gauge (ISCO Model 674, Lincoln, NE)

Quality Assurance Plan Overview

Quality Assurance

The following set of operating principles will be adhered to during the course of this project to ensure production of data of known and defensible quality. This project will investigate the occurrence and distribution of nutrients, and other analytes in water from agricultural runoff. To achieve this goal, laboratory and field experiments will be performed for various chemical, biological, and physical components (Section 1.0). The raw data collection, documentation of standard materials, sample receipt, formulation of standard operating procedures, data documentation and reporting protocols for this study will be outlined in the following sections (6.0-27.0).

1.1. Quality Control

Quality control procedures will be discussed on a per-batch basis. A batch is defined as the number of water samples accommodated by an analytical procedure at one time. If the analysis does not have a set number of samples it can accommodate, the number of samples collected in one sampling period will be deemed a batch. The following special elements will be used for quality control. They will be applied to each analytical procedure for which they are applicable.

1.2 Certification of Operator Competence

Before any analyst will be permitted to do reportable work, competence in performing the analysis will be demonstrated. The analyst will make a minimum of four replicate analysis of an independently prepared check sample having a concentration between 5 and 50 times the method detection limit (MLD) for that procedure. Measured concentrations should be within 10% of actual concentrations. If the concentrations are not within range, problems will be resolved before the analyst is allowed to analyze samples.

1.3 Determination of Method Detection Limits

The method detection limits (MDL) of each analyte will be determined before initial analysis may begin and every six months. To determine MDL values, seven replicate aliquots of a blank fortified with a concentration of 2 to 3 times the estimated instrumental detection limit will be taken through the entire analytical process. Calculate the MDL as:

$$MDL = (t) \times (s)$$

Where t = the Student's t value for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom and s = the standard deviation of the replicate analyses.

1.4 Quality Control Check Standards (QCCS)

Accuracy of analytical procedures will be estimated by running external and internal standards and comparing the measured value with the actual known value. Quality control check standards (described here) will be run along with externally supplied standards (described below) and internal standards (IS). Acceptable accuracy levels are listed in Table 2.

A QCCS is a standard having a concentration of approximately the midpoint of the calibration range and is prepared exactly as the calibration standards are prepared from ACS certified reagents. The QCCS is analyzed after the calibration standards (before the first sample), as every tenth sample, and as the last sample of the batch. The QCCS should be within 10% of the actual concentration. If the concentrations

are not within range, problems should be resolved and all samples since the last good QCCS are re-analyzed.

Accuracy of air temperature, soil temperature, and precipitation will be performed by comparing the values taken by the Campbell CR10 datalogger to those read on manual models of thermometers and rain gauges.

1.5 Detection Limit Standards (DLS)

The DLS is a standard 2 to 5 times the required detection limit. One DLS is analyzed after the first QCCS and before the first sample (as the 2nd sample). The DLS should be within 20% of the actual concentration. If the DLS is not within range, problems will be resolved before continuing with the analysis.

1.6 Analysis of Externally Supplied Standards (ESS)

Two externally supplied, National Institute of Standards and Technology (NIST) traceable standards (ESS) will be run with each batch of samples. This will be done only for the initial batch analysis for each analyte. After the procedures have been tested with the ESSs and come out within range, these ESSs will be replaced in subsequent batch analyses with internal standards (IS). The ISs will be prepared as the calibration standards and QCCSs are but with a different stock reagents. These standards should be placed equidistant within each batch run. The measured concentration must be within 10% of the actual concentration. If the concentrations are not within range, problems should be resolved and all samples since the last good ESS are re-analyzed.

1.7 Analysis of Reagent Blanks

Reagent blanks will be analyzed whenever new reagents are used or as required by specific methods. For a batch of 100 samples, five reagent blanks will be analyzed per batch. One blank before the first sample and the others placed equidistant within the batch. Blanks will consist of the reagents used to prepare the calibration standards (i.e. reagent grade water).

1.8 Duplicate Sample Analysis Precision is a measure of similarity between repetitive analyses of a given sample. Overall precision for this project will come from the analysis of duplicate samples to assess random uncertainties. Calculations for precision follow that found in *Standard Methods for the Analysis of Water and Wastewater*. From duplicate analyses, the average difference is calculated by summing all the differences and dividing by the number of observations. Standard deviation is then calculated by dividing the sum of squares by the degrees of freedom and then taking the square root of this resultant number.

Four sample duplicates will be run in each batch of 100 samples. Precision levels for duplicate analysis are given in Table 2. These levels were taken from AWWA 1992 and will be modified to increase precision levels (decrease range) after the analysis of samples begins. Precision is specified by standard deviation and should be calculated after each batch is run and an accumulative precision should be calculated after every 20 duplicates have been run. Percent relative standard deviation (%RSD) will be calculated as shown in equations 1 and 2, between duplicates. The duplicate precision should not exceed the values given in Table 2. If duplicate %RSD values do fall outside the range, a problem exists, the problem should be resolved. After resolving the problem, a second sample should be analyzed in duplicate. Acceptable results should be obtained prior to further analysis.

$$\%RSD = (S/Xbar) \times 100 \qquad (1)$$

$$S = ((\sum(Xbar - X)^2)/(n-1))^{1/2} \qquad (2)$$

Environmental Variables:

Precipitation	mm	0-3	NA	NA	99%	100%
Runoff Flow	m^3s	0-100	NA	NA	NA	100%

1.9 Matrix Spike Analysis (MS)

Matrix spikes will only be run in the first set of analyses unless a need for further use is shown. In the first batch run, three matrix spikes will be quantified. The MSs will be prepared by spiking a portion of a sample with a known quantity of analyte. The spike concentration should be the larger of either two times the endogenous level or ten times the required detection limit. The volume of the spike should be negligible. Acceptable recovery levels for matrix spikes for the various analytes are shown in Table 3. After the first batch, including the matrix spikes, has been run and if it falls within desired limits, the sample spaces previously filled by the MS's will be filled with extra QCCS's.

Table 2. Acceptable Recovery Levels for Spiked Sample Analyses.

Analyte/ Procedure	Recovery of Known Additions Acceptable %	Analyte/ Procedure	Recovery of Known Additions Acceptable %
Ammonia	80-120	Bromide	80-120
Carbon, Inorganic	80-120	Denitrification	NA
Nitrogen, Total Kjeldahl	80-120	Phosphate, Ortho-	80-120
Phosphorous, Total Kjeldahl	80-120	Soil Redox Potential	NA
Total Suspended Solids	NA	NA	NA

The percent recovery of the spike is calculated as:

$$\%\ \text{spike recovery} = \frac{\text{measured concentration of sample + spike} - \text{measured concentration of unspiked sample}}{\text{actual concentration of spike added}} \times 100$$

2.1.10 Linear Calibration Range

The linear calibration range will be determined before analysis begins for each batch. Four or five known standards and a blank will be analyzed to verify linearity of the standard curve. Determined concentrations must be within 10% of the known values. The correlation coefficient of the standard curve must be between 0.99 and 1.00 before analysis can continue.

2.1 Quality Assessment/Oversight

2.2 Performance Audits

Performance audits will be conducted once every six months by the principal investigators. The purpose of the audits is to detect any deviations from the standard operating procedures so that corrective actions can be taken. The audit should be performed with a checklist which assesses daily, weekly, monthly, and yearly operation procedures. These procedures should include routine operations, calibration, and maintenance procedures.

Table 3. Example Performance Audit for Determination of Total Suspended Solids.

Procedure	Comment	Remarks
1. Balance calibrated	yes	Once a year
2. Balance cleaned and zeroed	yes	Daily
3. Filters dried for 2 hours at 103-105ºC	yes	Daily
4. Data Sheet filled out	no	Site ID not written down
5. Vacuum filtration procedures followed	yes	Batch of water samples properly filtered
6. Drying procedures followed	yes	Final weight recorded

During the performance audit the MLD should be redetermined and externally supplied samples with known analyte concentrations should be analyzed by the analyst (Environmental Monitoring Systems Laboratory, U.S. EPA, 26 West Martin Luther King Drive, Cincinnati, Ohio, 45268). The measured concentrations should be within 10% of the actual known concentrations.

2.3 Control Charts

Control charts will be prepared for each analytical procedure. The charts will be constructed from the average and standard deviations of the standards. The charts will include the central baseline (mean), the upper and lower warning levels (+/- 2 standard deviations), and the upper and lower control levels (+/- 3 standard deviations). These values should be obtained from standard reference materials. The X axis of the chart is time and the Y axis is concentration. Every time a QCCS or an ESS (IS) is analyzed it is plotted on the chart as a point.

If a point exceeds the control level, the analysis of the standard should be repeated immediately. If this new analysis is within range, the analysis should continue; if it again exceeds the control limit, the analysis should be discontinued until the problem can be corrected. If two out of three successive points fall outside of the warning levels, another sample should be analyzed. If the next point is within the levels, the analysis may continue; if it also exceeds the levels, the analysis must be discontinued until the problem is corrected.

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Applicant: William R. Horwarth

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Section A projects must complete Life of investment, column VII and Capital Recovery Factor Column VIII. Do not use 0.

Table C-1: Project Costs (Budget) in Dollars)

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)	Life of investment (years) (VII	Capital Recovery Factor (VIII)	Annualized Costs $ (IX)
	Administration[1]								
	Salaries, wages	$800,921	0	$800,921	$165,000	$635,921	0	0.0000	$0
	Fringe benefits	$107,165	0	$107,165	$28,050	$79,115	0	0.0000	$0
	Supplies	$68,760	5	$72,198	$0	$72,198	0	0.0000	$0
	Equipment (laptops)	$4,000	0	$4,000	$0	$4,000	0	0.0000	$0
	Consulting services	$0	0	$0	$0	$0	0	0.0000	$0
	Travel expences	$6,000	0	$6,000	$0	$6,000	0	0.0000	$0
	Other		0	$0	$0	$0	0	0.0000	$0
(a)	Total Administration Costs	$986,846		$990,284	$193,050	$797,234			$0
(b)	Planning/Design/Engineering	$0	0	$0	$0	$0	0	0.0000	$0
(c)	Equipment Purchases/Rentals/Rebates/Vouchers	$127,245	5	$133,607	$40,000	$93,607		0.0000	$0
(d)	Materials/Installation/Implementation	$105,000	5	$110,250	$10,000	$100,250	0	0.0000	$0
(e)	Implementation Verification	$0	0	$0	$0	$0	0	0.0000	$0
(f)	Project Legal/License Fees	$0	0	$0	$0	$0	0	0.0000	$0
(g)	Structures	$0	0	$0	$0	$0	0	0.0000	$0
(h)	Land Purchase/Easement	$0	0	$0	$0	$0	0	0.0000	$0
(i)	Environmental Compliance/Mitigation/Enhancement	$0	0	$0	$0	$0	0	0.0000	$0
(j)	Construction	$0	0	$0	$0	$0	0	0.0000	$0
(k)	Other (Specify) Overhead (25%)	$307,369	0	$307,369	$48,263	$259,107	0	0.0000	$0
(l)	Monitoring and Assessment (nutrients and Pesticides analyses)	$111,375	5	$116,944	$0	$116,944	0	0.0000	$0
(m)	Report Preparation	$54,838		$54,838	$0	$54,838	0	0.0000	$0
(n)	**TOTAL**	$1,692,673		$1,713,292	$291,313	$1,421,980			$0
(o)	Cost Share -Percentage				17	83			

1- excludes administration O&M.

Applicant:

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Table C-2: Annual Operations and Maintenance Costs

Operations (1) (I)	Maintenance (II)	Other (III)	Total (IV) (I + II + II)
$0	$0	$0	$0

(1) Include annual O & M administration costs here.

Table C-3: Total Annual Project Costs

Annual Project Costs (1) (I)	Annual O&M Costs (2) (II)	Total Annual Project Costs (III) (I + II)
$0	$0	$0

(1) From Table C-1, row (n) column (IX)
(2) From Table C-2, column (IV)

Table C- 4: Capital Recovery Table (1)

Life of Project (in years)	Capital Recovery Factor
1	1.0600
2	0.5454
3	0.3741
4	0.2886
5	0.2374
6	0.2034
7	0.1791
8	0.1610
9	0.1470
10	0.1359
11	0.1268
12	0.1193
13	0.1130
14	0.1076
15	0.1030
16	0.0990
17	0.0954
18	0.0924
19	0.0896
20	0.0872
21	0.0850
22	0.0830
23	0.0813
24	0.0797
25	0.0782
26	0.0769
27	0.0757
28	0.0746
29	0.0736
30	0.0726
31	0.0718
32	0.0710
33	0.0703
34	0.0696
35	0.0690
36	0.0684
37	0.0679
38	0.0674
39	0.0669
40	0.0665
41	0.0661
42	0.0657
43	0.0653
44	0.0650
45	0.0647
46	0.0644
47	0.0641
48	0.0639
49	0.0637
50	0.0634

(1) Based on 6% discount rate.

Applicant:

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Table C-5 Project Annual Physical Benefits (Quantitative and Qualitative Description of Benefits)

	Qualitative Description - Required of all applicants[1]				**Quantitative Benefits - where data are available [2]**
	Description of physical benefits (in-stream flow and timing, water quantity and water quality) for:	Time pattern and Location of Benefit	Project Life: Duration of Benefits	State Why Project Bay Delta benefit is Direct[3] Indirect [4] or Both	Quantified Benefits (in-stream flow and timing, water quantity and water quality)
Bay Delta				Both	0
Local				**Not applicable.**	

[1] The qualitative benefits should be provided in a narrative description. Use additional sheet.

[2] Direct benefits are project outcomes that contribute to a CALFED objective within the Bay-Delta system during the life of the project.

[3] Indirect benefits are project outcomes that help to reduce dependency on the Bay-Delta system. Indirect benefits may be realized over time.

[4] The project benefits that can be quantified (i.e. volume of water saved or mass of constituents reduced) should be provided.

Applicant:

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Table C-6 Project Annual Local Monetary Benefits

ANNUAL LOCAL BENEFITS	ANNUAL QUANTITY	UNIT OF MEASUREMENT	ANNUAL MONETARY BENEFITS
(a) Avoided Water Supply Costs (Current or Future Source)	0		$0
(b) Avoided Energy Costs	0		$0
(c) Avoided Waste Water Treatment Costs	0		$0
(d) Avoided Labor Costs	0		$0
(e) Other (describe)	0		$0
(f) Total [(a) + (b) + (c) + (d) + (e)]			$0

Table C-7 Project Local Monetary Benefits and Project Costs

(a) Total Annual Monetary Benefits [(Table C-6, row (f)]		$0
(b) Total Annual Project Costs (Table C-3, column III)		$0

Table C-8 Applicant's Cost Share and Description

Applicant's cost share %: (from Table C-1, row o, column V)	**17**
Describe how the cost share (based on relative balance between Bay-Delta and Local Benefits) is derived. (See Section A-7 for description.)	
Provide Description in a narrative form.	