

MONITORING AND ASSESSMENT OF SOIL SALINITY, BORON, AND SELENIUM IN DRAINAGE-IMPACTED LANDS

A Research Proposal submitted to

CALIFORNIA DEPARTMENT OF WATER RESOURCES

CALIFORNIA BAY-DELTA WATER USE EFFICIENCY PROGRAM, Section
B

by

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January 11, 2005

Project Information Form

Applying for:

Urban

Agricultural

1. (Section A) **Urban or Agricultural Water Use Efficiency Implementation Project**

(a) implementation of Urban Best Management Practice, # _____

(b) implementation of Agricultural Efficient Water Management Practice, # _____

(c) implementation of other projects to meet California Bay-Delta Program objectives, Targeted Benefit # or Quantifiable Objective #, if applicable

(d) Specify other: _____

2. (Section B) **Urban or Agricultural Research and Development; Feasibility Studies, Pilot, or Demonstration Projects; Training, Education or Public Information; Technical Assistance**

(e) research and development, feasibility studies, pilot, or demonstration projects

(f) training, education or public information programs with statewide application

(g) technical assistance

(h) other

3. Principal applicant
(Organization or affiliation):

California State University, Fresno Foundation

4. Project Title:

Monitoring and assessment of soil salinity, boron, and selenium in drainage-impacted lands

5. Person authorized to sign and submit proposal and contract:

Name, title Thomas McClanahan

Associate Vice President

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Telephone (559) 278-0840

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6. Contact person (if different)	Name, title	<u>Florence Cassel S.</u>
		<u>Soil and Water Scientist</u>
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7. Grant funds requested (dollar amount): \$192,872
(from Table C-1, column VI)

8. Applicant funds pledged (dollar amount): \$100,000

9. Total project costs (dollar amount): \$292,872
(from Table C-1, column IV, row n)

10. Percent of State share requested (%) 66%
(from Table C-1)

11. Percent of local share as match (%) 34%
(from Table C-1)

12. Is your project locally cost effective?
Locally cost effective means that the benefits to an entity (in dollar terms) of implementing a program exceed the costs of that program within the boundaries of that entity. (a) yes

(If yes, provide information that the project in addition to Bay-Delta benefit meets one of the following conditions: broad transferable benefits, overcome implementation barriers, or accelerate implementation.) (b) no

11. Is your project required by regulation, law or contract? (a) yes
If no, your project is eligible.

If yes, your project may be eligible only if there will be accelerated implementation to fulfill a future requirement and is not currently required. (b) no

Provide a description of the regulation, law or contract and an explanation of why the project is not currently required.

12. Duration of project (month/year to month/year): 01/2006 to 12/2008
13. State Assembly District where the project is to be conducted: 26 and 30
14. State Senate District where the project is to be conducted: 12 and 16
15. Congressional district(s) where the project is to be conducted: 18 and 20
16. County where the project is to be conducted: Fresno, Kern counties
17. Location of project (longitude and latitude): Subregions 10 and 14
(West side San Joaquin Valley)
18. How many service connections in your service area (urban)? N/A
19. How many acre-feet of water per year does your agency serve? N/A
20. Type of applicant (select one):
- (a) City
 - (b) County
 - (c) City and County
 - (d) Joint Powers Authority
 - (e) Public Water District
 - (f) Tribe
 - (g) Non Profit Organization
 - (h) University, College
 - (i) State Agency
 - (j) Federal Agency
 - (k) Other
 - (i) Investor-Owned Utility
 - (ii) Incorporated Mutual Water Co.
 - (iii) Specify _____
21. Is applicant a disadvantaged community? If 'yes' include annual median household income. (Provide supporting documentation.)
- (a) yes, _____ median household income
 - (b) no

Signature Page

By signing below, the official declares the following:

The truthfulness of all representations in the proposal;

The individual signing the form has the legal authority to submit the proposal on behalf of the applicant;

There is no pending litigation that may impact the financial condition of the applicant or its ability to complete the proposed project;

The individual signing the form read and understood the conflict of interest and confidentiality section and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant;

The applicant will comply with all terms and conditions identified in this PSP if selected for funding; and

The applicant has legal authority to enter into a contract with the State.

Signature

Name and title

Date

A. PROJECT SUMMARY

Elevated levels of soil salinity, boron (B), and selenium (Se) are serious problems in many irrigated lands of California, and particularly in the Westside San Joaquin Valley (WSJV) due to high water tables and inadequate drainage that prevent leaching of soluble salts. The necessity to reduce these problems and improve the efficiency of irrigation water use has led to a collaborative effort between the California Department of Water Resources (DWR) and WSJV districts which called for the implementation of drainage management practices in the region. Such practices are expected to conserve irrigation water by reducing drainage water outflow within the farm boundaries. Knowledge of soil salinity, B, and Se distribution on a farm level is critical to evaluating the effects of the new practices and maintaining crop productivity. In 2001, a soil salinity assessment program was developed by the Center for Irrigation Technology (CIT) at California State University, Fresno with funding provided by the CALFED Water Use Efficiency Program. The goal of the project was to assess and map soil salinity using the electromagnetic (EM) technology in farms implementing drainage management practices within their boundaries. The salinity program was very successful and provided annual field salinity maps that were used by farmers and local/state/federal agencies as decision-making tools for improving drainage and irrigation management practices on the farms. The CALFED-supported program ended in June 2003. Since then, farmers and agencies, including the Westside Resource Conservation District, Westlands Water District, San Joaquin Valley DWR, and the Bureau of Reclamation have expressed the need to pursue the salinity program developed by CIT. Therefore, the goal of this project is to continue the salinity program started in 2001 and to extend it to soil B and Se assessment on drainage-impacted lands. The proposed research will be conducted over three years in several farms of sub-regions 10 and 14. It will partially address CALFED Quantifiable Objectives 106, 109, 163 and 166 by helping decrease flows to salt sinks and provide long-term diversion flexibility to increase the water supply for beneficial uses. The research will also help reduce salinity, B, and Se concentrations to enhance and maintain beneficial uses of water. The monitoring and assessment study will provide vital data for evaluating the extent of salinity, B, and Se problems in the surveyed lands and use this information as a decision-making tool for developing integrated drainage, irrigation and crop management strategies. The research will be valuable to WSJV growers, local/state/federal agencies, and the scientific community by evaluating the effectiveness of drainage reuse systems on reducing soil salinity, B, and Se and improving water use efficiency.

B. STATEMENT OF WORK

B.1. Relevance and Importance

B.1.a. Problem statement and project need

Elevated levels of soil salinity, boron (B), and selenium (Se) are important and persistent problems in many irrigated lands of California, and particularly in the Westside San Joaquin Valley (WSJV). Fine-textured soils, shallow clay layers, saline high water tables and inadequate drainage result in the build-up of salts and other elements due to reduced water percolation. The drainage-impacted lands of the WSJV are located in the San Joaquin and Tulare Basins which are filled with broad alluvial fans composed primarily of deposits derived from shale and

sandstone. These deposits, particularly dark shales and sediments, contain high, naturally-occurring concentrations of salts, Se and B (McNeill and Balisteri, 1989).

The San Joaquin Valley is a very productive agricultural area which is maintained through intensive irrigation. The application of irrigation water for crop production further exacerbates the salinity, B, and Se problems in soils and groundwaters. Approximately 45% of the state irrigated farmlands (10 million acres) are affected by saline soils or saline irrigation water (Letey, 2000). In the San Joaquin Valley (SJV), the net daily salt inflow during the irrigation season is about 1.46 million tons (San Joaquin Valley Drainage Program, 1998). Excessive soil salinity can affect crop productivity, soil structure, water quality, and eventually result in soil erosion and land degradation. Many agricultural crops are also sensitive to high boron concentrations in soils. Elevated selenium levels in drainage waters pose the greatest hazard for wildlife and animals causing reproductive failure and deformities in birds (Eisler, 1985).

Additionally, the intensive irrigation practiced by growers in the region contributes to high volume of subsurface drainage waters that must be discharged in regional drainage networks or pumped to evaporative sinks. The drainage waters usually contain elevated levels of salts and toxic trace elements, such as Se. Prior to 1985, the drainage waters collected from farmlands in the western Fresno County was discharged into the San Luis Drain with the ultimate objective of disposal into saline Bay-Delta waters. However, the San Luis Drain was closed due to public concern over the environmental degradation of the Sacramento-San Joaquin Bay-Delta estuary ecosystem as well as the increased selenium contamination at the Kesterson Reservoir which resulted in waterfowl poisonings and deformities. The termination of this drainage water disposal service has severely limited the drainage options available to growers.

Thus, local, state, and federal agencies, in collaboration with growers in the San Joaquin Valley, have responded to the need of developing drainage plans for reducing on-farm and regional drainage volumes and sustain crop production. Several methods were proposed to reuse the subsurface drainage waters collected from irrigation applications: 1) sequential reuse, 2) single reuse, 3) blending, and 4) cyclic use. These methods were evaluated by several researchers, including Rhoades (1989), Grattan and Rhoades (1990), Bradford and Letey (1993), Cervinka (1994), and Posnikoff and Knapp (1996). In sequential reuse systems, also called integrated on-farm drainage management systems, the drainage waters collected in subsurface tiles are used from one field to another to irrigate crops of increasing salinity and B tolerance. Drainage water, salts, B and Se are managed on the farm and are used as resources. The single reuse systems where drainage waters are utilized once for the irrigation of crops and forages are usually implemented as an initial phase of drainage management plan. In blending systems, saline water is mixed with good quality water to achieve an irrigation water of suitable quality based on the salt and B tolerance of the chosen crop. The cyclic method involves using saline drainage water only on certain crops and during specific crop stages. Good quality water is applied during salt-sensitive growth stages or when salt-sensitive crops are grown. Several benefits result from the implementation of reuse drainage systems: conservation of fresh canal water and decrease of the need for imported irrigation water; greater water availability for crop production; on-farm management of salt, B, and Se in the drainage water.

Monitoring and assessment of soil salinity, B, and Se levels in these drainage-impacted lands is important to determine the soil conditions and extent of the drainage problems over time, evaluate the benefits of the management practices, and recommend appropriate cropping systems. Therefore, we propose to monitor and assess salinity, B, and Se changes in the soil profiles over time by conducting annual surveys on farms implementing drainage management practices.

B.1.b Innovations in salinity, boron, and selenium monitoring and assessment

Limited methods are available to the growers to determine rapidly and precisely the extent of salinity, B, and Se problems on their farmlands. Soil salinity is difficult to quantify because of rapid changes over space and time. Traditional measurement methods, such as four-electrode probes and soil sampling, require extensive data collection and laboratory analyses that are very slow, labor-intensive, and expensive (Davis et al., 1999). However, the electromagnetic (EM) induction technique has become a very useful and cost-effective tool to monitor soil salinity over large areas, because it allows for rapid, aboveground measurements with non-invasive sampling (Ceuppens et al., 1997; McKenzie et al., 1997). Additionally, EM sensors generally provide better and faster estimates than direct methods (Sudduth et al., 1999). The EM instrument's transmitter coil induces a magnetic field in the ground, which in turn creates a secondary magnetic field that is measured by the receiver coil (McNeill, 1980). By producing this electromagnetic field, the EM meter is able to measure the depth-weighted apparent electrical conductivity (EC_a) in a volume of soil below both coils (Rhoades and Corwin, 1990). Since solid soil particles and rock material have very low EC (McNeill, 1980), the instrument response is primarily influenced by soil salinity. Several researchers have demonstrated the usefulness of EM surveys as a rapid and economical technique to provide 3-D quantification of soil salinity levels (Hendrickx et al., 1992; Lesch et al., 1992; Diaz and Herrero, 1992) as well as to predict potential crop yield reduction due to elevated salinity (Bennett and George, 1995). Additionally, the EM technique can also be used to monitor other soil properties, such as B and Se.

Geostatistical analyses of the EM data are also necessary to characterize the spatial distribution of soil salinity, B, and Se. Geostatistical methods have been extensively used to describe the spatial distribution of soil properties in agriculture (Cambardella et al., 1994; Meirvenne and Hofman, 1989). Knowledge of the variability of these soil parameters and characterization of their spatial distribution are important for statistically evaluating areas of low and high salt, B, and Se contents, and providing management recommendations. Geostatistical methods are also important to determine the spatial dependency between EM measurements, which is necessary for recommending optimum sampling scheme. The geostatistical equations characterizing the spatial distribution of the three soil parameters will be used in the interpolation process of map development.

B.1.c. Nature, Scope, and objectives of the project

In 2001, a soil salinity assessment program was developed by the Center for Irrigation Technology (CIT) at California State University, Fresno with funding provided by the CALFED Water Use Efficiency Program. The goal of the project was to assess and map soil salinity using the EM technology in farms implementing drainage management practices within their

boundaries. The salinity program was very successful among WSJV farmers and provided annual salinity maps of fields surveyed with the EM technology. The maps were very helpful in locating areas of high salinity in the farms surveyed and were used by farmers and local/state/federal agencies as decision-making tools for improving the drainage and irrigation management practices on the farms. The CALFED-supported program ended in June 2003. Since then, farmers and agencies, including the Westside Resource Conservation District, Westlands Water District, San Joaquin Valley DWR, and the Bureau of Reclamation have expressed the need to pursue the salinity program developed by CIT. Several farmers not involved in the 2001 salinity assessment program have also indicated their need for such assessment on their drainage-impacted lands. All the equipment necessary to conduct the EM surveys is available at CIT. Therefore, the goal of this project is to continue the salinity program started in 2001 and to extend it to soil B and Se assessment.

Monitoring and assessment of soil salinity, B, and Se patterns and time-dependent changes in drainage-impacted farmlands will be conducted in sub-regions 10 and 14 in the WSJV. The hypotheses of this study are that annual monitoring and assessment of these three soil parameters will help in developing and evaluating the implementation of drainage management practices to reduce water use and drainage volumes, and increase productivity on salt-affected soils in the WSJV of California. The specific objectives of the proposed research are:

1. To annually monitor soil salinity, boron, and selenium on farms implementing drainage management practices using the EM induction technique,
2. To characterize the spatial distribution of these soil parameters using geostatistical methods, and,
3. To map soil salinity, boron, and selenium using the EM and geostatistical data.

B.1.d. Support of California Bay-Delta Program Goals

The goals of the Water Use Efficiency Program as defined by the California Bay-Delta Program “include water quantity, water quality, and in-stream flow and timing improvements that directly or indirectly provide benefits to the Bay-Delta”. The proposed project contributes to several of these goals, as defined for sub-regions 10 and 14 (Valley Floor west of San Joaquin River and Westlands Area) but also for other CALFED sub-regions where drainage, soil salinity, B, and Se are major problems. The project will partially address quantifiable objectives 106, 109, 163 and 166 by helping decrease flows to salt sinks and provide long-term diversion flexibility to increase the water supply for beneficial uses. The research will also help reduce salinity, B and Se concentrations to enhance and maintain beneficial uses of water. More specifically, the proposed project will contribute to:

- 1) increase the water quantity in the San Joaquin River and San Joaquin Basin,
- 2) improve the ecosystem and quality of the San Joaquin River, and
- 3) decrease salt loading of subsurface and ground waters acquired during percolation through different soil layers.

Non-quantified outcomes are also expected to directly or indirectly benefit the CALFED program. The proposed research is expected to evaluate the effectiveness of drainage management practices in reducing soil salinity, B, and Se. Repeated surveys will provide the rate of salinity, B, and Se increase or reclamation on the farms. Measurements at various depths

will reveal the presence of uniform, regular or inverted (i.e., EC decreases with depth) salinity profiles in the fields. The study will also lead to crop rotation and drainage management recommendations. The project is expected to increase the operating efficiency of the drainage reuse systems. Site assessment and ongoing monitoring of the soil parameters within the management areas are important to maintaining the productivity of the cropping areas. Monitoring trends can facilitate changes in management strategies to optimize the operational efficiency of the system.

B.1.e. Water management plans

The concepts of drainage reuse systems are consistent with local and regional water and drainage management plans. The Federal-State Interagency San Joaquin Valley Drainage Program's final report, *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, September 1990, recommends several measures for managing subsurface agricultural drainage, which are employed by drainage reuse systems. Monitoring and assessment of soil parameters in farms implementing these systems will provide important data to SJV growers and local/state/federal agencies by identifying salt-affected areas that may need reclamation and leaching to control built-up.

B.2. Technical/Scientific Merit, Feasibility

B.2.a. Methods, procedures, equipment

The project will be conducted on 12-15 fields in farms located in sub-regions 10 and 14 of the West Side San Joaquin Valley. Monitoring and assessment of soil salinity, B, and Se will be performed annually over a three-year period. The EM technology will allow to determine the spatial and temporal variability of these soil parameters in drainage-impacted farmlands. The geostatistical analyses will help characterize the spatial structure of the soil parameters. Both EM and geostatistical data will be used to develop maps of soil salinity, B, and Se on the surveyed fields. The methodology for the objectives outlined in section B.1.c. is detailed below.

EM surveys

A Mobile Assessment (MA) System is available at the Center for Irrigation Technology to perform extended EM surveys on the farmlands (Attachment 1 – Figure 1). The MA system is comprised of four basic components mounted on a Spra-Coupe tractor: (1) an EM-38 sensor (Geonics Limited), (2) a global positioning system (GPS), (3) a computer, and (4) a hydraulic soil sampler. The EM-38 sensor will be used to measure soil electrical conductivity down to a depth of 3 ft. The EM instrument will be placed in a carrier-sled attached about 10 ft behind the Spra-Coupe tractor to avoid any EM reading interference due to metallic objects. The GPS unit will provide the geographical coordinates of each measurement point. Two digital interfaces will connect the EM sensor and GPS receiver to an on-board computer that will instantaneously record the EM readings along with their GPS location. A survey and statistical software (Lesch and Rhoades, 1999) will be used to record and analyze the EM data. Researchers and technicians at CIT have been using the MA system and related software for several years.

The EM and GPS data will be collected along transects (field rows) 100 to 125 ft apart depending on row spacing, and recorded on a 5 second interval which will correspond to measurements every 30 ft at a travel speed of 4 mph. This procedure will result in recording 12 to 15 EM data per acre. Based on the EM readings, an optimal soil sampling plan will be generated by the ESAP software to calibrate the data. The sampling plan will consist of six or twelve locations characterizing the spatial distribution of EM readings in the survey field (Lesch and Rhoades, 1999). The number of locations will be based on the field size. At these sites, soil samples will be collected in 1-ft increments to a depth of 3 ft using the hydraulic soil sampler. Then, the samples will be analyzed for electrical conductivity, moisture content, and texture, following standard analytical methods (Rhoades, 1996; Klute, 1986). Soil B and Se will be assayed using Inductively Coupled Plasma Spectrometer as described in Meyer and Keliher (1992) and Tracy and Moeller (1990).

Based on the EM and laboratory data, a stochastic calibration equation will be developed with the ESAP software to estimate the soil salinity, B, and Se values for the entire survey area. Estimates of these three parameters will be provided for each soil profile depth (0-1, 1-2, and 2-3 ft) as well as for the average 0-3 ft depth. Maps of B and Se will be produced if correlation exists with the EC data.

Geostatistical analyses

Geostatistical analyses of the calibrated soil data will be conducted using the GS+ Software, (Gamma Design Software, 2000). The spatial structure of the soil variable will be determined through fitted variograms in a two-step procedure: (i) computation of experimental variograms, and (ii) fitting them to theoretical models validated by the cross-validation technique. Model fitting for the variograms will be selected based on sample variograms and statistical results obtained from cross-validation (Vieira et al., 1983). Such validation is a technique in which the known data points are evaluated using the fitted model. Model variograms will help determine the distance up to which soil measurements are auto-correlated (i.e., the distance between which salinity, B, and Se data are likely to be similar). Such findings will be valuable to design optimum sampling scheme and to determine if salinity, B, and Se levels are statistically different within fields.

Mapping of soil salinity, boron, and selenium

Contour maps showing the spatial distribution of salinity, B, and Se on all fields surveyed will be generated using ArcGIS (Environmental System Research Institute, 2001). The kriging interpolation method will be used to estimate the soil variable across the entire fields. The kriging is a linear unbiased estimation method that provides estimates at unsampled points based on the surrounding data collected at precise locations (Isaaks and Srivastava, 1989). The intrinsic hypothesis is that the variogram depends on the distance between samples and not on the sampling location. Kriging will thus provide soil variable information at any point in the fields. Contour maps will be developed using kriging and the variogram models selected above for each variable. One-dimensional graphs showing differences in salinity, B, and Se levels with depth along transects will also be produced. Examples of such contour maps are presented in Appendix 1- figure 2.

B.2.b. Task list, deliverables, schedule, and projected costs

The following tasks will be performed to satisfy the above-described objectives and outreach activities of the proposed project. The schedule for accomplishing these tasks is presented in Attachment 2. The deliverables and estimated costs for all tasks are detailed in Attachments 3 and 4.

Task 1 - Develop annual EM survey plan

The first phase of the project will consist in selecting farms that could enroll in this monitoring and assessment program, i.e., farms where recycled drainage water is used as part of a drainage management system. Several meetings will be organized with engineers and scientists from the Department Water Resources in Fresno and the Westside Resource Conservation District to determine the appropriate farmlands for the EM surveys. Farms initiating the implementation of drainage management practices will also be selected. Then, an initial meeting will be conducted with the owner of each farm to explain the research project, select the particular fields to survey, and obtain some detailed information on the soil properties, cultural practices, irrigation scheduling, and drainage management practices performed on the farms. The EM surveys will be conducted on each field once a year at the same period.

Deliverables: List of farms and fields to be surveyed annually and maps showing locations of these farms. Report detailing crop, irrigation, and drainage management practiced on the farms.

Task 2 – Perform annual EM surveys and calibrate EM data

The EM surveys and calibration of the EM data will be conducted following the methodology described above. Scheduling of the EM surveys will be based on the soil moisture content of the soils, crop growth and vegetation cover in the fields, and irrigation scheduling. Surveys will be conducted between irrigation cycles and when the crop is at an early vegetative stage to avoid damaging the plants. The soil sampling will be performed within 24 hours of the EM surveys.

Deliverables: Survey scheduling. Annual EM survey and laboratory analyses. Report detailing methodologies for EM surveys

Task 3 – Conduct geostatistical analyses of EM data

The geostatistical analyses will be performed on the calibrated EM data obtained for each field survey from Task 2. Equations or variogram models describing the spatial distribution and variability of soil salinity, B, and Se will be developed as noted in B.2.a.

Deliverables: Geostatistical equations characterizing the spatial distribution of soil salinity, B, and Se in each field surveyed annually.

Task 4 – Develop maps of soil salinity, boron, and selenium, and provide recommendations

Based on the calibrated EM data and geostatistical equations, annual maps of soil salinity, B, and Se will be produced for each field surveyed. Maps for each depth sampled (0-1, 1-2, and 2-3 ft) as well as bulk average maps (0-3 ft) will be generated using the ArcGIS software. The maps will then be given to farmers, local and state agencies for monitoring levels

of soil salinity, B, and Se over space and time, and developing adequate crop, irrigation, and drainage management practices. Recommendations on soil reclamation, amendment, and drainage plans will also be provided.

Deliverables: Annual maps of soil salinity, boron, and selenium for each field surveyed and each depth sampled. Field and crop management recommendations.

Task 5 – Write reports and disseminate results

Quarterly, annual, and final reports will be written as required by the Water Use Efficiency Program. These reports will document the farmlands surveys, EM and laboratory data, geostatistical models, and will include annual maps of soil salinity, B, and Se. Bulletins and peer-reviewed scientific papers will also be written. Research and results will be presented and disseminated annually to growers, DWR, RCD, cooperators, and the scientific community through seminar, workshop, field days, and professional meetings.

Deliverables: Quarterly, annual, and final reports. Peer-reviewed scientific papers. Bulletins, workshop, field day, presentations of research results at conferences.

B.2.c. Environmental documentation

This is not a CEQA project as defined by the California Code of Regulations, Title 14, Division 6, Chapter 3, Section 15378.

B.3. Monitoring and Assessment

The EM surveys, geo-referencing, and geostatistical analyses will be conducted annually over a three-year period. Following each EM survey, maps of soil salinity, B, and Se will be produced. Details of data monitoring and assessment are provided in section B.2. Levels (variability, distribution) of soil salinity, B, and Se will be compared each year and used for crop rotation and drainage management recommendations to growers. Effectiveness of drainage management practices and reduction of AF/ac from quantifiable objectives 106 and 163 will be assessed for each farm.

Results from each task will be documented and deliverables will be included in quarterly reports submitted to DWR. Evaluation of the project will also be conducted quarterly and after completion of each task. Success of the project will be determined based on task completion, deliverables, dissemination and outreach of the research to interested parties as described below. Project success will also be recognized if farmers use the soil maps to take decisions regarding crop, irrigation, and drainage management practices. The effectiveness of the reuse drainage plans will also be established if soil salinity, B, and Se decrease over time.

C. QUALIFICATIONS OF THE APPLICANTS AND COOPERATORS

C.1. Resumes of project manager(s)

See enclosed resumes of Drs Florence Cassel and David Zoldoske (CIT).

C.2. External cooperators

The research will be conducted in collaboration with the California Department of Water Resources (DWR), Westside Resource Conservation District (WRCD), and Westlands Water District (WWD) as well as with WSJV farmers. Copies of support letters sent by Mr. Jose Faria from the California Department of Water Resources and Mr. Red Martin of the Westside Resource Conservation District, are attached with this proposal.

C.3. Previous water use efficiency grant projects

CIT was awarded a grant project under the Water Use Efficiency Program in 2001. The goal of the project was to assess and map soil salinity using the EM technology in farms implementing drainage management practices within their boundaries. The purpose of these management practices was to conserve fresh canal water by utilizing drainage water produced within the farm. The project was successful in locating areas of very high salinity through the soil salinity maps. The maps were then used by the farmers as decision-making tools for improving their drainage and irrigation management practices. The results of this project have been detailed in the final report to DWR (Cassel et al., 2003). This report has been extensively used by engineers from DWR-Fresno and by Westside farmers involved in the drainage program. The research work was also reported in an article published by *California Farmer* in September 2002 (pp16-19).

D. OUTREACH, COMMUNITY INVOLVEMENT AND DISSEMINATION

Target audiences: The results will be transferred to farmers, DWR/WRCD/WWD managers and program coordinators, irrigation/water districts, WSJV water interests, USBR, cooperators, public, and the scientific community.

Meetings-seminars-workshops: Results findings will be presented using maps, photographs, posters, and slides during farmer/community meetings, seminars, workshops, as well as statewide, regional, and national meetings and conferences. The level of details and scientific concepts will be based on the target audience. Field day will be conducted to show the use of the MA system and EM technology *in-situ*, present the results of the project, and inform interested parties on the rapid procedure to monitor and assess soil salinity, B, and Se in drainage-impacted farms.

Reports and publications: Reports will be written quarterly and a final report will detail the three-year results. Project objectives and findings will be published in newsletters, brochures, bulletins, or in popular trade/local journals. The research will be disseminated to the scientific community through refereed journal article in which thorough analyses of the results inferred from rational soil, crop, and economic concepts will be presented. Description of the EM technology, uses and advantages for salinity, B, and Se assessment as well as findings and reports will also be posted on the CIT website.

E. BENEFITS AND COSTS

F.1. Project Costs (Budget)

The state funding request is \$192,872, which represents 66% of the total project costs calculated at \$292,872. A contingency provision of \$3,331 has been estimated for the project. Equipment valued at \$100,000 is available at CIT to conduct the EM surveys; and includes the Spra-Coupe tractor, the truck and trailer to haul the tractor to the survey sites; the hydraulic soil sampler. The detailed budget for this three-year project is presented in Attachment 5.

A. *Administrative costs* include:

- (1) Secretarial salaries and benefits to maintain the contract.
- (2) Supplies needed to conduct the EM surveys and maintaining the MA system; office supplies and software to generate data, reports, maps, and manuscripts, reproduction.
- (3) Travel to the research site, meetings and conferences. Provision of \$2,000 per year is made for driving the MA system from Fresno to farms in sub-regions 10 and 14 and to collect EM data and soil samples. Additional costs include travel for meetings with farmers and cooperators, research dissemination and presentations during workshops, seminars, and conferences.
- (4) Other costs are requested for laboratory analyses of the soil samples.
- (5) Cost-share equipment of \$100,000 available at CIT. The same equipment was used to conduct the EM surveys for the project funded from the 2001 Water Use Efficiency Program.

B. *Planning/Design/Engineering costs* of \$19,807 are budgeted for conducting Task 1.

C. *Costs for Outreach and dissemination, Monitoring and Assessment, and Report preparation* include salaries and benefits for the investigators, technicians and students involved in the project to accomplish Tasks 2 through 5.

D. *University indirect costs* represent 18% of the total estimated costs.

F.2. Potential benefits of study and estimates of total expected water savings

The overall research will be beneficial for SWJV growers faced with the problem of salinization, B and Se loads, reduced crop yields, and overall degradation of the quality of their farmlands. This study will help identify salt-, B-, and Se-affected areas that may need reclamation and leaching to control built-up. The project is also important to assist growers in developing sound management practices related to drainage, irrigation, and crop rotations. Good soil information will lead to better operational decisions and will help ensure the long-term viability of drainage projects, which protects the substantial investment put forth by the growers and others. Stability of this practice should improve the grower's ability to forecast economic returns. This in turn will provide a more stable base to the local community. High, on farm use efficiency will reduce the growers' need to seek additional water supplies. Up to ninety percent of the water potentially lost to deep saline sinks can be utilized by the drainage reuse systems. CIT is proposing to assess and monitor approximately 6,000 acres with an estimated aggregate savings of 1,000 and 1,200 acre-feet of water.

The results of the project will also be studied by cooperators and scientists to understand the long-term effects of saline drainage water and toxic element accumulation on soil quality. Therefore, growers, but also water/irrigation districts, local/state/federal agencies, and the scientific community can directly benefit from this study. The research areas identified in this proposal provide an opportunity for interdisciplinary work among researchers at CIT, DWR, RCD, WWD, and growers.

The results of the proposed study will have applicability to all growing areas of the state facing salinity, B, and Se problems. The overall research will be agro-economically beneficial for California. The success of the project will be evaluating based on the decrease in drainage volumes and Se loads, implementation of reuse drainage systems, and increase in crop productivity observed with soil monitoring and assessment. The project will also be successful if, during the three years, more WSJV growers take interest in the EM technology and use soil maps as a management tool to manage drainage water.

As mentioned above, the proposed project will help contribute to increase the water quantity in the San Joaquin River and San Joaquin Basin, reduce on-farm and regional drainage water, improve the ecosystem and quality of the San Joaquin River, and decrease salt loading of subsurface and ground waters acquired during percolation through different soil layers.

G. REFERENCES

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Attachment 1.

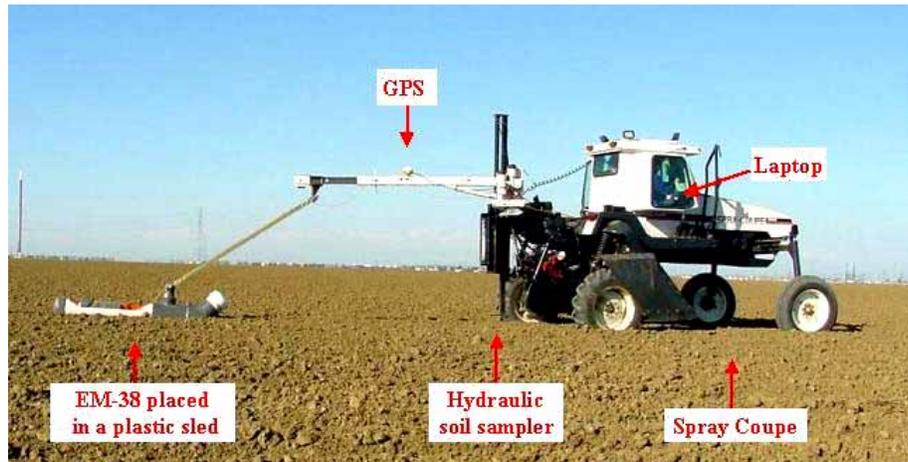


Figure 1. Mobile Assessment (MA) system available at CIT to conduct EM surveys

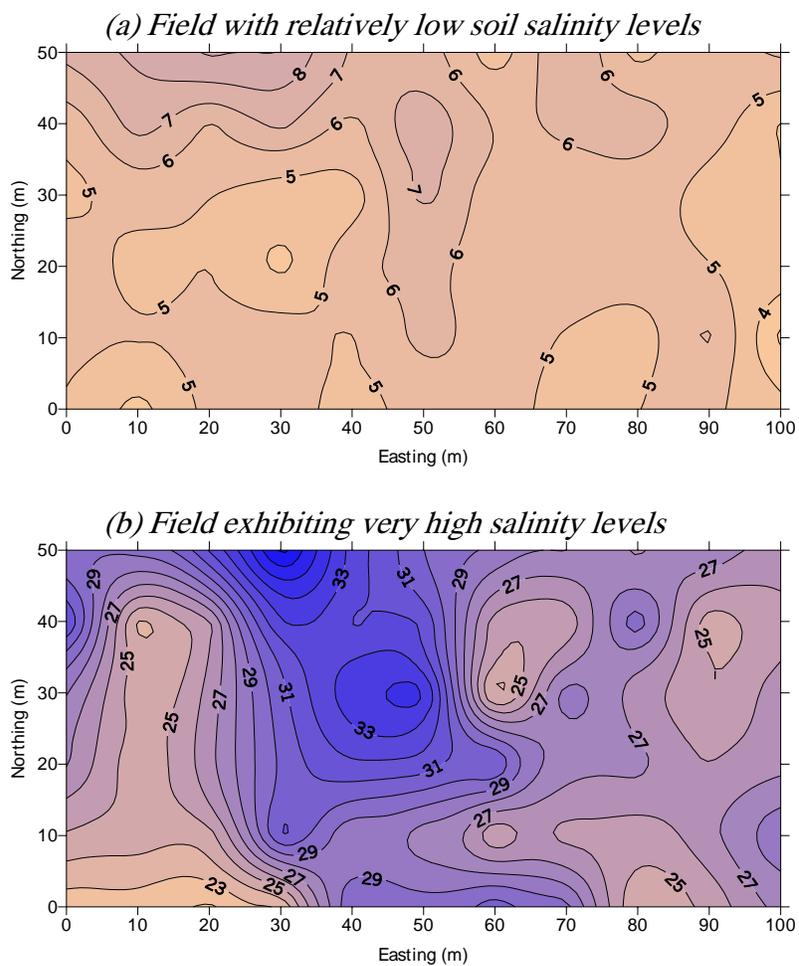


Figure 2. Maps of soil salinity distribution (dS/m) in EM-surveyed fields (0-3 ft).

Attachment 2. Task Schedule

Task	2006	2007	2008
	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
1. Develop annual survey plan	s-----c	s-----c	s-----c
2. Perform annual EM surveys and calibrate EM data	s-----c	s-----c	s-----c
3. Conduct geostatistical analyses of EM data		s-----c	s-----c
4. Develop maps of soil salinity, boron, and selenium		s-----c	s-----c
5. Write reports and disseminate results		s-----c	s-----c

s = start date, c = completion date

Attachment 3. Task deliverables

Task No.	Task Description	Deliverables
1	Develop annual EM survey plan	List of farms and fields to be surveyed annually and maps showing locations of these farms. Report detailing crop, irrigation, and drainage management practiced on the farms.
2	Perform annual EM surveys and calibrate EM data	Survey scheduling. Annual EM survey and laboratory analyses. Report detailing methodologies for EM surveys.
3	Conduct geostatistical analyses of EM data	Geostatistical equations characterizing the spatial distribution of soil salinity, boron, and selenium in each field surveyed annually.
4	Develop maps of soil salinity, boron, and selenium, and provide recommendations	Annual maps of soil salinity, boron, and selenium for each field surveyed and each depth sampled. Field and crop management recommendations.
5	Write reports and disseminate results	Quarterly, annual, and final reports. Peer-reviewed scientific papers. Bulletins, workshop, field day, presentations of research results at conferences.

Attachment 4. Requested and match funds by task

TASK No.	TASK DESCRIPTION	DWR REQUEST	MATCH FUNDS	TOTAL PROJECT BUDGET
			CIT	
1	Develop annual EM survey plan	\$ 20,437		\$ 20,437
2	Perform annual EM surveys and calibrate EM data	\$ 91,854	\$ 100,000 ¹	\$ 191,854
3	Conduct geostatistical analyses of EM data	\$ 10,904		\$ 10,904
4	Develop maps of soil salinity, boron, and selenium, and provide recommendations	\$ 9,904		\$ 9,904
5	Write reports and disseminate results	\$ 24,297		\$ 24,297
Contingency		\$ 3,331		\$ 3,331
Total direct costs		\$ 160,727		\$ 260,727
University indirect and administrative staff costs (20% of DWR request)		\$ 32,145		\$ 32,145
TOTAL BUDGET		\$ 192,872	\$ 100,000¹	\$ 292,872
<i>Percentage of total project budget</i>		<i>66%</i>	<i>34%</i>	<i>100%</i>

¹Equipment valued at \$100,000 is available at the Center for Irrigation Technology to conduct the EM surveys. The same equipment was used for the project funded from the 2001 Water Use Efficiency Program

Attachment 5. Project budget (in dollars)

	Category	Project Costs	Contingency % (ex. 5 or 10)	Project Cost + Contingency	Applicant Share	State Share Grant
	(I)	\$ (II)	(III)	\$ (IV)	\$ (V)	\$ (VI)
	Administration ¹					
	Salaries, wages	\$5,740	0	\$5,740	\$0	\$5,740
	Fringe benefits	\$2,296	0	\$2,296	\$0	\$2,296
	Supplies	\$15,000	0	\$15,000	\$0	\$15,000
	Equipment	\$100,000 ¹	0	\$100,000	\$100,000 ¹	\$0
	Consulting services	\$0	0	\$0	\$0	\$0
	Travel	\$12,112	5	\$12,718	\$0	\$12,718
	Other	\$39,690	0	\$39,690	\$0	\$39,690
(a)	Total Administration Costs	\$174,838		\$175,444	\$100,000	\$75,444
(b)	Planning/Design/Engineering	\$19,807	0	\$19,807	\$0	\$19,807
(c)	Equipment Purchases/Rentals/Rebates/Vouchers	\$0	0	\$0	\$0	\$0
(d)	Materials/Installation/Implementation	\$0	0	\$0	\$0	\$0
(e)	Implementation Verification	\$0	0	\$0	\$0	\$0
(f)	Project Legal/License Fees	\$0	0	\$0	\$0	\$0
(g)	Structures	\$0	0	\$0	\$0	\$0
(h)	Land Purchase/Easement	\$0	0	\$0	\$0	\$0
(i)	Environmental Compliance/Mitigation/Enhancement	\$0	0	\$0	\$0	\$0
(j)	Construction	\$0	0	\$0	\$0	\$0
(k)	Other - Outreach, dissemination	\$6,603	0	\$6,603	\$0	\$6,603
(k')	Other - University indirects	\$24,109	0	\$24,109	\$0	\$24,109
(l)	Monitoring and Assessment	\$54,500	5	\$57,225	\$0	\$57,225
(m)	Report Preparation	\$9,684	0	\$9,684	\$0	\$9,684
(n)	TOTAL	\$289,541		\$292,872	\$100,000	\$192,872
(o)	Cost Share -Percentage				34	66

¹Equipment valued at \$100,000 is available at the Center for Irrigation Technology to conduct the EM surveys.

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EDUCATION

Ph.D. 1998 *Soil-Water Physics and Agronomy*, University of Wyoming, Laramie, WY.
M.S. + B.S. 1994 "Diplôme d'Ingénieur en Agriculture", *Agricultural Engineering*, Ecole Supérieure d'Agriculture d'Angers (E.S.A.), France.

PROFESSIONAL EXPERIENCE

- 2001- Present: *Soil and Water Scientist*, Center for Irrigation Technology, California State University, Fresno.
- 1998-2001: Elected *Executive Council Member-at-Large* to the Pacific Division of American Association for Advancement of Sciences, San Francisco, CA.
- 1999-2000: *Research Scientist and Associate* (Post-Doctoral) of Soil-Water Sciences and Agronomy, Department of Plant Sciences, University of Wyoming, Laramie, WY.
- 1995-1998: *Research and Teaching Assistant* (Doctoral) of Soil-Water Physics and Environmental Sciences, Department of Renewable Resources, University of Wyoming, Laramie, WY.

RESEARCH INTEREST

- Soil salinity and canal seepage assessment using electromagnetic (EM) induction methods.
- Site-specific salinity management using variable rate technology for seeding and gypsum applications.
- Remote sensing techniques (satellite/aerial imagery) to predict crop performance, evapotranspiration, and irrigation needs.
- Agro-chemical contamination in soil and water systems; Water flow and chemical transport in soils.
- Effects of land application of food-processing effluent waters on soil and groundwater quality.
- Irrigation system design, management, and water application scheduling (drip, sprinkler, flood).
- Economic best management practices for sustainable crop production and pollution control.

HONORS, AWARDS AND PROFESSIONAL SERVICES

- Nominated for the Outstanding Research Award, College of Agricultural Sciences & Technology, California State University Fresno (2002 & 2003).
- Nominated for the Outstanding Dissertation Award, University of Wyoming (1999).
- Biographical citations and certificates in recognition of Outstanding Merit, Accomplishment, Academic Excellence and Achievement, Community Leadership - Who's Who Among Students in American Universities & Colleges (1998, 1999), Dean's List Among Students (1998), Gamma Sigma Delta, Honor Society of Agriculture (1997), Phi Kappa Phi Honor Society (1997), and Alpha Zeta (1996).
- Peer-reviews of research papers and proposals for Journal of Environmental Quality, Precision Agriculture, Wine Institute, and California State University - Agricultural Research Initiative Program.
- Member of American Society of Agronomy and Soil Science Society of America.

FUNDING HISTORY (\$1.1 million as P.I.; \$363,000 as co-P.I.):

- California State University - Agricultural Research Initiative Program: Use of Remote Sensing Techniques for Improving Soil and Crop Management Practices. \$213,000 (2004-2007). F. Cassel S., M. Spiess, B. Taylor, and D. Zoldoske.
- United States Department of the Interior - Bureau of Reclamation: *Remote Sensing of Evapotranspiration for Verification of Regulated Deficit Irrigation*. \$120,000 (2004-2005). F. Cassel S. and D. Zoldoske.
- California State University - Agricultural Research Initiative Program: *Assessment of Canal Seepage Using Electromagnetic Technique*. \$96,000 (2004-2006). F. Cassel S. and D. Zoldoske.
- California State University - Agricultural Research Initiative Program: *Salinity Assessment for Precision Farming in Cotton Systems*. \$50,600 (2002-2004). F. Cassel S., D. Goorahoo, and D. Zoldoske.
- California Department of Water Resources - CALFED Water Use Efficiency Program: *Assessing Spatial and Temporal Variability of Soil salinity on Farms Implementing Integrated Drainage Management Practices*. \$175,010 (2001-2003). F. Cassel S., D. Goorahoo, D. Zoldoske, and P. Canessa.

PUBLICATIONS

1. Cassel S., F., B. Taylor, and D. Zoldoske. 2004. Electromagnetic Sensing of Salinity and Boron for Predicting Variable Seeding Zones. Agronomy Abstracts, Soil and environmental Quality Division. Annual Meetings, American Society of Agronomy-Crop Society of Agronomy-Soil Science Society of America, Madison, WI.
2. Cassel S., F., D. Zoldoske, E. Norum, and T. Jacobsen. 2003. Detecting Canal Seepage using the Electromagnetic Induction Technique. Technical Conference of the Irrigation Association, San Diego, CA.
3. Cassel S., F., D. Zoldoske, and M. Spiess. 2003. Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices. Final Report. California Department of Water Resources, CALFED Agricultural Water Use Efficiency Program, Sacramento, CA, 35 pp.
4. Cassel S., F., B. Taylor, B. Roberts, and D. Zoldoske. 2003. Precision Farming Applications in Cotton Systems of California. Final Report, Cotton Incorporated, Cary, NC. 19 pp.
5. Cassel S., F., M. McClanahan, S. S., and D. Goorahoo. 2003. Evaluation of Various BOD Loading Rates for Land Application of Food-Processing Wastewater. Final Report. United States Environmental Protection Agency, Washington D.C., 22 pp.
6. Cassel S., F., T. Jacobsen, E. Norum, P. Canessa, and D. Zoldoske. 2002. Rapid Assessment of Seepage Potential in Earthen Canals using Electromagnetic Survey. Quarterly Research Report, U.S. Bureau of Reclamation, Sacramento, CA. 8pp.
7. Cassel S., F., D. Zoldoske, T. Jacobsen, and E. Norum. 2002. Use of Electromagnetic Survey to Assess Potential Canal Seepage. Proceedings, California Plant and Soil Conference. California Chapter of American Society of Agronomy and California Plant Health Association. Fresno, CA. p.169.
8. Cassel S., F., M. McClanahan, D. Goorahoo, S. S., J. Kipps, S. Klein, R. Crites, and J. Smith. 2002. BOD loading impact on land application percolate water quality. Water Environment Federation 75th Annual Technical Exhibition and Conference, Alexandria, VA. 19 pp.
9. Cassel S., F., S. S., S. Miller, G. Vance, and R. Zhang. 2001. Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugarbeets. *Agricultural Water Management*. 46(3):241-251.
10. Cassel S., F., S. S., L. Held, S. Miller, G. Vance, and R. Zhang. 2001. Agro-economic analysis of drip irrigation for sugarbeet production. *Agronomy Journal*. 93:517-523.

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AREAS OF EXPERTISE:

- Program Leadership • Educational Development • Analytic Studies • Grant/Contract Management

EDUCATION:

EdD, Education University of La Verne, La Verne, CA (Leadership)

MS, Agriculture, California State University, Fresno, Fresno, CA (Economics)

BS, Agricultural Business California State University, Fresno, Fresno, CA

PROFESSIONAL EXPERIENCE: (*Note:* Current job responsibilities include parts of three positions).

- 1994- **Present: Director (70%)**, Center for Irrigation Technology (CIT), California State University, Fresno. Requires administrating all aspects of the management of the Center including: planning and budgeting (currently at 21 million dollars); promotion and public relations with community and industry; liaison with advisory board; provide educational opportunities to the public, development of contracts and grants for applied research, hiring and supervision of staff; and training and publications efforts.
- 2000 - Present: **Associate Director (20%)**, California Water Institute, California State University, Fresno. Given the charge by the Provost and funded from Proposition 13 to develop the Water Institute. Activities include developing partnerships with three sister CSU campuses, working with campus president to secure funding from CSU Chancellor's office, obtain building space, hire and supervise staff, allocate and fund campus research projects, and create an industry advisory board.
- 2002 – **Present: Interim Director (10%)**, International Center for Water Technology, California State University, Fresno. Working directly with approximately 40 water technology companies in the San Joaquin Valley to secure funding for a proposed 50 million dollar technology center to be located on campus. Responsibilities include establishing an interim industry board, project leadership, providing liaison between the community and the University, and fund raising.
- 1996: Lecturer, Department of Agriculture, College of the Sequoias, Visalia, CA.
- 1993: Lecturer, Department of Plant Science and Mechanized Agriculture, College of Agricultural Sciences and Technology, California State University, Fresno, Fresno, CA.
- 1988 – Present: Almond Grower, owner and operator of farming operation. Activities include orchard development, cultural practices, and general business requirements for a successful farming enterprise.
- 1990 – 1993: Assistant Director, Center for Irrigation Technology (CIT), California State University, Fresno. Specific duties include developing educational programs for the irrigation industry, promotion of Center activities, developing grant and contract proposals, supervision of staff and students positions, supporting the director's duties as required, and performing special projects as assigned.
- 1986 – 1990: Hydraulic Lab Manager, Center for Irrigation Technology (CIT), California State University, Fresno. Responsible for the operations of the internationally recognized research laboratory, including program development, liaison with private sector clientele, educational efforts, and supervision of staff and students positions.
- 1983 – 1985: Research Technician, Center for Irrigation Technology (CIT), California State University, Fresno. Worked primarily in laboratory and field research to advance new water use efficient technologies. Assisted faculty and graduate students in conducting applied research.
- 1981 – 1982: Research Assistant, Department of Agricultural Economics, California State University, Fresno. Conducted research funded by US Agency for International Development.

HONORS AND RECOGNITION:

- Recognized nationally as one of 18 Environmental Stewards and Innovators in the Golf Industry by the Golfweek's Superintendent NEWS, October 26th, 2001.
- Honorary Life Membership in the American Society of Irrigation Consultants, May 2001.
- National Water and Energy Conservation Award presented to CIT by the Irrigation Association, 1998.

SELECTED EDUCATIONAL PROGRAMS:

- Responsible for the national and international IA certification program. The program offers five different certifications. Since 1994, we have administered over 6,216 exams, with approximately 3,217 individuals achieving certification.
- Editor of two books that served as study guides for the IA's Certified Irrigation Contractor (CIC) and the IA's Certified Irrigation Designer (CID) program.
- Conceived and developed in partnership with the US Bureau of Reclamation a two-acre educational site demonstrating drought tolerant plants and water efficient irrigation methods for the San Joaquin Valley. Site is targeted for K-12 students and community visitors.
- Developed a statewide training program in partnership with the Department of Pesticide Regulations for Agricultural Wellhead Protection. Provided training for the Ag Commissioner's office in 52 counties utilizing Mobile Education Center. Program required development of training program, manual, and pass/fail written examination.
- Developed regional educational program in partnership with the California Department of Water Resources to train San Joaquin Valley growers on source control and drainage management.
- Developed web based educational and water management site in partnership with the US Bureau of Reclamation. The site is located at Wateright.org and designed for homeowners, commercial and agricultural water users. It is available in five western states, California, Oregon, Washington, Idaho, and Montana.
- Created the Central Valley Water Education Center that provides public forums on water issues facing the San Joaquin Valley. A total of five local events have been held to date.

PUBLICATIONS

- Zoldoske, D.F. 2001. "The Water/Energy/Environmental Matrix". California Grower magazine, Vol. 25, No. 11, December 2001, pg 22.
- Goorahoo, D., Carstensen, G., Norum, E., Zoldoske, D.F., and Mazzei, A. 2001. "Using Air in Sub-Surface Drip Irrigation (SDI) to Increase Yields in Bell Peppers", 2001 Proceedings, International Irrigation Show, The Irrigation Association, San Antonio, TX, November 4-6, 2001, pgs, 95-102.
- Zoldoske, D.F. 2001. "Water, Energy and Education: Where Professionalism Does Make a Difference". Full Coverage Irrigation, The Newsletter of the American Society of Irrigation Consultants, Winter/Spring, 2001, pgs 6-8.
- Zoldoske, D.F. and V.P.J. Farley, editors. 1990. "Xeriscape Update: Planning and Practice," CATI Publication No. 900407, Center for Irrigation Technology, California State University, Fresno, CA, 158 pp.
- Zoldoske, D.F., and M.Y. Miyasaki, editors. 1986. "Micro Irrigation: Methods and Materials Update," CATI Publication No. 861103, Center for Irrigation Technology, California State University, Fresno, CA, 295 pp.