2004 Water Use Efficiency Proposal Solicitation Package

Proposal: Benefits and Costs of Deficit Irrigation in Alfalfa

APPENDIX A: Project Information Form

Applying for:	❑ Urban	**X 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**	**X (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):	The Regents of the University of California
4. Project Title:	**Benefits and Costs of Deficit Irrigation in Alfalfa**

5. Person authorized to sign and submit proposal and contract:	Name, title	Rene Domino Contracts and Grants Analyst
	Mailing address	Office of the Vice Chancellor for Research, Sponsored Programs, 118 Everson Hall One Shields Avenue, University of California Davis, CA 95616
	Telephone	530-752-2075
	Fax.	530-752-5432 (fax)
	E-mail	rhdomino@ucdavis.edu

6. Contact person (if different):	Name, title.	Daniel H. Putnam
	Mailing address.	Specialist in Cooperative Extension
		Department of Plant Sciences
		One Shields Avenue, University of California
		Davis, CA 95616
	Telephone	530-752-8982
	Fax.	530-752-4361 (fax)
	E-mail	dhputnam@ucdavis.edu

7. Grant funds requested (dollar amount): **$981,984**

(from Table C-1, column VI)

8. Applicant funds pledged (dollar amount): $0

9. Total project costs (dollar amount): **$981,984**

(from Table C-1, column IV, row n)

10. Percent of State share requested (%) **100%**

(from Table C-1)

11. Percent of local share as match (%) **0%**

(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.

(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.)

❑ (a) yes
X (b) no

11. Is your project required by regulation, law or contract?

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.

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

❑ (a) yes
X (b) no

12. Duration of project (month/year to month/year):	**Jan 2006 – Dec 2008**
13. State Assembly District where the project is to be conducted:	**(NA – Statewide)**
14. State Senate District where the project is to be conducted:	**(NA – Statewide)**
15. Congressional district(s) where the project is to be conducted:	**(NA – Statewide)**
16. County where the project is to be conducted:	**(NA – Statewide)**
17. Location of project (longitude and latitude)	**(NA – Statewide)**
18. How many service connections in your service area (urban)?	**NA**
19. How many acre-feet of water per year does your agency serve?	**NA**

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
- **X (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
- **X** (b) no

2004 Water Use Efficiency Proposal Solicitation Package
APPENDIX B: 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

2004 Water Use Efficiency Proposal Solicitation Package

Proposal: Benefits and Costs of Deficit Irrigation in Alfalfa

STATEMENT OF WORK

SECTION 1. RELEVANCE AND IMPORTANCE

This project addresses the first four Goals/Objectives for the CALFED Water Use Efficiency Program as stated below:

The 2000 Record of Decision (ROD) defines the Water Use Efficiency Program (WUEP) broadly. "The Water Use Efficiency Program will assure high efficiency through programs that benefit local water users, districts, regions, and the State". To achieve CALFED fundamental goals, the ROD WUEP (pages 2.1 and 2.2), in part, has the following objectives:

- Reduce existing irrecoverable losses – by reducing losses currently unavailable for reuse (because they flow to salt sink, inaccessible or degraded aquifer, or the atmosphere), CALFED will increase the overall volume of available water.
- Achieve multiple benefits - by reducing losses that currently return to the water system (either as groundwater recharge, river accretion, or direct reuse) CALFED can achieve multiple benefits, such as making water available for irrigation or in-stream flow during dry periods, improving water quality, decreasing diversion impacts, and improving flow between the point of diversion and the point of reentry.
- Preserve local flexibility …maintaining the flexibility of implementing water use management and efficiency improvements at the local level while exploring regional programs to maximize benefits.
- Use incentive-based over regulatory action. Principal incentives include planning, technical, and financing assistance to local water users and suppliers…

This project specifically addresses two areas of priority research listed in the current Project Solicitation:

- Potential benefits and costs of alfalfa summer dry down
- Exploration of new technologies and water management practices to improve water use efficiency

By quantifying the potential for real water savings and impact on crop production in statewide field trials, the first two goals are addressed directly by this project:

1) Consumptive water use as ET in alfalfa will be reduced, reducing irrecoverable loss of water to the atmosphere, and in the case of the Imperial Valley, efficiency improvements will reduce losses to saline sinks.
2) Losses returning to groundwater via deep percolation and tailwater runoff would be greatly reduced or virtually eliminated during the peak irrigation season due to the drier soil moisture conditions created under deficit ET management. The operational benefits to water districts resulting from reduced demand for surface water diversion due to reduced irrigation frequency, along with potential water quality improvements, can be quantified for different regions based on the acreage typically planted to alfalfa. In some intermountain watersheds, this project has the potential to increase water available for in-stream flows during the critical

fall dry period, a time period of vital importance to the reproduction and survival of salmonids.

Besides “diversion flexibility”, “non-productive evaporation” is the only other targeted benefit listed for all basins of California. (Table 1.1, CALFED Agricultural Water Use Efficiency Details of Quantifiable Objectives Revised: December, 2000). No other crop grown in California has been as widely adapted and cultivated as alfalfa. Thus, information on potential water conserving practices for this crop is a perfect fit with this statewide Targeted Benefit.

Table 1.1. Categories of Targeted Benefits by Sub-Region.

Targeted Benefits will be achieved by altering flow paths of irrigated agriculture.

			Abbreviated Categories of Targeted Benefits											
				Quality							Quantity			
Region		Sub-Region	Flow / Timing	Nutrients	Group A Pesticides	Pesticides	Salinity	Native Constituents	Temperatures	Sediments	Long-Term Diversion Flexibility	Nonproductive Evaporation	Short-Term Diversion Flexibility	Flows to Salt Sinks
Sacramento Valley	1	Redding Basin	✔								✔	✔		
Sacramento Valley	2	Sacramento Valley, Chico Landing to Red Bluff	✔			✔			✔		✔	✔		
Sacramento Valley	3	Sacramento Valley, Colusa Basin	✔		✔	✔	✔				✔	✔		
Sacramento Valley	4	Mid-Sacramento Valley, Chico Landing to Knights Landing	✔			✔	✔				✔	✔		
Sacramento Valley	5	Lower Feather River and Yuba River	✔		✔	✔	✔		✔		✔	✔		
Sacramento Valley	6	Sacramento Valley Floor, Cache Creek, Putah Creek, and Yolo Bypass	✔			✔					✔	✔		
Sacramento Valley	7	Lower Sacramento River below Verona	✔			✔	✔		✔		✔	✔		
Delta & Tributary	8	Valley Floor east of Delta	✔						✔		✔	✔		
Delta & Tributary	9	Sacramento - San Joaquin Delta	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔
West Side SJ Valley	10	Valley Floor west of San Joaquin River	✔		✔	✔	✔	✔		✔	✔	✔		✔
East Side SJ Valley	11	Eastern San Joaquin Valley above Tuolomne River	✔	✔	✔	✔	✔		✔		✔	✔		
East Side SJ Valley	12	Eastern Valley Floor between Merced and Tuolomne Rivers	✔		✔	✔	✔		✔		✔	✔		
East Side SJ Valley	13	Eastern Valley Floor between San Joaquin and Merced Rivers	✔		✔	✔	✔		✔		✔	✔		
West Side SJ Valley	14	Westlands Area								✔	✔	✔		✔
Southern SJ Valley	15	Mid-Valley Area									✔	✔		✔
Southern SJ Valley	16	Fresno Area	✔		✔	✔	✔		✔		✔	✔		
Southern SJ Valley	17	Kings River Area									✔	✔		✔
Southern SJ Valley	18	Kaweah and Tule River Area									✔	✔		✔
Southern SJ Valley	19	Western Kern County									✔	✔		✔
Southern SJ Valley	20	Eastern Kern County									✔	✔		
Southern SJ Valley	21	Kern River Area									✔	✔		✔

✔ represents 1 or more TB

CALFED Agricultural Water Use Efficiency
DRAFT Details of Quantifiable Objectives 8 Revised December, 2000

Large-scale adoption by growers in a given region will be the litmus test that shifts this idea from “potential” into real water savings for California. Deficit irrigation of alfalfa would have no relevance to CALFED without illustrating a mechanism that would make economic sense for alfalfa producers. A longer-term educational and institutional effort will be necessary to demonstrate an economic advantage to alfalfa producers to replace revenue lost from reduced yields. Tentative calculations are as follows: At a water cost of $80/ac-ft, a 6-inch reduction in applied water is a $40/acre savings for the grower. This savings alone, however, is insufficient to make up for a potential yield loss of 1-1.5 ton/ac due to decreased ET for crop production. Ignoring the reduction in harvest costs, approximately $80 to $140/acre additional income to the alfalfa grower may be needed to put this idea into practice (assuming $120 per ton alfalfa price). However, the true costs and benefits are likely to be region-specific, require further analysis, and are the subject of this project.

Success of deficit irrigation may be achieved through a combination of several factors. These include: 1) **Detailed documented costs and benefits** of deficit irrigation, knowledge and experience of the long- and short-term consequences of these practices through scientific and grower experimentation, 2) **Knowledge of what agronomic and irrigation** techniques may improve success of deficit irrigation, 3) **educational outreach** for improved agronomic management under deficit irrigation conditions, 4) **incentive programs at the district level** that give growers enough value for water "saved" by committing alfalfa acreage to this program. This project addresses the first three aspects, and forms the basis for analysis of the last. Water managers may find that deficit irrigation strategies may be of interest to growers due to market price stabilization for summer-cut alfalfa, which has traditionally suffered a 20 to 40% drop in price due to large supplies and lower quality in the San Joaquin Valley.

Successfully integrating these factors into a workable system might play out as follows in meeting the 3rd and 4th CALFED goals:

3) Local water management flexibility is potentially improved as water districts can now shift the "saved" water to other uses – either to make up for short supplies in low water years or put into water banking programs or sell to the Environmental Water Account (EWA).

4) Educational, technical and financial incentives could be offered to growers in the form of first rights to options on higher value water trades with municipalities or the EWA. Technical assistance for soil moisture monitoring and irrigation techniques could be provided. Water districts might opt to underwrite the cost of crop insurance that guarantees growers will be made whole for the yield losses likely experienced with the deficit ET. This project aids in both educational aspects and projecting yield losses.

This is a comprehensive statewide proposal that aims to evaluate and demonstrate the potential for deficit irrigation of alfalfa to provide a partial solution to California's water shortages in drought years. This project seeks to identify practices that will maximize the amount of water conserved while minimizing the negative effects on alfalfa production. The results from this project are important to establish the factual background needed to promote this practice and provide the impetus for a more sustained extension/education program that can begin with this project.

Importance of Alfalfa to California's Water Management. Since alfalfa is the state's largest water user, substantial water savings may be realized through irrigation strategies designed to reduce the quantity of water applied. The overall objective of this project is to discover methods that would enable voluntary transfers of water from alfalfa production in drought years while at the same time sustaining the economic viability of the crop. The costs and benefits of different approaches will be documented. There is reason to believe that growers may be interested in such temporary transfers, if economic incentives are adequate, the technical aspects can be resolved, and it does not threaten their long-term standing in terms of agricultural water use. Summer harvests are often worth less in value, and as such, yield losses may be acceptable under certain economic conditions, enabling temporary water transfers. Certainly these options may appear superior to draconian measures of complete fallowing or cutoffs to an irrigation districts, if the technical, economic and logistical issues can be resolved. The alfalfa option may offer late-season flexibility which is not present with other ag transfer schemes, which must be resolved early in the season.

Importance of Alfalfa. Alfalfa is a vital component of California's cropping systems, currently the largest acreage crop in the state. It is a key feed for the state's number one agricultural industry: dairy. Since dairy production is likely to expand in the state, the demand for alfalfa will likely increase in the future. While some prognosticators predicted the demise of alfalfa production due to increased water costs and replacement with high-value crops, the opposite has proved to be the case. The highest acreage year occurred in 2002, and in 2004, prices were at a record level, proving the ongoing viability of alfalfa in the state. Unlike some crops, which may ultimately succumb to foreign competition from low-cost overseas competition, alfalfa's primary markets are here within the state. While water and environmental issues may ultimately circumscribe dairy expansion in California, many experts believe that it will continue its expansion, at least for some time. Currently, CA produces 20% of the nation's milk. This is likely to increase. As of 2004, Land-o-Lakes experts estimated CA will produce 36% of the nation's milk by 2025. Due to the continued strength of the dairy industry in California as well as the growth in other livestock sectors, particularly horses, alfalfa is very likely to remain a viable component of California's agricultural future.

Furthermore, in spite of the high water use of alfalfa, there are strong environmental arguments in favor of keeping a perennial legume such as alfalfa on the agricultural landscape. These include its ability to protect soil, mitigate nitrate pollution of groundwater, prevent air pollution with particulates, supply beneficial insects for biodiversity, and provide wildlife habitat. It has been shown that 23% of the state's wildlife use alfalfa for cover, feeding or reproduction (Putnam, 2001).

Alfalfa and Water Use. Alfalfa is California's single largest agricultural water user due to its large acreage and long growing season (see Figure 1), utilizing about 19-20% of the state's agricultural water.

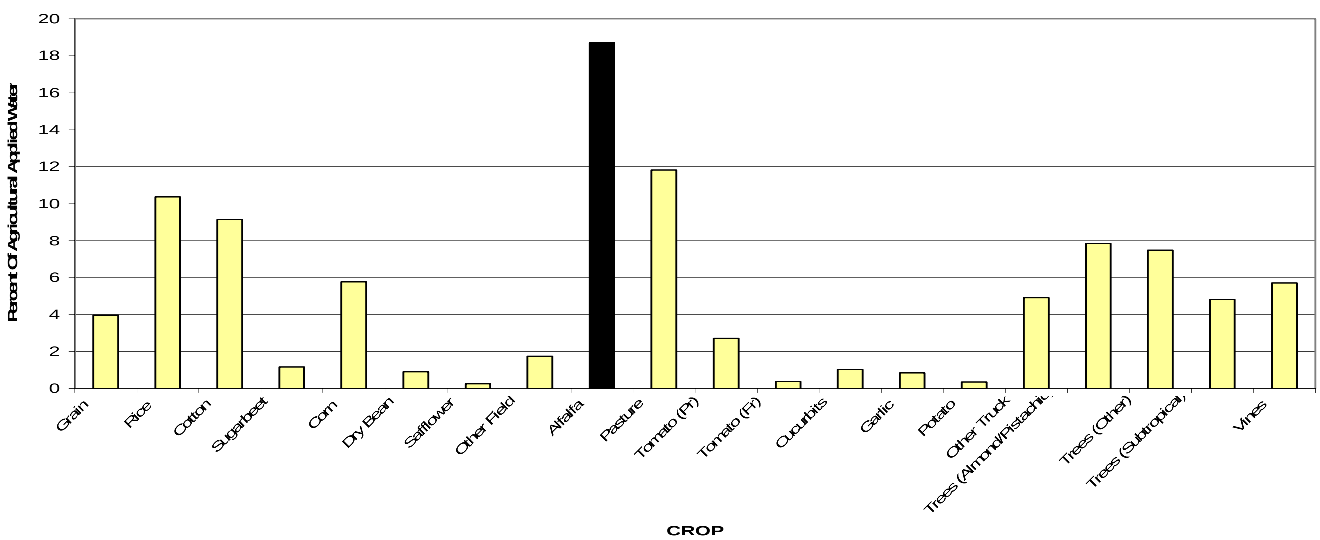

Figure 1. Comparative water used by different California crops (Source: California Department of Water Resources)

Alfalfa is a major crop (and water user) in many of the different watersheds where water conflicts are intense, including the Klamath Basin (CA/OR), the Sacramento Valley, the San Joaquin Valley, and the Imperial Valley. Figure 2 shows alfalfa water use in different watersheds. It is clear that, with the exception of several important coastal areas, alfalfa is a primary water user in all major agricultural regions. Klamath Basin is included in the North Coast region. It is likely that water limitations or transfers will be important in virtually all of these regions in the future.

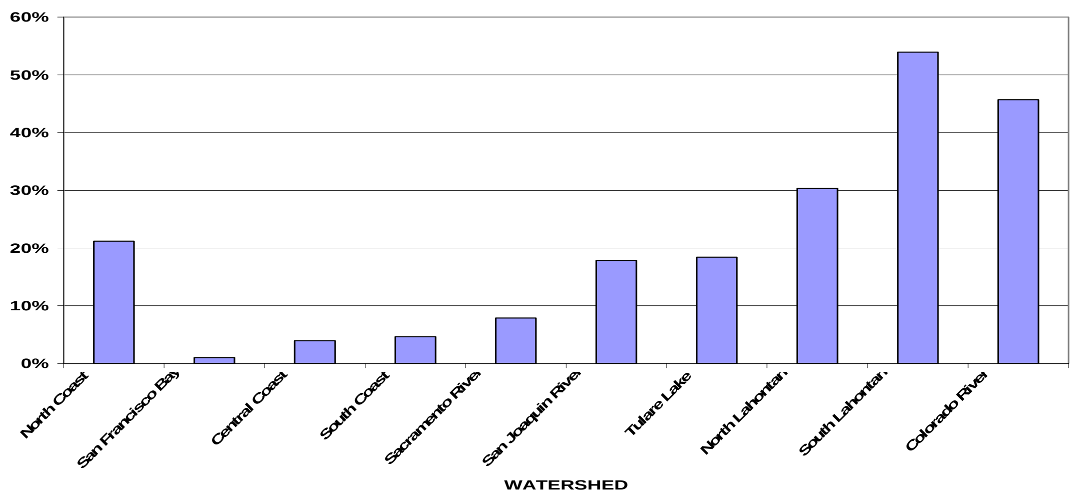

Figure 2. Percentage of agricultural water used by alfalfa for different watersheds in California (Source: California Department of Water Resources)

Irrigation water applications to alfalfa range from 24 to over 100 inches per year, depending primarily on the region where it is grown (DWR estimates). An average of 4 to 5.5 million acre feet of water are applied to California's alfalfa crop each year, depending on alfalfa acreage that year, weather patterns, and method of estimation.

Pasture Water Use: The primary focus of the proposal relates to water consumption by alfalfa. However, irrigated pasture is a major water user as well, second only to alfalfa (Figure 1). Irrigated pasture is an especially significant component of agricultural water use in the northern part of the state. Therefore, a secondary element of this proposal is to investigate deficit irrigation strategies for irrigated pasture in northern California to conserve water without plant mortality and a long-term reduction in pasture performance (see Intermountain section of Work Methods below).

Water Use Efficiency: Although some have called alfalfa a 'water waster', actually alfalfa has some advantages in water efficiency in agricultural systems. Its water use efficiency is high (yield of economic product for each unit of applied water). A comparison of crops in the Sacramento Valley showed alfalfa to be the most water-use efficient compared with crops such as corn grain, wheat, sugarbeet, rice and almonds. This is because 1) the entire above-ground portion of the plant is harvested, 2) considerably less water is used for stand establishment since alfalfa is a perennial and does not need to be established each year, 3) its vegetative yield is high, and 4) alfalfa has very deep roots which help to decrease deep percolation of irrigation water past the root zone. Although *seasonal water demand* is greater than most other crops, due to its long growing season, the *water-use-efficiency* of alfalfa is high. However, as a perennial crop, growers have an added investment in a given field that has continuing irrigation requirements over 3 to 5 years. Curtailing irrigation, or even reducing the amount of irrigation has traditionally been viewed as causing permanent harm to alfalfa stands affecting long-term production and viability. However, there is limited data on a statewide basis that suggests that deficit irrigation of alfalfa could be feasible, in light of the potential for water transfers (Orloff, 2003). In light of the amount of water that could be conserved with deficit irrigation and the potential for water transfers, this research is critically important.

Irrigation Patterns: Irrigation requirements of alfalfa in California vary depending on the growing region and method of irrigation. In northern California winter precipitation supplies much of the irrigation needs of the crop in the spring, and in wet years irrigation may be unnecessary until after the first harvest. In the intermountain region, where sprinklers dominate, irrigation continues into early fall. In the desert regions of southern California and the southern San Joaquin Valley, irrigation starts earlier (beginning in January or February in Imperial Valley). Thereafter, growers normally fully irrigate alfalfa throughout the growing season to maximize yield. Eighty five percent of the state's alfalfa fields are flood irrigated, where growers irrigate either once, twice or three times between cuttings. This schedule essentially represents a very short growth and harvest period, with water requirements between 4" and 14" for each cutting, depending upon location and time of year. Harvests range from 3 cuts in the Intermountain region, up to 9-12 cuts in Imperial Valley. Most flood irrigation events infiltrate between 3 and 6". The 'deficit irrigation' concept entails curtailment of irrigation during one or more growth periods. Eliminating just a single irrigation in California's alfalfa crop each year could generate an estimated 400,000 acre-feet of water statewide.

Deficit Irrigation – A middle ground strategy. In spite of its high water use, alfalfa is relatively drought tolerant and can endure periods with less than full irrigation, depending upon the conditions. Deliberate deficit irrigation of alfalfa ('summer dry down', early irrigation cut-off, or other deficit strategies) is proposed as a 'middle-ground' strategy for maintaining agricultural production, while conserving water. This proposal would develop the technical infrastructure to quantify crop impacts (documentation of yield loss, techniques for lessening negative consequences, and economic analyses) as a 'package' to the point where parties could consider this option.

Deficit irrigation approaches include:

- complete withdrawal of irrigation water (rain-fed only), which is not physiologically or economically feasible in most areas of California,
- no irrigation during portions of the growing season (winter or summer dry-down), or
- controlled deficit irrigation (irrigating at a reduced level during all or a portion of the season).

These strategies all reduce alfalfa yield to varying degrees, but which deficit irrigation strategy has the least detrimental effect on profitability and long-term stand viability is unknown. Additionally, there are techniques (such as variety selection, irrigation method, or other agronomic techniques) that may enhance the success of deficit irrigation.

These strategies represent a 'middle ground' between crop fallowing for water transfers and full use of irrigation water for agriculture. This approach could result in a significant water savings, while still maintaining a viable agriculture and local service economy that depends on continued farming. The concept of 'deficit irrigation is contrasted with 'fallowing', which has been the primary strategy proposed for water transfers in California. Fallowing has the advantages of simplicity—if no crop is grown, water normally used for agriculture can be transferred for other uses. However, fallowing has a number of negative environmental and social consequences. While an individual farm owner might benefit economically from a water transfer, the decimation of farm acreage has a severe effect on farm worker families that make a living from those farms, the supporting businesses, and the tax base of the community. The 'ripple effect' on the economic viability of an agricultural region is significant, and the consequences of unemployment on social services and the economy of entire rural areas must be considered. Additionally, complete fallowing, if permanent may encourage urbanization of rural areas. From an environmental perspective, there are advantages to keeping fields in a perennial cover, such as alfalfa, rather than creating dusty, weedy fallow fields with little wildlife or aesthetic value.

Deficit Irrigation, a Working Hypothesis: Evapotranspiration (ET) for alfalfa is highest during summer months and lowest during spring and fall months. Yields tend to be highest during spring harvests, and lower during summer months. In addition, forage quality of alfalfa tends to be lower during summer months due to hot weather, resulting in price reductions of up to 40%. These factors combine to cause Water Use Efficiencies to be lowest during the periods of late June, July, and August, especially when economic value of the crop is considered.

A substantial portion of the seasonal water use occurs during July and August. Approximately 14-18 inches of irrigation water in the Central Valley (about 35% of the seasonal water use) is used by alfalfa during this period. The Central Valley (San Joaquin and Sacramento Valleys) accounts for about 65% of California's alfalfa production. These two months of alfalfa irrigation may account for about 700,000 acre-feet in the Central Valley and 500,000 AF in the Imperial Valley. The same principle holds for the intermountain valleys (saving water during hot summer periods), but the actual deficit irrigation strategies may differ, and the amounts differ.

During times of insufficient water, high water costs, low crop prices, or other economic factors, growers may be interested in ceasing production of alfalfa (therefore cease watering) during summer months, and/or explore water transfer opportunities. In some studies, controlled deficit irrigation has been successful. Total seasonal yield is reduced but "success" is defined by the ability to reduce irrigations, and to attain normal yields upon re-watering.

Previous Experience: Experience with deficit irrigation of alfalfa is mixed. Research on deficit irrigation of alfalfa has been conducted in several areas of the West. Studies in Arizona were conducted in Yuma and Maricopa (Ottman et al, 1996). In California, studies were conducted in the Imperial Valley and Palo Verde Valley in the Low Desert, Fresno County in the Central Valley, and Siskiyou County in the intermountain area (Robinson et al, 1994; Putnam et al, 2000; Frate et al, 1988; Orloff et al, 2003). Different irrigation termination dates were imposed or the number of irrigations between cuttings varied. The effects of deficit irrigation varied depending on the location and the soil type. Deficit irrigation reduced yield, and the yield reduction the year the irrigation cut-offs were imposed was generally greatest the earlier the irrigation termination date. The primary difference between studies relates to how long it took the field to recover from moisture stress and whether or not the alfalfa fully recovered.

In most published studies, there was not a significant reduction in stand, with the exception of work conducted in the low desert regions. In the Imperial Valley study there was a significant reduction in stand if the mid-summer irrigation cut-off occurred for more than one year (Robinson et al, 1994). The Palo Verde study actually showed a significant reduction in stand after just the first year, possibly attributable to the very sandy soils at that location (Putnam et al, 2000). Results were similar for the Arizona studies. In the Yuma study (Ottman et al, 1996), alfalfa yield did not recover after irrigation was withdrawn in summer and there was significant stand loss. In contrast, in Maricopa yields recovered during the first growth cycle one year and during the second growth cycle the second (most likely due to difference in precipitation in the different years). Soil type appears to be a determining factor, as severe stand loss occurred on the sand in Yuma and no affect on stand from summer irrigation termination on the sandy loam with a higher water holding capacity in

Maricopa. This is a similar result to a trial done on heavier soils in the Imperial Valley where there appeared to be no adverse impact on alfalfa yields the following season in a program implemented by Imperial Irrigation District in 12 grower fields where summer irrigations ceased entirely and then received one irrigation in October, (Mark Roberson, personal communication, 2005). In northern California, stand loss did not occur in irrigation cut-off experiments in the Sacramento Valley and Siskiyou County (unpublished data Putnam and Orloff). Similar results were observed in research conducted in Fresno County (Frate 1988). Therefore, environmental factors (including soil type and climate) and agronomic practices may be very important factors influencing the success of this approach. Further research is needed to define the conditions that result in success or failure.

When stand loss occurs, the long-term viability of the crop is threatened, weeds invade, and the ability to sustain perennial crop production is jeapordized. Research on agronomic methods is needed to improve the chances of success of irrigation termination, to make this a viable option for growers. It is important to demonstrate and examine these practices over multiple years for a perennial crop like alfalfa. Efforts to 'dry down' alfalfa in the early 1990s in the Imperial Valley (a production practice designed to diminish silverleaf whitefly pressure) resulted in serious alfalfa stand loss and accompanying economic losses.

There may be economic incentives for growers to cease irrigating alfalfa during the summer in drought years if commodity prices are low and incentives for water transfers are sufficient—provided it can be adequately demonstrated that temporary water deficits do not harm the alfalfa crop long term. However, scientific support for this technique is currently insufficient and more research under a range of environmental conditions is warranted.

Reality of Water Transfers: Although usually contentious, most water experts agree that water transfers (voluntary, economic, court-driven, or regulatory) are likely to be increasingly common in California's future. While most proposals include fallowing agricultural land for water transfers to cities or for environmental uses, our proposal is focused on 'middle ground' strategies between cessation of agriculture and full agricultural production in drought years when there are insufficient water supplies for competing uses. This "middle ground" concept has the following benefits over land fallowing programs:

1) Maintenance of some forage production and economic viability of alfalfa in the face of drought and water transfers, thus contributing to the local service sector economy
2) Consideration of support for the state's #1 agricultural industry (dairy) and to maintain the viability of agricultural communities in the face of drought and water transfers.

Widespread, successful implementation of this concept is dependant on the development of a series of technical and economic recommendations about deficit irrigation of alfalfa, which could be employed in the case of water transfers or drought.

Benefits to Cal-Fed and State. This scope of this project has comprehensive statewide project impact for the following reasons:

1) Alfalfa is grown from Oregon to the Mexican border and is a major player in nearly every agricultural region of the state,
2) Water transfers and restrictions on water use in drought years are a reality in all of the regions where alfalfa is grown,
3) There are significant differences due to soil type, irrigation method, and watersheds in the viability of the deficit irrigation concept by climatic region across the state.

Depending upon the results of our study, the capacity for water savings is large. In our preliminary studies, we have measured savings totaling 1-2 ac-ft/ac within a short period of time (2 months) (Orloff *et al*. 2003). Assuming alfalfa acreage in the Central Valley (both San Joaquin and Sacramento Valleys) at about 600,000 acres, the savings of two 6" irrigations during the month of August would total 600,000 acre feet, if the normal applications are credited. A 2-month summer deficit strategy for Imperial Valley may yield 400,000 acre-feet. A late-summer deficit strategy for the Intermountain region could yield 100,000 acre-feet. Theoretically, and depending upon how the water savings is calculated, this quantity may be available for voluntary transfers by growers IF 1) long-term stand loss is minimal, 2) Yield loss and grower costs can be determined, and 3) mechanisms for orderly voluntary exchange are developed. Smaller scale water transfers may be feasible in specific watersheds and irrigation districts, if needed. However, currently no 'package' exists which would fully enable implementation of these strategies.

A key issue with this approach relates to quantification of how much water is saved with deficit irrigation and the question of ET as a function of both applied water and the depletion of stored soil moisture. Is the water saved equal to the amount that is no longer applied, just the reduction in alfalfa ET, or somewhere in between? The majority of ET, which occurs during the summer months, is the focus of our research. However, high water tables and/or residual moisture can maintain growth during drought periods; resulting in no significant decrease in alfalfa ET. Methods to manage alfalfa growth during deficit irrigation and to understand the balance between applied water and residual water will be the subject of our research. A key aspect will be methods to reduce vegetative growth during dry-down, and measures to ensure successful re-watering (through irrigation or rainfall) for complete recovery of the crop.

A focused effort on deficit irrigation could provide a strategy for water planners and farmers during periods of critical water shortage. Transferring water from alfalfa production has the advantage over fallowing or transfer from other crops, since a decision on water transfers can be made later in the season (e.g. May-June). Decisions on transfers from most crops (or fallowing) must be made early (Feb-March) before the full extent of water supplies is known. Agencies run the risk of overestimating water supplies and being forced to discontinue irrigation part way through the season. This would have catastrophic consequences for most crops such as high value vegetables, tree fruits, rice or cotton, as curtailing irrigation mid season may result in little or no marketable crop. However, utilizing the alfalfa deficit irrigation concept, it would be feasible to institute transfers as late as July, August or September, during the worst brunt of a drought year. Additionally, temporary voluntary transfers from alfalfa production enable partial crop production, sustaining incomes and local communities.

STATEMENT OF WORK

SECTION 2. TECHNICAL/SCIENTIFIC MERIT, METHODS, PROCEDURES, EQUIPMENT AND FACILITIES

Project Goals and Objectives

The two central goals of this program are to:

1) Determine impediments, yield losses, and economics of deficit irrigation in alfalfa, and develop a program that allows for successful implementation, particularly techniques to prevent alfalfa stand loss.

2) Determine evapotranspiration (ET) of alfalfa across 4 California Environments (Intermountain, Sacramento Valley, Lower San Joaquin Valley, and Imperial Valley) under fully irrigated and deficit irrigated conditions. This will assist in improving irrigation scheduling and in estimating real seasonal water demand for alfalfa across these regions. This will also help determine how deficit irrigation influences alfalfa ET, a critical factor in assessing water savings with deficit irrigation.

The following three objectives are the foundation for the project scope of work as we attempt to accomplish the above goals.

1) Implement grower-based demonstration and testing of deficit irrigation practices. This includes documentation of yield losses, forage quality effects, water savings, and stand loss. This has the advantage of working closely with growers to ascertain the impact of deficit irrigation strategies on-farm, and determine grower attitudes regarding the technology.

2) Continue field station-based irrigation and plant physiology research experiments to assist in the discovery of better methodologies for deficit irrigation. These experiments will examine the interactions between varieties, growth regulator treatments, and other techniques aimed at reducing the growth of alfalfa during deficit periods.

3) Statewide documentation of alfalfa ET across environments. This will be done at 4 California locations. It is important to document ET of alfalfa across environments, since CIMIS and other techniques depend upon this, in addition to the documentation of ET savings through deficit strategies.

This proposal will encompass 4 regions of California. These 4 regions are:

- **Intermountain.** Alfalfa is the major crop, and dominates the water usage in many intermountain valleys. Over 15% of the state's production occurs in this area.
- **Sacramento Valley.** Alfalfa is not the largest acreage crop in this region (>10% of state's production), but is important in water use, and opportunities for water exchange in this region exist.
- **Southern San Joaquin Valley.** Alfalfa is a key crop—50% of the state's alfalfa is grown in the San Joaquin Valley, with predominant acreage in the southern part. Alfalfa is an integral component of dairy farming in this area.
- **Imperial Valley.** Alfalfa is the largest acreage crop in the desert region—over 20% of the state's crop is grown in this region, and alfalfa is the largest water user in this area.

<u>Proposed Field Work for All Regions</u>

Grower-Based, On-Farm demonstration/data collection sites are proposed. We will have at one to two sites with replicated treatments at each of the 4 locations. We will impose deficit irrigation treatments on selected units (checks or other units depending upon irrigation system), of a field. Experimental design is a randomized complete block design, with 3 irrigation treatments and 4 replications. Replications are in strips or checks, depending upon logistical constraints. The three irrigation treatments will be: 1) Full irrigation treatment 2) Deficit irrigation for short period, (approx. 1 month) 3) Deficit irrigation for long period (approx. 2 months). Soil moisture and irrigation amounts will be monitored. Yield and quality will be measured to determine the economic penalty of the deficit irrigation technique. Yield will be determined through approximately 3' x 20' lengths harvested in replicates in each treatment. The experimental design will be modified for each region to account for irrigation and regional differences in production and irrigation practices. Field evaluations will continue for one year on each field, and the residual effect determined in the following year. In years two and three, we will repeat the experiment on a different field or different area of the same field. These grower trials will be constructed in a manner similar to that described for the San Joaquin Valley Region.

General data collection: Starting in 2006 yield data will be collected from the on-farm studies across the four regions**:** dry matter yields and forage quality, acid detergent fiber (ADF), neutral detergent fiber (NDF) and crude protein (CP), will be determined for all treatments. Field on-flow and outflow will be monitored along with soil moisture measurements, canopy temperature and canopy coverage for the different irrigation treatments in this study. The cutting schedule will simulate a typical cutting schedule used by growers in the area. These data will be used to analyze the response of the crop to stress. Alfalfa stand density will be rated each year. Alfalfa stand density will be assessed at the end of each production year and again in the spring.

ET estimates and their accuracy is one of the basic limitations to the implementation of the deficit irrigation concept. Without this information the potential water savings for other purposes cannot be known. This is also a basic limitation to the management of irrigation water in alflafa. ET of a well irrigated production scale alfalfa field of a similar soil type to replicated treatment fields will be measured over the entire season using the Surface Renewal Method (Snyder, 1996*)* in each of the four project regions (Klamath, Davis, Kern County, Imperial County). Equipement for this method is sufficiently economical for permanent installation in each of the four regions and should provide a reliable real time measurement of crop ET. However, there are some questions as to varying accuracy depending on the calibration to local conditions. To address this uncertainty we propose purchasing two Eddy Covariance Systems (Kizer, 1991) that will be moved from one region to another for periodic cross-calibration during different times during the season in the demonstration fields permanently outfitted with the Surface Renewal instrumentation.

The comprehensive determination of ET for California's most important water user across most key environments in California will be an accomplishment by itself. It aids greatly in the issue of deficit irrigation techniques and will provide important baseline data for irrigation management and implimentation of CIMIS techniques.

Regional Trials: The following sections describe additional work that will be done on a regional basis, adapted, where called for, to the particular conditions of that region and building on earlier work that was and/or is currently being done in that region.

Intermountain, Klamath Basin and Varietal Interactions
Field trials have been established at two sites in the intermountain area. These funds are requested to continue with these experiments. One site is at the UC Intermountain Research and Extension Center, Tulelake (IREC) and another in Malin with a grower cooperator. The experimental design is a factorial in a split plot arrangement. The main plot is the irrigation treatment and the split plot is the alfalfa variety. The plots were established in the spring of 2002 and received full irrigation to establish the alfalfa. Irrigations in this area are applied with sprinklers and allow for greater controlled deficits than surface, border irrigation. The irrigation treatments are as follows:

1. Full irrigation (100% of ET)
2. Moderate deficit irrigation (66% of ET)
3. Severe deficit irrigation (33% of ET)

4. Irrigation termination at first cutting (June)
5. Irrigation termination after second cutting (mid July)
6. No irrigation

Fourteen alfalfa varieties will be evaluated representing a range of fall dormancies to see if fall dormancy has an effect on alfalfa production under moisture-limiting conditions. In addition, some of the varieties were bred for production under moisture limiting conditions. Soil moisture will be monitored in each irrigation treatment (main plot) using Watermark® sensors and a neutron probe.

Irrigated Pasture Studies: Irrigated pasture is less drought tolerant than is alfalfa. Information is needed regarding the ability of irrigated pasture to withstand periods of deficit irrigation. This proposal will document how much production declines and plant density is reduced with deficit irrigation, ascertain which deficit irrigation strategies have the lease negative effect, and determine if some grass species are better suited to deficit irrigation than others. As with alfalfa, there will be large-scale grower demonstration plots. These will be conducted in the Scott Valley of Siskiyou County. Existing pastures will be subjected to four different irrigation treatments. The proposed treatments include normal irrigation, irrigation cut-off in June, irrigation cut-off in July, and normal irrigation up to June with only a single irrigation in each of the summer months (June, July and August). Yield and stand persistence will be evaluated as indicated in the description of the alfalfa studies. Small-plot studies will evaluate approximately 16 different pasture grasses (some of which were bred to go dormant in mid summer and some more drought tolerant than others) and their performance under 3 different irrigation regimes.

Sacramento Valley and Varietal Interaction

Field trials were established in 2002 on the University of California Agronomy Research Headquarters, Hutchison Road in Davis. Further follow-up experiments will have the following treatments.

1. Full irrigation according to normal grower practice on check-flood fields,
2. Ceasing irrigation during 4 weeks in August, with re-watering in September
3. Ceasing irrigation for 8 weeks during July and August, with no rewatering
4. Reducing irrigations from 2-3 per month to 1 per month during the months of June, July and August (continual deficit irrigation).

Sub plots would include variety (6-8 varieties, chosen for characteristics such as salt tolerance and stress tolerance, and Fall Dormancy). We also will apply several treatments utilizing growth regulators (several growth regulators which induce dormancy or reduce plant growth) in these sub plots (these will be conducted as separate trials within the main irrigation plots). The hypothesis is that growth regulators or variety choice may enable the alfalfa to more successfully induce a 'summer dormancy' which may improve plant survival and reduce alfalfa ET. Survival of plant stand has been the most challenging aspect of controlled irrigation deficits. Each irrigation treatment will be imposed with 'travelling boom' irrigation lines, with drop hoses and appropriate equipment for measuring flow rates and water application.

Building on this work will be the installation of grower field trails in the Sacramento Valley area set up in the same manner as described below for the San Joaquin Valley.

Southern San Joaquin Valley and Soil Type Interaction
Two adjacent fields (or 2 halves of an 80 or 160 acre field) on a similar/same soil type, farmed by the same grower will be selected for this part of the project. Both fields equipped with flow meters and 4 neutron probe access tubes installed to a depth of 10 feet, @ 200 feet from the head and 200 feet from the tail in 2 different irrigation checks. Water content measurements will be made before and after each irrigation. Gravimetric soil samples will be taken to determine water content for the 0-1 foot depth. Soil moisture matric potential monitoring with Watermark blocks and Hansen AM400 datalogger at the 6, 3 and 1 foot depths at one head and one tail neutron probe site in each field. Forage quality samples will be taken from every cutting during the summer. The grower will supply production data for each cutting after commercial harvest.

Field 1: Standard 2 to 3 irrigations/cutting in summer. This field only will be equipped with instrumentation for measuring ET by the surface renewal method.

Field 2: Controlled deficit irrigation, TARGET ET REDUCTION OF 6 TO 10 INCHES – 1 irrigation/cutting during July and August, maybe June depending on infiltration rates, residual soil moisture and the onset of stress.

Field trials with replicated treatments to develop statistically valid yield, quality and soil moisture depletion comparisons: 2 separate fields – One field with a heavy soil type (Buttonwillow area), the second field with lighter soil (Shafter/Wasco area).

Treatments:

1. Control – normal 2 irrigations/cutting for May through September
2. Deficit irrigation – only 1 irrigation/cutting for July and August.
3. July cutoff – no irrigation after June cutting, until late August, about 50 days

Selected fields will have ¼ mile runs and 36 to 60 foot wide checks. Using border checks as plots the 3 treatments will be replicated 4 times, as follows: Soil water content monitoring with the neutron probe at the midpoint of the field to a depth of 8 feet, will be replicated three times in all treatments for a total of 9 sites in each field, before and after each irrigation. Gravimetric sampling of the 0-1 foot depth will be done mid June through September. Swathing would need to be done without overlapping borders in order to allow for yield determination for each plot. Replicated samples for forage quality will be taken in July, August and September. Watermark blocks at the 6, 3 and 1 foot depths will be installed in adjacent borders of one replication of the Control and Deficit treatments adjacent to neutron probe access tubes and attached to one Hansen AM400 logger.

Water savings through reduced ET will be estimated by comparing the water content depletion of deficit treatments against that measured in the fully irrigated. This will be compared to the differences in water applied to each check.

Imperial Valley and Shallow Saline Water Table Interaction

Field trials will be designed to assess the effect of deficit irrigation on alfalfa yield, alfalfa water use (WUE), and irrigation efficiency. The trials will be conducted on a 40-acre alfalfa field in the Imperial Valley. Alfalfa will be planted on 65-102 ft wide and 1200 ft long border checks in October 2005. The following irrigation treatments will be implemented:

1- Standard irrigation practices (two irrigations per cutting)
2- Complete summer deficit irrigation (no irrigation between July and September)

3- Summer deficient irrigation (one irrigation per cutting July- September)
4- Winter deficient Irrigation (one irrigation per cutting November – March)

Each treatment will consist of one border and will be replicated three times. Other than altering the irrigation practices and the volume of water applied, all other agricultural practices will remain identical. Alfalfa yields will be determined from flail-type forage harvesters at 3-4 locations per treatment, depending upon range of variability. Also, immediately after baling, we will count hay bales on each border, weigh selected bales and record bale moisture from bales in each border.

The quantity and the rate of Colorado River water applied and the amount and quality of surface runoff will be determined for each treatment. Flow rates will be measured using trapezoidal and long-throated flumes, for applied water and surface runoff respectively (see Table below for details). Irrigation and surface runoff water quality parameters (N, P, turbidity, and salinity) will be determined using standard analytical methods, as shown in the Table below.

Although several alfalfa water use studies have been conducted across the south-western states, there remains a lack of information regarding water table contribution (WTC) to alfalfa water use when grown on moderately saline (4-6 dS/m) soils having a relatively shallow (6 ft deep) moderately saline (6-8 dS/m) water table. This condition is common in the Imperial Valley. Deficit irrigation or reduced irrigation frequency has a pronounced effect on WTC to alfalfa ET (Bali & Grismer, 2001). Ground water contribution to crop ET generally increases with deficient irrigation. In this study, we will determine the seasonal variation in WTC to alfalfa water use for each of the above irrigation treatments. Twenty-four sampling locations will be established (2 per border-check) to determine the salinity of the profile (surface –48”). Soil salinity will be measured roughly every three months by direct soil sampling and subsequent soil-water extraction and analysis in the laboratory. In addition, twenty-four 10-ft deep observation wells will be installed (2 per border-check). The observation wells will be used to assess the water table elevation and shallow groundwater salinity and chloride concentrations.

Table 1. Analytical instruments and flow rate measurement methods.

Parameter	Method	Units	Detection limit	Sensitivity	Precision	Accuracy
Water delivered	Trapezoidal flume	Cfs	0 to 25	0.5 cfs	±4%	±10%
Runoff water	long-throated flume	cfs	0 to 9	0.2 cfs	±5%	±10
PO_4	US-EPA 365.2 (Acid Persulfate Digestion)	mg/L	0-3.5	0.01	±5%	±5%
Salinity	EC (Tanji, 1990)	dS/m	0-3.0	0.05	±2%	±5%
NO_3	Spectrum™ (Cadmium Reduction Method)	mg/L	0-30.00	0.01	±5%	±10
Turbidity	US-EPA 180.1	NTU	<0.02	0.01	±10	±10

In addition to measurements of applied water (irrigation and rainfall) and runoff water, we will estimate the seasonal contribution of the shallow water table to alfalfa water use. We will employ the chloride mass balance method described by Wallender et al. (1979) with the exception that we will account for the chloride concentration in the irrigation water. We will determine the Cl concentration for each 12-inch depth increment of the soil profile in the root zone (48 inches) at each of the 24 soil salinity/water table monitoring locations. Chloride levels in soil, water table, and irrigation water will be determined prior to alfalfa planting, and approximately four times during each year. Water table contributions will be estimated from the mass transport of chloride from the water table to the depth increment of interest.

Growth Manipulation/Regulation and variety Interaction (Davis and Klamath). A key issue of deficit irrigation is whether alfalfa growth will actually cease once irrigation water is withdrawn. Our current experience tells us that under some circumstances, vegetative growth continues well past the point when water is withdrawn. This was particularly the case when high water table contributions to ET. This presents several difficulties: 1) Plants are stressed, potentially leading to more stand loss, 2) Water is used, complicating the issue of water transfers, 3) A sub-economic growth level would cost too much to harvest and manage. We will institute several different experiments with the aim of discovering methodologies to cause near cessation of alfalfa growth. We will conduct trials at UC Davis and Tulelake to study different varieties and growth regulators which have the effect of reducing or ceasing alfalfa growth during periods of deficit irrigation.

<u>Task List and Schedule</u>: (NOTE: this list will be modified for the different regions as necessary)
January, 2006. Begin Project. Principles meet to determine strategy and plans.
February, 2006 Hiring of Project Coordinator, field staff.
March, 2006 Finalization of field plans. Discussions with growers. Establishment of ET monitors at each site.
April-June, 2006 Field Monitoring, Begin some deficit treatments
July-September, 2006 implement summer deficit treatments
October, November, 2006 Field Monitoring
December, 2006 Presentation of field results at California Alfalfa Symposium.

January, 2007. First Annual report. Principles Meet to determine second year strategy and plans.
February-March, 2007 Finalization of field plans. Discussions with Growers. Establishment of ET monitors at each site.
May-September, 2007 Presentation of Field Experiments at Field Days at each location.
April-June, 2007 Field Monitoring, Begin some deficit treatments
July-September, 2007 implement summer deficit treatments
October, November, 2007 Field Monitoring
December, 2007 Presentation of field results at California Alfalfa Symposium.

January, 2008. Second Annual report. Principles Meet to determine third year strategy and plans.
February-March, 2008 Finalization of field plans. Discussions with Growers. Establishment of ET monitors at each site.
May-September, 2008 Presentation of Field Experiments at Field Days at each location.
April-June, 2008 Field Monitoring, Begin some deficit treatments
July-August, 2008 implement summer deficit treatments
September, 2008 implement deficit irrigation treatments
October, November, 2008 Field Monitoring
December, 2008 Presentation of field results at California Alfalfa Symposium.

February, 2009. Final Report

STATEMENT OF WORK

SECTION 3. MONITORING AND ASSESSMENT

Present data on alfalfa ET in actual production settings is sparse to non-existent. A few fields in the San Joaquin Valley were monitored for soil water content depletion (Dave Scruggs, DWR, personal communication 2004, DWR, 1993) in the 1980's and limited lysimeter evaluations by Pruitt, et al. (1987). These measurements estimated average alfalfa ET in the Central Valley to be about 48 inches. The average crop coefficient (Kc) calculated from these data was 0.95 for non-dormant alfalfa. Nearly all subsequent estimates of alfalfa ET for other basins across California have been calculated based on this crop coefficient multiplied by estimates for local potential grass ET (ETo). The development of the California Irrigation Management Information System (CIMIS) over the last 20 years has greatly expanded the geographic specificity of real-time ETo data and public access to these data. Recently developed isolines of ETo (Jones, et al., 1999, Rick Snyder, UC Davis, personal communication) using CIMIS station averages for the San Joaquin Valley are 10 to 15% higher than the average ETo formerly estimated by DWR from long-term Class A Evaporation Pan measurements during 1977-1992 (DWR, 1993).

All of these factors contribute to the present uncertainties regarding the "true" crop water use of most of California's crops and certainly alfalfa. Tom Goerhing (personal communication, 2004), current chair of the CALFED Ag Water Measurement Task Force, has said that the uncertainty surrounding climatic and crop variability, coupled with water district and on-farm errors in estimating flow rates and applied water could produce an error of +/- 30% in our estimates of true water requirements and actual application. Upon the successful award of this project we propose the following actions:

1. Collate baseline data/resources/references describing ETo and alfalfa ET in California for the last 20 years. Identify the theoretical assumptions driving these various estimates, quantify and attempt to explain the variance between these data/resources, especially with respect to alfalfa.
2. Compare alfalfa ET measurements made in this study with real-time CIMIS data for area stations. Calculate crop coefficients and compare to published values. Accuracy of this project data will be analyzed for consistency by region over the life of the project from one year to the next and by comparison with neutron probe determined soil water content depletion. This self-calibrated consistency over time will be the best measure of accuracy.
3. Summarize the above findings in a section on "Determining Potential ETo in California" in a University of California Cooperative Extension Bulletin documenting the results of this project and the agronomic practices required for successful implementation of deficit irrigation of alfalfa.

- *An explanation of the monitoring methodologies that will be used and the project monitoring data that will be collected to assess project results.*

The basis for consideration of Deficit Irrigation techniques by growers or water managers will be a cost-benefit analysis. For example, the maximum potential yield loss in Imperial Valley may be 15% of seasonal yield. The cost of this loss is $83/ton*8 tons/yr*0.15=$100/yr (based on the average value of alfalfa produced in the IV in 2003 (Imperial Valley Crop Management Guidelines: http://ceimperial.ucdavis.edu) The potential water savings a may be approximately 1-2 ac-ft/ac per year (including the free water table contribution. Therefore, the grower will lose about $100/a/yr in lost hay revenue but will save approximately $39 in production costs related to swath, rake, baling, hauling and stacking etc., and save approx. $16-32 (avg. $24) for the cost of 1-2ac-ft of water. So the net loss would be 100 minus 39 minus the 16 to 32) = $29 to $45 per ac per year loss. Therefore, the cost per ac-ft of water saved per ac is from $30-$45 under this scenario. That compares very well with other current water conservation measures. You may add a cost of management ($5-10 per ac/ft) to implement the practice of reduced irrigation, and of course there is always the willingness of growers to trade water (at any price). Currently, the cost of conserved ac-ft of water in Imperial using fallowing is $60, and the cost of conserved water form tailwater recovery systems is $130 per ac-ft (the two most common methods for conserving water in Imperial these days). This example illustrates the types of analyses which would be possible with documented costs and benefits of these techniques from scientific field studies, and better ET estimates.

Outreach and Extension. The Project progress reports along with the various cost/benefit scenarios as they unfold across the different regions will be posted on our University of California Alfalfa and Forage Workgroup website. An extension bulletin as described above will be written upon completion of the project. Project investigators will present project results at local and statewide workshops (including local and regional alfalfa production meeting and the annual California Alfalfa Symposium), professional society meetings and water district meetings. (For example: Every spring Blake Sanden attends the board meetings of 8 different large water districts in Kern County to report on soil moisture monitoring and irrigation management activities.) Other meetings for all investigators include those of the Farm Bureau, Natural Resources Conservation Service, the Farm Services Agency, and more.

- *An explanation of how the above data will be used to evaluate success in relation to project goals and objectives.*

Substantial contact numbers, especially regarding extension bulletins sold/downloaded over the internet, will mean that a fair amount of interest has been generated by the concept. However, we should be clear that this is a technical, demonstration, and proof-of-concept project. The implementation of these techniques will depend upon policy, political, economic, and weather patterns beyond the control of the investigators. The overall goal here is to create a ‘management package’ with respect to deficit irrigation of alfalfa that could be implemented given certain economic, legal, and policy trends that mean growers would buy into the idea. However, the research program we propose has current value by increasing the known options growers and water managers will have to allow for such “alternative” programs in the future.

- *A description of how external factors such as changes in weather, cropping programs, or social conditions will be taken into account.*

Unseasonably wet winter and spring in the Sacramento Valley and Intermountain Areas can cut the need for early-season irrigation by a large percentage, thus reducing total applied water for the entire season. This is almost never the case in the southern SJV or Imperial County. However, since this project focuses on reduction of ET during the summer period when weather conditions are relatively constant from year to year, weather change is not an important issue. It is conceivable that social issues or severe drought in California might accelerate the demand and opportunity for trading water at higher prices than typical for water districts and this could trigger rapid interest in deficit irrigating alfalfa, but this should have no impact on successful completion of this project.

It is conceivable that we might get a trial field that collapses after extended dry down, or a field trial fails. We believe this to be a remote possibility, but if it were to happen in one of the regions we would rule out any untoward disease or insect infestation and attempt to corroborate the problem in a second season.

- *Information about how the data and other information will be handled, stored, and reported and made accessible to DWR and others.*

Dissemination of the results of this project was discussed above under baseline data and project monitoring data. Reports will be made available to funding agencies and to the public via extension programs.

- *The estimated costs associated with the implementation of the monitoring and evaluation plan.*

No additional cost to DWR is incurred in implementing this monitoring and evaluation plan as it is executed as part of the education and outreach program conducted by all the investigators associated with this project. As researchers and extension personnel with UCCE our core deliverables are practical solutions for current problems facing California agriculture. The cost to deliver this benefit is borne by the University and reflected in the value of the percent of our time spent on this project. The approximate dollar value of this time is listed (but not documented) in the cost share quotient of the budget. Though, cost sharing is not required for research projects we felt it useful to reflect the value of our time, and the University of California's contribution to this project.

OUTREACH, COMMUNITY INVOLVEMENT AND ACCEPTANCE

Outreach techniques such as newsletters, bulletins, and web-based communication, as well as the annual Statewide California Alfalfa symposium will be used to get the word out to the public (as described above). It should be pointed out that all of the investigators on this project are intimately involved with the alfalfa industry, and work very closely with alfalfa growers. The PI is on the board of the state-wide California Alfalfa & Forage Association, which has been kept abreast of this project. We have introduced this concept to growers, and have worked through several (but not all) of the economic and political aspects of this concept. Our project is designed to continually monitor the acceptability and viability of this concept to growers, by conduction trials in grower-cooperator fields. Additionally, ongoing discussions with water experts in DWR and other agencies to discover the viability of this concept for the future will be held. By the completion of the project, these interactions should lay the groundwork for full evaluation of this concept, and result in a 'package' of practices and approaches which may be acceptable to growers and water managers.

BENEFITS AND COSTS

The potential benefits of this project are to provide a technical package for a viable option to allow mutually-acceptable temporary trading of water from alfalfa production to other uses during drought years. A focus on alfalfa allows greater seasonal flexibility than other options, when decisions need to be made late in the year (e.g. June), rather than before the cropping season. This enables full assessment of water resources for that year. Growers may have an interest in this concept if it can be amply demonstrated that stands are not threatened and they are compensated adequately for the yield losses. Summer harvests tend to be lower value anyway, and this may help stabilize prices. This concept is a 'middle ground' between full agricultural water use and fallowing, which has a number of negative consequences, both towards farming, the environment, and rural communities. The potential water yields will depend upon region affected, the need, and how many growers were interested. However, this project will test the feasibility of deficit irrigation strategies that may yield between 200,000 to 600,000 AF or possibly greater if interest and need arises (see estimates in Statement of Work, Section 1). This proposal will form the basis for orderly understanding of the ability to implement this strategy in the future.

Specifically, **using the categories of benefits listed in Table C-5**, the potentially ½ MAF of water that could be released to other uses in the latter part of the irrigation season could be used to:

- Increase local or system-wide water project flexibility to make up for short deliveries to other vital crops, municipal or in-stream demands *(Physical benefits)*
- In the peak demand period for California's water system, anywhere in the state that alfalfa is grown *(Timing and location of benefit)*
- For as long as people continue to use milk and alfalfa is a major crop in California *(Duration of benefits)*
- Providing an indirect Bay-Delta benefit, by allowing for a decrease in total irrigation demand *(Bay-Delta Benefit)*
- With a possible steady yield of 200,000 ac-ft at a very moderate cost to water districts along with improved price stability to alfalfa growers to more than ½ MAF with greater incentive payments to growers; while at the same time avoiding the draconian impact on the local economy that occurs with land fallowing programs. *(Project yield)*

The cost of this project is $981,984. Given the successful development of the proposed agronomic management package for the deficit irrigation of alfalfa and a possible steady yield of 200,000 ac-ft/year – this would provide 4 MAF over 20 years. **Thus, the amortized cost of this project over 20 years would be less than $0.25/ac-ft.** Grower incentive payments that will most likely be required to offset yield losses and, depending on the market price of alfalfa, local water prices and yield impacts, cost from $40 to $150/ac-ft.

Project costs are listed in Table C-1 below, with detail provided in an accompanying spreadsheet. Matching funds are not formally listed, but estimated contribution of time for each of the five UC principle investigators is 15 to 20% upon commencement of the project.

INVESTIGATORS, ROLES AND QUALIFICATIONS OF APPLICANTS

The members of this team represent key individuals with knowledge of alfalfa, expertise on irrigation, and state-wide scope of activity. The diversity and substance of their past and current research and extension efforts in water management are reflected in the experience and publications documented in the resumes attached to the end of this project proposal. The below list provides the designation of roles/responsibilities and contact information for each researcher.

Dan Putnam is the UC Cooperative Extension Statewide Alfalfa Specialist (12 years), and will serve primarily as statewide coordinator and industry and agency liaison for this project. He will continue field station trials at UCD and also help establish the Sacramento Valley grower trials.

> UCD, Dept. of Agronomy and Range Science, One Shields Ave., University of California, Davis, CA 95616. Phone: 530-752-8982, FAX: 530-752-4361. Email: dhputnam@ucdavis.edu. Website: http://alfalfa.ucdavis.edu

Steve Orloff is the Plant Sciences Farm Advisor for UCCE in Siskiyou County (13 years), and will conduct the field station and on-farm part of this project for the Intermountain Area.

> UCCE Siskiyou County, 1655 S. Main St. Yreka, CA 96097 Phone: 530-842-2711, FAX: 530-842-6931. Email: sborloff@ucdavis.edu.

Blaine Hanson is a UCCE Statewide Irrigation and Drainage Specialist (27 years), and serves as the statewide technical coordinator for water monitoring in this project and establishing the Sacramento Valley region grower trials.

> UCD, Dept. of Land, Air, and Water Resources, One Shields Ave., University of California, Davis, CA 95616. Phone: 530-752-1130. FAX: 530-752-5262. Email: brhanson@ucdavis.edu

Blake Sanden is the UCCE Irrigation & Agronomy Farm Advisor in Kern County (13 years), and will establish and monitor the San Joaquin Valley grower trials. Blake was involved in an earlier CALFED Water Use Efficiency project over 9,600 acres in Kern County from 2002-2003 (Quantification of Benefits Attributable to Irrigation Scheduling as an On-Farm Water Management Tool, DWR Contract No. 4600001638) which had previously been awarded to WaterTech Partners.

> UCCE Kern County, 1031 S. Mt. Vernon Ave., Bakersfield, CA 93307. Phone: 661-868-6218. Fax: 661-868-6208. Email: blsanden@ucdavis.edu

Khaled Bali is the UCCE Irrigation/Water Management Advisor in Imperial County (13 years), and will establish and monitor the Imperial Valley grower trials.

UCCE Imperial County, 1050 East Holton Rd. Holtville, CA 92250-9615. Phone 619-352-9474. Fax: 619-352-0846. Email: kmbali@ucdavis.edu

Rick Snyder is a Biometeorology Specialist with the Department of Land , Air and Water Resources, University of California, Davis. He has nearly 25 years of experience in this postion. He will be involved in setting up, maintaining, and evaluating data from the eddy correlation and surface renewal system for measuring crop evapotranspiration.

One Shields Ave, LAWR, UC Davis, Davis, CA 95616. Phone: 530-752-4628; FAX 530-752-5262, Email rlsnyder@ucdavis.edu.

LITERATURE CITED

Bali, K. M., M. E. Grismer, M. E. and R. L. Snyder. 2001. Alfalfa Water Use Pinpointed in Saline, Shallow Water Tables of Imperial Valley. California Agriculture, Vo. 55, No. 4, 38-43.

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Ottman, M.J., B.R. Tickes, and R.L. Roth. 1996. Alfalfa yield and stand response to irrigation termination in an arid environment. Agronomy Journal, Vol.88:44-48.

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Putnam, D., H. Takele, R.Kallenback, and W. Graves. 2000. Irrigation alfalfa in the Low Desert: Can Summer Dry-down be Effective for Saving Water in Alfalfa? Report submitted to the Bureau of Reclamation (USDI), Yuma, AZ.

Putnam, D.H., M. Russelle, S. Orloff, J. Kuhn, L. Fitzhugh, L. Godfrey, A. Kiess, R. Long. 2001. *Alfalfa Wildlife and the Environment—The Importance and Benefits of Alfalfa in the 21st Century.* California Alfalfa & Forage Association, Novato, CA. (http://alfalfa.ucdavis.edu)

Robinson, F.E., L. R. Teuber, and L. K. Gibbs. 1994. Alfalfa Water Stress Management During Summer in Imperial Valley for Water Conservation. Desert Res. and Ext. Center, El Centro, CA.

Synder, R.L., 1996. Surface renewal analysis for sensible and latent hear flux density. Boundary-Layer Meteorology 77: 249-266.

Wallender, W. W., D. W. Grimes, D. W. Henderson, and L. K. Stromberg. 1979. Estimating the contribution of a perched water table to seasonal evapotranspiration of cotton. Agron. J. 71:1056-1060.

Proposal: Benefits and Costs of Defict Irrigation in Alfalfa
Applicant: University of California

THE TABLES ARE FORMATTED WITH FORMULAS: FILL IN THE SHADED AREAS ONLY

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)
	Administration[1]					
	Salaries, wages	$354,564	0	$354,564	$0	$354,564
	Fringe benefits	$102,824	0	$102,824	$0	$102,824
	Supplies	$50,000	0	$50,000	$0	$50,000
	Equipment	$104,000	0	$104,000	$0	$104,000
	Consulting services	$0	0	$0	$0	$0
	Travel	$51,000	0	$51,000	$0	$51,000
	Other	$144,000	0	$144,000	$0	$144,000
(a)	Total Administration Costs	$806,388		$806,388	$0	$806,388
(b)	Planning/Design/Engineering	$0	0	$0	$0	$0
(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 (Specify)	$175,597	0	$175,597	$0	$175,597
(l)	Monitoring and Assessment	$0	0	$0	$0	$0
(m)	Report Preparation	$0	5	$0	$0	$0
(n)	**TOTAL**	$981,984		$981,984	$0	$981,984
(o)	Cost Share -Percentage				0	100

1- excludes administration O&M.

NOTES:

1 This proposal is a comprehensive state-wide project, for 3-years duration, with 5 collaborators.

2 Salary, wages, includes a state-wide coordinator, plus a technical person to impliment field trails at each location

3 Equipment includes ET measurement equipment at all four locations, including 4 Bowen Ratio units ($6,000 each) and 1 Eddy Covariance Unit ($30,000).

4 Supplies includes soil moisture monitoring equipment, flow meters, piping, etc.

5 Travel includes support for PI and collaborators to meet 3 x per year at a central location to coordinate efforts, Project coordinator, and scientific meetings

6 "Other" under admin. Costs is payments to growers for yileld losses sustained by deficit irrigation practices on their farms, which are done as part of the on-farm demonstrations.

7 Overhead for UC is listed under (k) other, and is 25% of the non-equipment funding.

PROJECT BUDGET DETAIL

			Year 1	Year 2	Year 3	Totals	Totals
Personel:		Project Coordinator (UC Davis)					
	1	SRA or GRAD Student	35,016	35,016	35,016	105,048	
	2	Field Assistant @ 80% (Tulelake)	20,793	20,793	20,793	62,379	
	3	Field Assistant @ 80% (Davis)	20,793	20,793	20,793	62,379	
	4	Field Assistant @ 80% (Kern Co.)	20,793	20,793	20,793	62,379	
	5	Field Assistant @ 80% (Imperial Co.)	20,793	20,793	20,793	62,379	
		Total Personel	**118,188**	**118,188**	**118,188**	**354,564**	**354,564**
	1	Benefits	10,155	10,155	10,155	30,464	
	2	Benefits	6,030	6,030	6,030	18,090	
	3	Benefits	6,030	6,030	6,030	18,090	
	4	Benefits	6,030	6,030	6,030	18,090	
	5	Benefits	6,030	6,030	6,030	18,090	
		Total Benefits	**34,275**	**34,275**	**34,275**	**102,824**	**102,824**
Supplies		Field Supplies, Lab Analyses (misc)	8,000	8,000	8,000	24,000	
		Water meters, Flow meters	8,000			8,000	
		Piping, other field monitoring equipment	6,000			6,000	
		Soil Moisture Monitoring devices	6,000			6,000	
		Dataloggers	6,000			6,000	
		Total Supplies	**34,000**	**8,000**	**8,000**	**50,000**	**50,000**
Equipment:		4 Surface Renewal ET Units @ 6,000	24,000			24,000	
		2 Eddy Covariance ET Units @ 40.000	80,000			80,000	
		Total Equipment	**104,000**			**104,000**	**104,000**
Travel:		Field work and project coordination (Area researchers and field techs)	8,000	8,000	8,000	24,000	
		Statewide proejct coordinator travel	5,000	5,000	5,000	15,000	
		Travel to Field & Professional Meetings to present results (3)	2,000	5,000	5,000	12,000	
		Total Travel	**15,000**	**18,000**	**18,000**	**51,000**	**51,000**
Other:		Payments to Farmers to compensate for yield loss due to deficit irrigation	48,000	48,000	48,000	144,000	
		8 locatons x est. 6,000 each location/year					
		Total Other	**48,000**	**48,000**	**48,000**	**144,000**	144,000
TOTALS		(Funds for project)	353,463	226,463	226,463	806,388	
		UC Overhead @ 25% on non-equipt. Funding	**62,366**	**56,616**	**56,616**	**175,597**	**175,597**
		GRAND TOTAL	**415,828**	**283,078**	**283,078**	**981,984**	**981,984**

NOTES:

1 This proposal is a comprehensive state-wide project, for 3-years duration, with 5 collaborators.

2 Salary, wages, includes a state-wide coordinator, plus a technical person to impliment field trails at each location. Benefits and payroll burden calculated @ 29% of wages.

3 Equipment includes ET measurement equipment at all four locations.

4 Supplies includes soil moisture monitoring equipment, flow meters, piping, etc.

5 Travel includes support for PI and collaborators to meet 3 x per year at a central location to coordinate efforts, Project coordinator, and scientific meetings

6 "Other" under admin. Costs is payments to growers for yileld losses sustained by deficit irrigation practices on their farms, which are done as part of the on-farm demonstrations.

7 Overhead for UC is listed under (k) other, and is 25% of the non-equipment funding.

Daniel H. Putnam, PhD
Extension Agronomist - Alfalfa and Forage Crops
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Education:
1986 Ph.D. (Plant and Soil Sciences), University of Massachusetts, Amherst
1983 M.S. (Plant and Soil Sciences), University of Massachusetts, Amherst
1977 B.S. (Agronomy), Wilmington College, Wilmington, Ohio

Employment History:

1993-present Cooperative Extension Specialist and Agronomist in the Agriculture Experiment Station–Alfalfa and forage crops, University of California, Davis, California
1986-1993 Assistant Professor, University of Minnesota, St. Paul, Minnesota. Specialist in New and Alternative Crops.
1985-1986 Research Associate, University of Massachusetts, Amherst, Massachusetts.

Current Position Description: ***Cooperative Extension Specialist and Experiment Station Scientist*** at UC Davis for alfalfa and forage cropping systems. This position entails statewide responsibility for extension and research activities related to alfalfa and forage crops. Currently chair of the California Alfalfa Symposium, and UC California Alfalfa Workgroup. Other interests include introduction of new crop species, crop ecology, and forage quality analysis methods, introduction of unique traits in alfalfa.

Research Interests: Alfalfa cultivar interactions with agronomic practices, introduction of unique traits in alfalfa, economics of the yield-quality tradeoff in alfalfa, forage quality analysis methods, irrigation techniques, alternative forage crops, interactions of alfalfa and the environment.

Honors, Awards:

1984-85 - Fulbright Scholarship for overseas study (India).
1999 - Hilgaard Award for Outstanding Teaching - Extension Specialist. California Association of Farm Advisors and Specialists.
2000 - Award for Excellence - American Society of Agronomy Extension Publications Award - Newsletter category, (California Alfalfa & Forage Review, candidate is editor)
2000 - Extension Education Award - National Association of Farm Advisors and Specialists
2000 - Achievement Award - California Associations of Farm Advisors and Specialists

Industry, Professional Memberships Chair, UC California Alfalfa Workgroup; Chair, California Hay Testing Consortium; Chair, California Alfalfa Symposium; Past President, and board member, National Forage Testing Association; California Alfalfa & Forage Association founding board member and Secretary; Member, American Society of Agronomy; Crop Science Society of America; California Farm Bureau Federation, Hay Advisory Committee; Alfalfa Council (national), Advisory Board; National Alfalfa Intensive Training Seminar Instructor

Consulting: USDA oversees development projects, World Bank Oilseed Project, with private parties in Egypt, Saudi Arabia, Pakistan, China, and India, subjects related to forage production, hay storage and marketing, spontaneous combustion of hay, hay quality, and the use of forages for mitigation of pollution including applications of effluent and industrial wastes. Scientific exchanges and consultancies to Chile, Russia, India, Poland, Australia, New Zealand, and Egypt.

Relevant publications:

Putnam, D.H. and M. Ottman. Emerging Issues with Alfalfa in the Desert and Mediterranean Regions of the Western United States. In Proceedings, Western Alfalfa and Forage Conference, 11-12 December, 2002, Reno, NV. UC Cooperative Extension, University of California, Davis.

Putnam, D.H. Producing Quality Alfalfa in the Western United States. Published In China International Grasslands Symposium Proceedings. 20-23 May, 2002 Beijing, China.

Long, R.F., M. Nett, D.H. Putnam, G. Shan, J. Schmierer, B. Reed. Insecticide Choice for Alfalfa may Protect Water Quality. California Agriculture 56(5):163:169.

Putnam, D.H., M. Russelle, S. Orloff, J. Kuhn, L. Fitzhugh, L. Godfrey, A. Kiess, and R. Long. Alfalfa, Wildlife and the Environment The importance and Benefits of Alfalfa in the 21st Century. 24 pages. California Alfalfa and Forage Association, Novato, CA.

Blank, S.C, S. Orloff, and D. H. Putnam. Sequential Stochastic Production Decisions for a Perennial Crop: The Yield/Quality Tradeoff for Alfalfa Hay. Journal of Agricultural and Resource Economics 26(2001): 195-211.

STEVE B. ORLOFF
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University of California Cooperative Extension
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Education
B.A. Geography 1978 San Diego State University
M.S. Agronomy 1984 California Polytechnic State University, San Luis Obispo

Employment
Plant Science Farm Advisor, University of California Cooperative Extension, 1984 to present

Steve Orloff has been a Farm Advisor for UC Cooperative Extension in Siskiyou County for the past 13 years. Prior to that he held a similar position in the high desert portion of Los Angeles and San Bernardino Counties for 8 years. He has conducted an extensive research and education program focusing on forage production—primarily alfalfa but also small grains, sugarbeets, onions, and pasture. Research efforts have been broad based, encompassing many of the management aspects of producing these crops. Alfalfa research efforts have focused on cultivar selection, improved irrigation practices, planting methods, weed and insect control, interseeding depleted alfalfa stands, rodent control, cutting schedules, and forage quality.

In addition to the research and education program, Orloff is also serving as County Director for the Siskiyou County Cooperative Extension Office. He supervises three University-paid employees and two county-paid employees. He serves as a liaison with county government, agricultural organizations, civic groups, and governmental agencies. He is also responsible for securing and administering the County budget for the office.

International Experience

Peace Corps Volunteer, El Salvador and Honduras, 1/79 to 4/81 Initiated a program on soil and water conservation in rural areas of El Salvador and Honduras. Was also involved in improving cultural practices for subsistence farmers producing corn and beans.

Keynote Speaker: Sociadad Espanola de Malherbologia (Spanish Weed Science Society). *La Transferencia de Tecnologia En Malherbologia Usado en California.* Spent a week in Spain and gave a 45 minute keynote presentation and radio and television interviews.

Consulting

Consulted in Romania six times in the last three years on US Agency for International Development-funded project to assess the feasibility and production practices for commercial alfalfa production in Romania. Served as a private consultant on alfalfa production on two occasions to ascertain crop production losses and to conduct a feasibility study on the production of alfalfa with effluent water. Served as an expert witness for three court cases involving alfalfa production.

Professional Activities and Memberships
Western Society of Weed Science
California Weed Science Society
American Society of Agronomy
Crop Science Society of America

Awards: Award of Excellence for Field Research by the California Weed Science Society
Outstanding Educational Materials Award from the American Society of Agronomy
Distinguished Service Award for Outstanding Educational Program-Farm Advisor

Selected Publications

Hanson, B., S. Orloff, and D. Peters. 2000. Monitoring soil moisture helps refine irrigation management. *California Agriculture*. 38–42 May./June 2000 Vol. 54 No. 3.

Orloff, S. B. and H. L. Carlson. 1997 *Intermountain alfalfa management*. Oakland: University of California Division of Agriculture and Natural Resources, Publication 3366. 138 p.

Orloff, S.B. 1999. Selecting cutting schedules—the yield and quality tradeoff. *Hoard's Dairyman*. p. 493. July.

Orloff, S.B. 2000. Monitoring alfalfa water use. Proceedings, 29th National Alfalfa Symposium. 111–118. December 11–12, Las Vegas, NV.

Orloff, S., Hanson, B., and Putnam, D. 2003. Utilizing soil-moisture monitoring to improve alfalfa and pasture irrigation management. Online: Crop Management doi:10.1094/CM-2003-01XX-01-MA.

CURRICULUM VITAE

Blaine R. Hanson
Extension Irrigation and Drainage Specialist
Department of Land, Air, and Water Resources
University of California, Davis 95616

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EXPERIENCE:

1974-77	Research Assistant, Colorado State University
1977-present	Irrigation and Drainage Specialist, University of California, Davis

EDUCATION:

B.S.	Civil Engineering, New Mexico State University, Las Cruces, New Mexico	1969
M.S.	Civil Engineering, Utah State University, Logan, Utah	1971
Ph.D.	Agricultural Engineering, Colorado State University, Fort Collins, Colorado	1977

PROFESSIONAL SOCIETIES:

American Society of Agricultural Engineers
American Society for Horticultural Science
California Irrigation Institute

EXTENSION EDUCATION AND TEACHING

Manuals:

Hanson, B.R., S.R. Grattan, and A. Fulton. 1993. Agricultural Salinity and Drainage. University of California Division of Agricultural and Natural Resources Publication 3375. 141 p.

Hanson, B.R., L.J. Schwankl, W. Bendixen, and K. Schulbach. 1994. Surge Irrigation. University of California Division of Agricultural and Natural Resources Publication 3380. 48 p.

Hanson, B. 1994. Irrigation Pumping Plants. University of California Division of Agricultural and Natural Resources Publication 3377. 127 p.

Schwankl, L.J., B.R. Hanson, and T.L. Prichard. 1995. Micro-irrigation of Trees and Vines. University of California Division of Agricultural and Natural Resources Publication 3378. 138 p.

Hanson, B.R. and L.J. Schwankl. 1995. Surface Irrigation. University of California Division of Agricultural and Natural Resources Publication 3375. 105 p.
Hanson, B.R., L.J. Schwankl, S.R. Grattan, and T.L. Prichard. 1997. Drip Irrigation for Row Crops. University of California Division of Agricultural and Natural Resources Publication 3376. 238 p.
Hanson, B. R, L. J. Schwankl, and A. Fulton. 1999. Scheduling Irrigations: When and How Much Water to Apply. University of California Division of Agricultural and Natural Resources Publication 3396. 202 p.
Orloff, S., B. Hanson, and D. Putnam. 2001. Soil-Moisture Monitoring. University of California Cooperative Extension, Siskiyou County.

PUBLICATIONS:

Tanji, K.K. and B.R. Hanson. 1990. Drainage and return flows in relationship to irrigation management. In: *Irrigation of Agricultural Crops*. American Society of Agronomy Monograph, American Society of Agronomy.

Hanson, B.R. and G.L. Dickey. 1993. Considerations in using neutron moisture meters. *California Agriculture* 47(6):29-31.

Hanson, B.R., T. Prichard, and H. Schulbach. 1993. Estimating furrow infiltration. *Agricultural Water Management* 24:291-298.

Orloff, S.B., H.L. Carlson, and B.R. Hanson. 1996. Irrigation. In: *Intermountain Alfalfa Management*, University of California, Division of Agriculture and Natural Resources, Publication 3366, pg.25-40

Hanson, B. R. and L. J. Schwankl. 1998. Error analysis of flowmeter measurements. *Journal of Irrigation and Drainage Engineering* 124(5):248-256.

Hanson, B. R. and K. Kaita. 1999. Historical reference crop ET reliable for irrigation scheduling during summer. *California Agriculture* 53(4):32-36.

Hanson, B. R., D. Peters, and S. Orloff. 2000. Effectiveness of tensiometers and electrical resistance blocks vary with soil conditions. *California Agriculture* 54(3):47-50.

Hanson, B. R., and D. Peters. 2000. Soil types affects accuracy of dielectric moisture sensors. *California Agriculture* 54(3):43-47.

Hanson, B.R. and J. E. Ayars. 2002. Strategies for reducing subsurface drainage in irrigated agriculture through improved irrigation. *Irrigation and Drainage Systems* 16: 261-277.

Blake McCullough-Sanden

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Education:

University of California, Davis. M.S. in Water Science/Irrigation and Drainage, 1987.
University of California, Davis. B.S. in International Agricultural Development/Agronomy, 1978.

Experience:

7/92-present: University of California Cooperative Extension, Kern County
Irrigation & Agronomy Farm Advisor
Education and research programs relating to soil/salinity/irrigation management and field crops agronomy in Kern County.

2/88-7/92: Paramount Farming Co.-Westside Ranch; Lost Hills, CA
Irrigation Technical Advisor
Management of irrigation on 26,000 acres of pistachios, almonds, olives, grain, and cotton.

1/85-2/88: Dept. of Land, Air, & Water Resources; University of California, Davis
Graduate Research Assistant/Teaching Assistant
Developed original research to monitor seepage of ponded drainwater in five agricultural drainwater evaporation ponds in the San Joaquin Valley.

6/83-1/85: Woodlake Union High School; Woodlake, CA
Farm Manager
Plan and carry out operations for maintenance/production on 44 acre high school farm.

7/78-5/83: United Presbyterian Church, USA; Zambia, Africa & U.S.
Fraternal Worker/Missionary
Developed strategies and programs stressing self-reliance for increasing agricultural production in a rural area of Zambia, Africa through demonstration plots of local field and vegetable crops, design and construction of hand-powered processors for some crops, village extension/education.

Professional Activities:

As the Irrigation and Agronomy Farm Advisor with the University of California Cooperative Extension, stationed in Kern County at the southern end of the San Joaquin Valley, I conduct a county-based, applied research and extension program focusing on three areas: **1) irrigation system management** -- scheduling, optimal system design and maintenance, **2) salinity/fertility management** -- reclaiming/improving soil structure and nutrient availability, and **3) agronomy** -- traditional commodity responsibilities for dry beans, sugar beets, safflower, alfalfa and other forage.

In addition to **traditional agronomic extension work** on the above crops, field trials and seminars are conducted on a variety of **resource management issues** such as water supply, greenwaste compost, application of biosolids to farm land, salinity management, wells and pumps, drip irrigation, irrigation system uniformity and irrigation scheduling. The results of this work are disseminated via local, statewide and national publications and meetings.

Consulting services for agronomic and irrigation management include work with Los Angeles County Sanitation District and ACDI/VOCA (US AID) in West Bank (Jericho), Uganda and Ethiopia.

Professional Societies:

American Society of Agronomy, American Society of Agricultural Engineers, California Association of Farm Advisors and Specialists, California Irrigation Institute, International Society of Horticultural Science, Irrigation Association

Selected Publications:

DeTar, W.R., G.T.Browne, C.J. Phene, **B.L.Sanden.** 1996. Real-time irrigation scheduling of potatoes with sprinklers and subsurface drip systems. Proceedings of the International Evapotranspiration and Irrigation Scheduling Conference. Amer. Soc. of Ag. Eng. Saint Joseph, MI. pp.812-824

Ferguson, L.**, B. Sanden,** S. Grattan, P. Metheney, H. Reyes. 1998. Potential for utilizing blended drainage water for irrigating West Side, San Joaquin Valley pistachios (Project 93-4). Annual Report, UC Salinity/Drainage Program Water Resources Center Prosser Trust, 1997-98, p. 6-15.

Grismer, M.E., **McCullough-Sanden, B.L**. 1989. Correlation of laboratory analyses of soil properties and infiltrometer seepage from drainwater evaporation ponds. Transactions of the American Society of Agricultural Engineers. Soil and Water Div.

McCullough-Sanden, B.L., Grismer, M.E. 1988. Field analysis of seepage from drainwater evaporation ponds. Transactions of the American Society of Agricultural Engineers. Soil and Water Div. 31(6):1710-14.

Sanden, B., W.R. DeTar, A.E. Hall, S. Temple. 1996. Irrigation scheduling and water quality in blackeyes. Proceedings of the International Evapotranspiration and Irrigation Scheduling Conference. Amer. Soc. of Ag. Eng. Saint Joseph, MI. pp.749-755

Sanden, B., J. Mitchell, L. Wu. 1997,1998. 1999. Effects of irrigation nonuniformity on nitrogen and water use efficiencies in shallow-rooted vegetable cropping systems (second year progress report). Proc. of the Fifth Annual Fertilizer Research and Education Program Conference. CA Dept. of Food and Ag., Sacramento, CA. p.39-43. Also presented as poster at 1997 Soc. of Hort. Sci. Annual meeting.

Sanden, B. 1997. Biosolids impacts on nutrient and water management in production agriculture-- field observations. 1997 California Biosolids Conference Syllabus. CA Water Environment Assoc., Jan.29&30, Sacramento, CA. 8 pp.

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EDUCATION:

Ph.D. (Soil Science; Soil Physics), University of California, Davis. 1992.
Dissertation: *Error Corrections for Gamma-attenuation Measurements of Multi-phase Flow in Porous Media.*

M.S. (Water Science; Irrigation and Drainage), University of California, Davis. 1987. Thesis: *Water Application Under Varying Infiltration and Time.*

B.S. (Soils and Irrigation), University of Jordan, Amman. 1984

POSITIONS:

Assistant, Associate, and Full Title Cooperative Extension Advisor-Irrigation/Water Management, University of California- Division of Agriculture and Natural Resources, UC Desert Research & Extension Center (1992-present).

Engineering Technician: City of Davis, Davis, CA (1990-1991).

Research and Teaching Assistant: University of California, Davis, CA (1985-1991).

AWARDS:

- Khaled Bali Xeriscape Demonstration Garden. Yuma Crossing State Historic Park. Dedicated on April 22, 2004. USBR & Yuma Crossing State Park.
- 2003 Water Conservation Award. USBR- Lower Colorado Region Regional Award- Yuma Area Office October 2003.
- 2003 American Society of Civil Engineers/Environmental & Water Resources Institute Best Practice Paper Award for our ASCE Journal of Irrigation and Drainage paper "Model for Estimating Evaporation and Transpiration from Row Crops. Journal of Irrigation and Drainage Engineering, Nov/Dec 2001".
- University of California-Office of the Vice President: 2002 Agricultural and Natural Resources Distinguished Service Award for Outstanding Teamwork
- University of California Outstanding Research Award .UC Academic Assembly Council. July 1997.
- Volunteers in Overseas Cooperative Assistance (VOCA)- Outstanding Contribution to VOCA. August, 1996.
- Outstanding Student of the College of Agriculture. University of Jordan. Awarded by the late King Hussein of Jordan. June 1984.
- Practical training scholarship at the University of Stuttgart, Germany. Awarded by DADD, Germany. June-September 1984.

FIVE RELEVANT PUBLICATIONS:

Bali, K. M., M. E. Grismer, M. E. and R. L. Snyder. 2001. Alfalfa Water Use Pinpointed in Saline, Shallow Water Tables of Imperial Valley. California Agriculture, Vo. 55, No. 4, 38-43.

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Curriculum Vitae of Investigators

CURRICULUM VITAE

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Education

Iowa State University, Ph.D. Agricultural Climatology, 1980; Iowa State University, M.S., Agricultural Climatology, 1978; University of Northern Iowa, B.A., Mathematics, 1971; North Iowa Area Community College, A.A., Mathematics, 1969

Experience

1980 - Present - Biometeorologist Specialist;University of California, Department of Land, Air and Water Resources, Davis, California

Professional Affiliation

American Meteorological Society
International Society for Horticultural Science
International Society of Biometeorology

Major Research and Teaching Activities

During my employment with the University of California, my main research and teaching activities were related to (1) testing and developing methods for estimating evapotranspiration, (2) irrigation scheduling, and (3) freeze protection of crops. In recent years, my research activities have expanded to include studies on (1) wildfire risk and (2) energy and carbon fluxes over restored wetlands.

For the past few years, we have conducted research to measure evapotranspiration and carbon fluxes from a restored wetland in conjunction with colleagues from the US Geological Survey. This research effort compliments the USGS efforts to monitor carbon balance in restore wetlands. The ultimate goal is to determine if the restored wetland is a source or sink of CO_2 and to determine the evapotranspiration of the wetland. This information is needed to insure drinking water quality for water transfers to Southern California and to make decisions on future management of the Sacramento-San Joaquin River Delta to minimize water losses. The carbon flux information is needed to determine if future Delta management will be beneficial or detrimental to the global carbon balance.

During the past 10 years, I have worked extensively with colleagues to develop the new “Surface Renewal” method for estimating sensible heat flux density using low-cost instrumentation. This has greatly facilitated our estimation of crop evapotranspiration for tomatoes, maize, sunflowers, grapevines, citrus and rice. The goal is to use this information to improve irrigation management and water resource planning in California.

In my early work at the University of California, I was the principal investigator on the California Irrigation Management Information System (CIMIS) research and development project. In this three-year project, a network of 43 electronic weather stations was established to gather data for the calculation of reference evapotranspiration. In addition, field testing of the ET_o data for use in irrigation scheduling, modeling and improving methods to access irrigation efficiency, analyzing the economic benefits of using CIMIS ET_o for irrigation scheduling, and studies on encouraging the adoption and use of CIMIS were conducted. More than 17 researchers were employed on the three-year project at a cost of approximately $3,500,000. Today there are about 150 electronic weather stations in the network. It is estimated that CIMIS saves California growers about $64 million per year from water savings and increased production. Following on this work, I have more recently been involved in the development of weather simulation application programs for use in long-term water resource planning in California.

As of September 2004, I have authored or co-authored 83 published or in-press refereed scientific papers on a wide variety of topics including frost protection, irrigation scheduling, wetlands ET and carbon fluxes, plant phenology, long-term water resource planning, surface renewal, etc. Reviewed publications that are related to this project are listed below.

Short list of Reviewed Publications (related to this topic)

Drexler, J.Z., Snyder, R.L., Spano, D. and Paw U, K.T. 2003. A Review of Models and Micrometeorological Methods used to Estimate Wetland Evapotranspiration. *Hydrologic Processes*, pp. 54 (in press).

Faber, B.A. and R.L. Snyder. 1988. Extension activities needed to address the limited use of evapotranspiration. J. of Agronomic Education, Vol. 19, No. 1, pp. 7-13.

Paw U, K.T., R.L. Snyder and D. Spano. 2003. Surface renewal. In: Micrometeorology in Agricultural Systems. Hatfield, J.L. and Baker, J.L (Eds.). ASA Monograph No. XX, ASA-CSSA-SSSA, Madison, WI. (in press).

Shaw, R.H. and R.L. Snyder. 2003. Evaporation and eddy covariance. In: *Encyclopedia of Water Science*. Stewart, B.A. and Howell, T. (Eds.). Marcel Dekker Inc., New York. Marcel Dekker Inc., New York. DOI: 10.1081/E-EWS 120010306.

Snyder, R.L. and W.O. Pruitt. 1992. Evapotranspiration data management in California. Irrigation and Drainage Session Proceedings Water Forum 1992, ASCE. August 2-6, 1992, Baltimore, MD., pp.128-133.

Snyder, R.L., D. Spano and K.T. Paw U. 1996. Surface renewal analysis for sensible and latent heat flux density. Boundary Layer Meteorol. 77: 249-266.

Snyder, R.L., M.A. Plas and J.I. Grieshop. 1996. Irrigation methods used in California: a grower survey. J. of Irrig. and Drain. Eng., Vol. 122, No. 4: 259-262.

Spano, D., R.L. Snyder, P. Duce and K.T. Paw U. 1997. Surface renewal analysis for sensible heat flux density using structure functions. Agric. & For. Meteorol. 86 (1997) 259-271.

Spano, D., R.L. Snyder, P. Duce and K.T. Paw U. 2000. Estimating sensible and latent heat flux densities from grapevine canopies using surface renewal. Agric. & For. Meteorol. 104 (2000): 171-183.

Snyder, R.L. 2000. Reference evapotranspiration and crop coefficients. Proceedings of the Agricultural Weather System Workshop. Hubbard, K.G. and M.V.K Sivakumar (eds.), Lincoln, Nebraska, March 6-10, 2000 High Plains Climate Center, Univ. of Nebraska-Lincoln and World Meteorol. Organization, Geneva. p. 149-161.

Ventura, F., B.A. Faber, K. Bali, R.L. Snyder, D. Spano, P. Duce and K.F. Schulbach. 2001. Model for estimating evaporation and transpiration from row crops. J. of Irrig. and Drain. Engng. 127(6): 339-345.