Integrating Forage Production with Dairy Manure Management in the San Joaquin Valley

Final Report - August 2003

Principal Investigator (main contact):

Dr. G. Stuart Pettygrove
Department of Land, Air & Water Resources, University of California
One Shields Ave., University of California, Davis
Davis, CA 95616-8680,
Phone: 530-752-2533
Fax: 530-752-1552
Email: gspettygrove@ucdavis.edu

Dr. Dan H. Putnam
Department of Agronomy and Range Science, University of California
One Shields Ave., University of California, Davis
Davis, CA 95616-8680,
Phone: 530-752-8982
Fax: 530-752-4361
Email: dhputnam@ucdavis.edu

Dr. Deanne M. Meyer
Department of Animal Science, University of California
One Shields Ave., University of California, Davis
Davis, CA 95616-8680,
Phone: 530-752-9391
Fax: 530-752-0175
Email: dmeyer@ucdavis.edu

Management Team

Stuart Pettygrove, UC Davis
Dan Putnam, UC Davis
Deanne Meyer, UC Davis
Alison Eagle, Project Coordinator, UC Davis
Stephen Brown, dairy producer, Frank S. Brown Co. Riverdale
Carol Frate, UCCE Farm Advisor, Tulare Co.
Ben Nydam, Certified Crop Advisor, Dellavalle Laboratories, Hanford
Jeff Strom, Project Mentor Grower, Clauss Dairy, Hilmar

Dairy Cooperators:

Bill Ahlem, Ahlem Farms
Tom Barcellos, T-Bar Dairy/Barcellos Farms

Stephen Brown, Frank S. Brown Co.
Gary Crowell, Bar-Vee Dairy
Loren and Linda Lopes, Lorinda Dairy
Steve Milanesio, Pinheiro Dairy
Joseph Ribeiro, Ribeiro Dairy Farms
John and JoAnn Tacherra, Morningstar Dairy
Hank Van Exel and Kees Kooger, Van Exel Farms
Richard Wagner, Wagner Dairy
Steve Wilbur and Sean Nicholson, SBS Ag.

UC Cooperative Extension Farm Advisors

Fresno Co.	Dr. Jerry Higginbotham (gehigginbotham@ucdavis.edu) and Dr. Shannon Mueller (scmueller@ucdavis.edu), 1720 S. Maple Ave., Fresno, CA, 93702.
Kings Co.	Carol Collar (ccollar@ucdavis.edu), 680 N. Campus Dr., Hanford, CA, 93230.
Madera Co.	Ron Vargas (cemadera@ucdavis.edu), 328 Madera Avenue, Madera, CA, 93637.
San Joaquin Co.	Dr. Marit Arana (former UC farm advisor) and Mick Canevari (wmcanevari@ucdavis.edu), 420 S. Wilson Way, Stockton, CA, 95205.
Stanislaus/Merced Co.	Marsha Campbell Mathews (mcmathews@ucdavis.edu) and Dr. Jonathan Merriam (former UC farm advisor), 3800 Cornucopia Way, Suite A, Modesto, CA, 95358.
Tulare Co.	Carol Frate (cafrate@ucdavis.edu) and Steve Wright (sdwright@ucdavis.edu), 4437 S. Laspina St., Ste. B, Tulare, CA, 93274-9539.

Technical Advisors:

Gene Aksland, Resource Seeds, Inc, Goshen, CA
Robert Fry, USDA-NRCS, Hanford, CA
Dr. Thomas Harter, LAWR, UC Davis
Dr. Tom Lanini, Vegetable Crops, UC Davis
Michael McElhiney, USDA-NRCS, Modesto, CA
Denise Mullinax, Hilmar Cheese, Hilmar, CA
Malia Ortiz, USDA-NRCS, Merced, CA
Dr. Larry Schwankl, LAWR, UC Davis
Dr. Roger Vinande, Pioneer Hi-Bred, Modesto, CA

Special Thanks to:

Adam Van Exel, Van Exel Dairy; Staff of the UC DANR Analytical Laboratory; Jiayou Deng, LAWR, UC Davis; Rigo Rios, UC Kearney Ag Center; Loren Lopes, Jr., Lorinda Dairy; Mike and Joe Machado, Ahlem Farms; Joe Williams, USDA-NRCS; Janet Broome, Max Stevenson, Beverley Ransom, and Marco Barzman, UC SAREP.

Table of Contents:

Executive Summary

There is a general consensus among researchers- that dairies in the Central Valley of California are a significant source of nitrate and other salts entering the groundwater. Also, there is some evidence that the largest source of the nitrate and other salts on dairies is the cropland to which manure (and usually commercial fertilizer) is applied, rather than corrals and manure storage ponds.

The goal of this project was to show that dairies in California's San Joaquin Valley having different soil types, irrigation water flows, and management styles could implement a customized package of improvements allowing them to apply agronomically and environmentally appropriate rates of manure water ("dairy lagoon water") to their forage fields. Many dairies in the Central Valley have barns and corrals with concrete lanes and stalls, allowing the farmer to flush manure into a liquid storage and distribution system. On many dairies, well more than 50% of excreted nutrients are collected in this liquid system and applied to crops via the gravity (border check and furrow) irrigation system.

Eleven dairies ranging in size from about 600 to 1800 (vs. valley-wide average of ~700) milking cows were recruited from four counties. Each dairy set aside 10 to 80 acres of land for comparisons of improved and conventional methods of manure water management. These dairies were offered a menu of possible improvements. Most dairies chose to adopt a manure nutrient tracking system, which required a specialized flow meter and manure water nutrient testing. Some dairies began using an on-farm manure testing system, while others relied on the project personnel to provide this service. Farmers at two of the dairies demonstrated unconventional cropping practices – annual ryegrass and berseem clover as a winter-spring forage, and in the other case, applying manure water to alfalfa. Monitoring activities were shared by the farmers and project personnel.

Compared to the conventional practices before the beginning of the project, BIFS participants found that by monitoring manure water application they could ensure sufficient nutrient supply and thus reduce commercial fertilizer use by an average of 130, 70, and 45 lbs/acre of N, P_2O_5, and K_2O, respectively. This amounts to a savings of $57/acre Assumes average retail fertilizer value for N, P_2O_5 and K_2O of $0.32, $0.15, and $0.13/lb, respectively. Values from UC Davis cost studies for San Joaquin Valley crops (1998-2001).(1) and more than $10,000 per farm if implemented on all fields. The elimination of this excess nutrient load to the groundwater would have a positive effect on the environment. Other reductions in nutrient loading to the groundwater have also taken place as some participants found that their total manure nutrient application exceeded crop needs. Therefore, these participants are working on increasing total land area available for manure application from their dairies.

Practices used on these farms may be useful on 150,000 to 200,000 acres of forage cropland managed by dairies in the Central Valley. This acreage estimate is based on several questionable assumptions or "educated guesses", due to lack of critical information. Data from a recent survey of Central Valley dairy producers conducted by the UC Sustainable Agriculture Research & Education Program may provide the basis for a more accurate estimate. Survey data analysis is in progress.

Project outreach activities were as follows: Dairy field days; a tri-fold brochure on flow meters for manure water; project newsletters sent to all participants plus another 50 dairy producers; small lunch meetings featuring an invited expert; presentations made to a dairy producer organization; posters or oral presentations and conference proceedings papers at several statewide conferences attended by forage growers, dairy farmers, Certified Crop Advisers, and other crop management professionals. Data collected during the BIFS project is also being used by a technical committee convened by the state USDA-NRCS to prepare a Technical Guide for Comprehensive Nutrient Management Plans, which is now in its third draft.

(1)Assumes average retail fertilizer value for N, P_2O_5 and K_2O of $0.32, $0.15, and $0.13/lb, respectively. Values from UC Davis cost studies for San Joaquin Valley crops (1998-2001).

Introduction

Note from the authors on terminology: *The focus of the project described in this report was on the management by dairy farmers of the cow feces and urine that is handled, stored, and applied to land as a liquid. Others have referred to this variously as* ***dairy wastewater, dairy lagoon water, liquid manure, slurry****, and* ***nutrient water****. For consistency, we have chosen in most of the report to use the term* **manure water***, in recognition of its very low solids content compared to slurry and liquid manure. We recognize that dairy manure water usually contains non-manure constituents, such as bedding, waste feed, and soil.*

The number one agricultural product in California in terms of farm gate income is milk & cream. The Great Central Valley of California is home to about 1,500 Grade A dairies with an average herd size of approximately 700 milk cows plus replacement stock. With few exceptions, Central Valley dairies house animals in confinement, i.e., in barns and corrals, not on pasture.

Water pollution – and in the last 20 years, specifically groundwater pollution with nitrate and salts – has become an increasing public concern. Since the passage of the Federal Clean Water Act and, at the state level, the Porter-Cologne Act, the dairy industry in California has made great strides in containing all manure and manure-laden irrigation water on the property where it was generated. The EPA, the USDA, the California State Water Resources Control Board, Regional Water Quality Control Boards, and in some cases county governments have turned their attention to groundwater. The improvements needed to reduce the potential and actual contamination of groundwater are, in many cases, different from the techniques used to eliminate surface runoff and are often more complex and expensive to implement.

On the great majority of Central Valley dairies, all or nearly all of the manure is collected as a solid or in a liquid waste stream and applied to forage crop land managed by the dairy or a grower in partnership with the dairy. The total amount of crop land owned or leased by dairies that is available for manure recycling is not known. Many "average to large" dairies in the Central Valley have 300 to 1000 acres, devoted mostly to forage production; however there are many smaller dairies having less than 300 acres. On individual dairies, alfalfa accounts for from 0 to 30% or more of this dairy forage acreage. The main dairy forages produced in the Central Valley are silage corn, cool season "small grain forages" (oats, wheat, barley, and triticale), and alfalfa. In recent years (2000-2002), silage corn has been produced on about 345,000 acres statewide. Much of this is grown in a double crop (i.e., two crops per year) rotation with the cool season grass forages. Alfalfa is produced on 1.1 million acres in California, but it is not known what percentage of this is grown by dairy producers (vs. non-dairy hay growers). Lacking some critical pieces of information, we suggest that the total forage crop area under dairy control that is hypothetically available for manure application in California is between 500,000 and 700,000 acres, most of which is in the Central Valley. This is a significant amount of land compared to the various estimates of the quantity of dairy manure produced in the Central Valley, and it suggests that the dairy industry in the Central Valley has sufficient land to handle the manure generated and use it as a source of nutrients for crops.

However, it is obvious that the cow:cropland ratio varies among dairies in the Central Valley, with some dairies clearly having less land than is needed to recycle manure nutrients at agronomic rates. Furthermore, a large portion (~50%?) of dairy manure in the Central Valley is collected by flushing with water and stored as a dilute liquid in retention ponds. Also, the distribution system (pipes and pumps) required to inject this manure water into the irrigation system is often lacking or is not optimized. The result at many dairies is very uneven application of nutrients. Most dairies purchase more commercial fertilizer than is hypothetically needed, because they are not able to deliver manure to fields in a timely and controlled manner. Another reason for heavy reliance on purchased fertilizer is the growers' uncertainty regarding the nutrient value of the manure.

How can dairies (especially existing dairies, which in many cases are family owned and operated) achieve agronomically and environmentally appropriate manure application rates and timing? The BIFS forage-dairy manure project proposal submitted in 1999 was based on the premise that while some dairies will need improved infrastructure (more storage capacity and piping, for example) or more land, all dairies will have to develop ways to track the manure nutrients and improve management of their crops and irrigation.

A few dairies in the state have adopted improved methods, foremost of which are the tracking of their manure water nutrients (for example, by use of flow meters and manure nutrient testing), keeping of detailed records, and careful application of manure to land at a targeted nutrient rate. These methods have been developed by the dairy industry with assistance from several public agencies. Many of the techniques used by these "early adopter" dairies were developed beginning in the 1980s and up to the present by Marsha Campbell Mathews, University of California Cooperative Extension farm advisor and her co-workers. These improved systems were developed for and have now been adopted by a few dairies in Stanislaus and Merced Counties in the northern San Joaquin Valley.

The general purpose of the dairy manure-forage BIFS project reported here was to demonstrate improved manure management practices on dairies over a greater range of soil types, irrigation water sources, and dairy management "styles" than are found in Merced and Stanislaus Counties. Several steps were taken to ensure that the demonstrations were carried out with active participation of the dairy operators themselves and were not simply test plots conducted by researchers on private land. These steps included Assumes average retail fertilizer value for N, P2O5 and K2O of $0.32, $0.15, and $0.13/lb, respectively. Values from UC Davis cost studies for San Joaquin Valley crops (1998-2001).(1) insisting that participating dairies choose from a menu of possible changes, Commercial fertilizer was applied to improved portion of the field due to miscommunication in 2001(2) frequent (typically weekly) contacts between project personnel, farm advisors, and the dairy farmer or employees at each dairy during the entire length of the project, and Year 1 – 294 contacts/11 participants = 26.7 per participant; Year 2 – 414 contacts/11 participants = 37.6 per participant; Year 3 – 348 contacts/10 participants = 34.8 per participant(3) use of project funds for intensive monitoring and data collection to provide each farmer with feedback.

The Dairy BIFS project began on July 1, 1999 and continued to carry out field work on participating dairies through October 2002. This gave three full seasons of data collection starting in 2000, as field set-up and installation of flow meters was required before beginning the data collection.

Project Objectives

The Dairy BIFS project was sponsored by the University of California Sustainable Agriculture Research & Education Program with the goal of improving dairy manure nutrient management in the San Joaquin Valley. This goal was specified in the following objectives:

> 1) *In cooperation with selected dairies in the San Joaquin Valley, to conduct field-scale demonstrations of improved methods for recycling liquid dairy manure nutrients to forage crops in both silage corn- and alfalfa-based crop rotations*
>
> 2) *Work with the participating dairies to monitor and evaluate the economic and environmental performance of the improved methods compared to more conventional practices,*
>
> 3) *Develop and implement an educational curriculum on dairy manure nutrient recycling, integrated with the Environmental Stewardship component of the California Dairy Quality Assurance Program, an industry-government-university partnership.*

On-Farm Demonstration

The Dairy BIFS project introduced improved manure nutrient management practices at all participating dairies (Table 1). These practices centered on the use of flow meters to measure manure water volume applied to fields, analysis of manure water for nutrient content, and calculation of manure nutrient application to the forage crops. In most cases, the monitoring of manure nutrient application resulted in significant reduction in commercial fertilizer use, as the producers realized that manure nutrients met or exceeded crop nutrient requirements. Total manure applications on the BIFS fields were also reduced in those situations where manure nutrient application was found to be excessive.

The BIFS participants set aside from 18 to 134 acres each for project fields, on which the manure nutrient application was measured, forage crop yield and nutrient uptake determined, and soil and plant tissue samples collected (Table 2).

These were set up as side-by-side comparisons of conventional and improved treatments, with the treatments depending on the location. For one participant, the conventional treatment consisted of growing forage crops utilizing only commercial fertilizer, while the improved treatment utilized manure water nutrients. Other comparisons involved less extreme comparisons, with the manure water and commercial fertilizer applied to conventional treatments and with commercial fertilizer reduced or eliminated for the improved treatments.

By the third year of the project, half of the participants determined that since they were no longer using commercial fertilizer on fields that received manure water nutrients, they would not use commercial fertilizer in the BIFS field either. Therefore, the conventional treatment was adjusted so that it received slightly more manure water than the improved treatment in these cases. Because of the difficulty in precisely controlling manure water application to the fields, the actual nutrient application differences between treatments became insignificant. The improved practices were thus being gradually applied over the entire BIFS field, and in a few cases, for all the fields on the farm that received manure water as a fertilizer source.

Table 1. Comparison of improved and conventional manure management practices used by project dairy participants.

Dairy	*Conventional Practices*	*Improved Practices*
D1	- Apply manure as in past for disposal purposes	- Use torpedoes in furrows to reduce total irrigation water use - Reduce manure application by eliminating one or more manure water irrigations
D2	- Apply manure as in past for disposal purposes	- Reduce manure application by eliminating one or more manure water irrigations
D3	- Apply manure water as pre-irrigation and in spring on ryegrass/berseem for disposal purposes	- Compare to no application of manure water on ryegrass/berseem
D5	- Commercial fertilizer only for silage corn production	- Manure water as only nutrient source for silage corn
D6	- Commercial fertilizer and manure water to supply corn nutrient needs	- Manure water only to supply corn nutrient needs[2]
D7	- Apply manure water to fields, assuming that 25% of organic N is available	- Apply manure water to fields, assuming that 80% of organic N is available - Fine tune with soil and tissue samples
D8	- Use commercial fertilizer only for silage corn production	- Use manure water as only nutrient source for silage corn
D9	- Avoid using manure on alfalfa	- Apply manure water to alfalfa at carefully monitored rates
D10	- Apply manure water during high water volume irrigation	- Apply manure water during low water volume irrigations, reducing total nutrient application
D11	- Apply manure water, assuming that 0% of organic N is available	- Apply manure water, assuming that 75% of organic N is available

Table 2. Summary of Dairy BIFS participants and crop areas of interest.

Dairy	*Total crop land (acres)*	*Forage crops (acres)*			*BIFS Program (acres)*	*Manure water metering, additional acres*
		Total	*Corn/winter forage*	*Alfalfa*		
D1	1400	735	240	495	28	52
D2	520	520	334	186	33	0
D3	1306	1306	826	480	37	0
D5	820	820	320	500	31	33
D6	1800	1091	566	525	134	154
D7	82	82	82	0	18	64
D8	270	270	270	0	80	190
D9	450	450	140	310	18	128
D10	2000	1500	970	530	76	0
D11	400	400	400	0	80	95

(2)Commercial fertilizer was applied to improved portion of the field due to miscommunication in 2001

Outreach and Extension

Extension of the improved BIFS practices required both regular interactions with the participating producers and outreach to the greater producer community. The large area covered by the project (>200 miles) and the complexity and year-round nature of dairy farming made valley-wide meetings impossible to schedule. Effective participation by producers in the project was ensured through contact by the project coordinator, principal investigators, and the farm advisors in the respective counties. Most of the organizational duties were carried out by the project coordinator, including planning harvests, soil and tissue sampling, and maintaining records on seeding and irrigation activities. Participating farmers collected lagoon water samples, flow meter readings, irrigation start-stop times, and in some cases crop yields and manure water analysis for ammonium-N. Farm advisors and the principal investigators served key roles in decision-making and in data collection.

Off-site contact with project participants consisted mainly of telephone conversations and some facsimile and email communication. During the three years from July 1999 through June 2002, each participant received or initiated an average of 33 Year 1 – 294 contacts/11 participants = 26.7 per participant; Year 2 – 414 contacts/11 participants = 37.6 per participant; Year 3 – 348 contacts/10 participants = 34.8 per participant(3) exchanges per year with the project personnel by phone, personal letter, facsimile, or email. Members of the management team met with participants for on-farm planning meetings an average of 1.7 Year 1 – 23 meetings/11 participants = 2.1 per participant; Year 2 – 22 meetings/11 participants = 2.0 per participant; Year 3 – 11 meetings/10 participants = 1.1 per participant(4) times per year. Farm visits for data collection by the project personnel and field assistants averaged 12.5 Year 1 – 85 visits/11 participants = 7.7 per participant; Year 2 – 177 visits/11 participants = 16.1 per participant; Year 3 – 136 visits/10 participants = 13.6 per participant(5) per farm per year. These are detailed in the previous annual reports.

In order to bring project participants together for exchange of ideas, lunch meetings were held regularly at two locations in the San Joaquin Valley. Due to the large distances between growers, the growers in the southern SJV (Tulare and Fresno Counties) met separately from those in the northern SJV (Stanislaus, Merced and San Joaquin Counties). To promote grower-to-grower communication, care was taken to limit the number of researchers and others attending, and staff from regulatory agencies or news media were excluded. To each lunch meeting, an expert was invited to discuss a single topic. Topics chosen included nutrient uptake in corn, regulatory issues related to manure management, irrigation system design, and salt management in manure. These also are detailed in the annual reports.

The BIFS demonstration sites were opened for observation by other dairy producers and the public during 12 field days held throughout the project period. The first field days at a BIFS site in the spring of 2000 exhibited different flow meters that had been proven to perform well with dairy manure water (Schwankl et al., 2003. Flow meters tested on dairy lagoon water. California Agriculture. p.93-95, 98, July-Sept issue). The propeller flow meters traditionally used in agricultural situations are not appropriate for measuring manure water flow, but doppler or electromagnetic meters that do not interfere with the flow of the debris-laden manure water are accurate and reliable.

Since the flow meters were shown to be reliable in this application, the results of using flow meters to measure manure nutrient application could be documented and displayed at further field days. These events involved demonstration of the use of flow meters and the use of valves to control flow rates of the manure water. Presenters also showed how to use a nitrogen quick test to perform an on-site test of ammonium N in the manure water. BIFS participants and project personnel presented data to show total manure nutrient application as measured with the flow meters, and the effects on forage crop yield at these sites. The dairy participants gave testimonials as to their support of the flow meter systems and told attendees that they had saved significant amounts of money by no longer needing commercial fertilizer after adopting this system.

Regular communication with participants, advisors, and other interested parties took the form of project newsletters. A total of nine issues were prepared and sent out to the mailing list. This mailing list began with about 40 recipients, including the dairy participants, the management team, and the technical advisors, but it expanded throughout the project period. In September 2000, the newsletter was sent to all Grade A dairy producers in the San Joaquin County, and fifty recipients requested to be added to the regular mailing list. Many field day attendees also indicated their desire to stay informed of the developments in dairy manure management, so that the mailing list totaled 145 by the end of the project.

News articles in industry publications also served to notify the public of the improvements demonstrated by the Dairy BIFS project. Articles on flow meters and their utilization in dairy manure management were written by project personnel and published in California Dairy and Hoard's West. Reporters from California Farmer, Western Farm Press, the UC Davis LAWR Newsletter, and California Dairy also published articles featuring the Dairy BIFS project and the use of flow meters for manure nutrient management. Copies of these articles were included with the previous annual reports.

Data collected by the Dairy BIFS project has also been used by project personnel and others (UCCE specialists and farm advisors) in the California Comprehensive Nutrient Management Plan (CNMP) technical guidance, which is in preparation by the USDA Natural Resources Conservation Service in California and in short-courses offered by UC Cooperative Extension. The CNMP guidance will be used by regulatory agencies in the state as they require management plans for dairy facilities with respect to nutrients. Manure management plays a large role in this planning. The ability of BIFS participants to utilize flow meters to monitor and control manure nutrient application to forage crops has shown that it is possible to improve manure nutrient management in California. Nutrient uptake, typical manure nutrient concentrations, N:P ratios and other data from the BIFS project have served to build the CNMP guidance. UC Cooperative Extension farm advisors Carol Frate and Marsha Campbell Mathews presented a short-course on lagoon water management for dairy producer audiences in Tulare, Fresno, Glenn, Stanislaus, Kings and Madera Counties during the winters of 1999-2000, 2000-01 and 2001-02, utilizing information gleaned from their experiences with the BIFS project. Data on nutrient inputs and outputs collected as part of the BIFS project have been used by the University of California Committee of Consultants, which is providing technical advice to the Central Valley (Region V) Regional Water Quality Control Board (Dr. Andrew Chang, UC Riverside, personal communication).

(3) Year 1 – 294 contacts/11 participants = 26.7 per participant; Year 2 – 414 contacts/11 participants = 37.6 per participant; Year 3 – 348 contacts/10 participants = 34.8 per participant

(4) Year 1 – 23 meetings/11 participants = 2.1 per participant; Year 2 – 22 meetings/11 participants = 2.0 per participant; Year 3 – 11 meetings/10 participants = 1.1 per participant

(5) Year 1 – 85 visits/11 participants = 7.7 per participant; Year 2 – 177 visits/11 participants = 16.1 per participant; Year 3 – 136 visits/10 participants = 13.6 per participant

Documentation and Evaluation

The main accomplishment of the Dairy BIFS project was to establish the use of flow meters and manure water nutrient analysis as a key aspect of manure management on participating dairies. The dairies are now able to monitor and control nutrient applications of manure water to forage crops and quantify the economic value of those nutrients. Some changes in farm management decisions will be needed before all participating dairies maintain these records for all fields or hire someone to perform these tasks. However, each BIFS dairy has gained a greater understanding of the value of the manure nutrients and has made a significant step toward improved management.

Manure water nutrient composition

The nutrient content of manure water samples at BIFS dairies was determined using both on-farm and laboratory methods. A quick test developed by Hach Instruments and farm advisor Marsha Campbell Mathews was used as an on-farm method to estimate ammonium and organic nitrogen (N) content. The results from this method have been compared with laboratory ammonium and organic N to confirm that it is a reliable method. However, some significant differences were noticed when the same sample was assessed by various operators. This problem deserves further investigation.

Electrical conductivity (EC) as measured with a hand-held meter was also monitored for most samples collected from BIFS dairies. For individual dairies this was found to have high correlation to the ammonium concentration as measured by analytical laboratory. The correlation decreased when sample values from different dairies were combined, and was also less significant when samples with large amounts of organic matter were included in the analysis. However, the low cost of this method (approximately $50 for the EC meter vs. $400 to $900 for the ammonium quick-test meter) and the ease of use make this a good potential for on-farm manure water ammonium concentration estimation.

In addition to EC and N concentration (both ammonium and organic N), the samples were analyzed for total K, total P, pH, and total solids. Manure water from the lagoons prior to dilution by fresh irrigation water varied significantly in nutrient concentration and other characteristics from dairy to dairy and even within the same facility (Table 3). This was a result of feeding, manure management, and water use practices on the facilities.

Table 3. Manure water characteristics at Dairy BIFS locations, prior to dilution with fresh irrigation water. Samples collected from March 2000 through August 2002.

		Total N	NH4-N	P	K	Total Solids	pH	EC
		-------------------µg/g------------------------				--%--		dS/m
Dairy 1								
	median	645	434	141	846	1.1	7.1	7.5
	range	424-1200	260-540	53-290	480-1040	0.4-2.5	7.1-7.4	4.5-9.5
Dairy 2								
	median	284	185	64	323	nes††	7.3	2.2
	range	171-1633	109-268	30-263	168-379	nes	7.0-7.6	2.1-3.4
Dairy 5								
	median	353	202	80	429	0.5	7.3	4.1
	range	110-637	70-320	28-254	169-722	0.2-2.5	6.8-7.5	2.1-5.7
Dairy 6								
	median	164	124	43	213	0.2	7.2	2.6
	range	51-332	10-203	9-63	35-408	0.1-0.8	6.8-7.8	0.7-4.2
Dairy 7								
	median	397	321	75	521	0.4	7.2	5.0
	range	222-513	168-433	43-122	282-705	0.3-0.6	6.8-7.5	3.1-6.4
Dairy 8†								
	median	325	258	52	652	nes	7.0	4.7
	range	240-345	220-267	45-58	486-773	nes	6.6-8.0	4.2-5.5
Dairy 9								
	median	214	175	48	245	0.3	7.2	3.7
	range	36-390	27-229	10-86	37-470	0.1-0.9	6.7-7.6	1.1-5.1
Dairy 10								
	median	391	272	70	602	0.4	7.2	4.9
	range	198-2420	158-370	26-380	280-880	0.2-2.0	6.9-7.5	3.0-6.1
Dairy 11								
	median	468	334	79	640	0.8	7.3	6.9
	range	249-953	135-554	39-283	258-992	0.3-2.0	6.8-8.1	3.6-9.6

† All values for N, P, K are based on lab analyses, except Dairy 8, where N is based on the Nessler quick test method

†† nes – not enough samples to analyze (5 or fewer samples with this analysis)

Manure Water Output Measured

Flow meters with volume totalizer read-outs were installed at seven of the participating dairies. This enabled us to record total volume output from the lagoon over a period of up to 24 months. The volume readings were associated with manure water nutrient concentrations to calculate total nutrient output over time. Since nutrient concentration changed over time, the calculations were more accurate when regular volume readings and samples were available. Some inaccuracy is assumed because significant volumes of manure water were pumped out of some of the lagoons without volume or sample monitoring taking place (i.e. when non-BIFS fields were irrigated with the manure water).

Total annual volume output can be used for planning manure water storage volume needs for the dairies. Volume output at these dairies ranged from 13.9 million gallons to 123 million gallons per year (Table 4). This means that in order to meet the recommended storage capacity of 120 days worth of storage, 4.6 to 40.4 million gallons of storage volume is needed. When corrected for size (number of animals), the volume of manure water per animal unit per year ranged from 13,000 to 64,000 gallons (Table 5).

Table 4. Total volume and nutrient output from manure water storage lagoons at participating BIFS dairies, total as measured for the entire dairy

Dairy	Time measured (months)	Total Volume (1000 gallons/ year)	NH_4-N (1000 lbs/year)	Organic-N (1000 lbs/year)	P (1000 lbs P_2O_5/year)	K (1000 lbs K_2O/year)
1	21	104,600	328	319	304	747
5	1.2	50,100	119	18	73	295
6	19	64,200	70	23	54	164
7	19	13,900	38	8	23	78
9	15	122,800	104	25	76	208
10	24	57,400	126	51	67	304
11	15	57,900	172	103	99	400

Dairies with a larger proportion of the animals in free-stall or other manure flush systems and/or who use more fresh water to clean out the storage lagoons ended up with a higher proportion of total manure water volume per animal unit. The cost per animal unit of pumping the manure water is also higher for these dairies. It must be noted that these values only pertain to manure water nutrients, and do not include any solid manure nutrients that are applied to fields or exported from the dairy. Therefore, this is not a measurement of total manure output from the dairy.

Total N applied to crops in manure water ranged from 36 to 171 lbs N per animal unit annually (Table 5). This large range in values occurred for a number of reasons. First, the dairies with highest manure water N tended to direct more of their manure to the liquid manure stream rather than the solid manure stream. Second, some dairies experienced more N losses because of differences in treatment and storage systems. Third, some of the differences may be due to variability in the data and might have been reduced with more frequent sampling and meter reading.

Table 5. Total volume and nutrient output from manure water storage lagoons at participating BIFS dairies, per animal unit as of Fall 2002. Volume and nutrient output measured from 2000-2002.

Dairy	Animal Units (AU)	Total Volume (1000 gallons/ AU/year)	Total-N (lbs/AU/year)	P (lbs P_2O_5/AU/ year)	K (lbs K_2O/AU/year)
1	3789	28	171	80	197
5	3788	13	36	19	78
6	2456	26	38	22	67
7	1020	14	45	22	77
9	1948	63	66	39	107
10	1719	33	103	39	177
11	3225	18	85	31	124

Land requirements for application of manure water to forage crops depend on typical crop nutrient removal as well as manure water nutrient production. Most California dairies will be required to apply manure water based on N content of the manure and N required by the crop. Therefore, the approximate land area needed to utilize the manure water as measured by the flow meters was calculated based on N (Table 6). 50% of the organic N in the manure is assumed to be available and therefore accounted for in the calculation. The calculations for each dairy are based on measured N uptake by silage corn/winter forage rotations, and assume that 100% of the land is in the silage corn/winter forage rotation .

As the dairies institute changes in crop production, feeding or manure handling and treatment practices, the total manure water N production will change, and total land area needed for manure water utilization will also change. For example, one dairy has recently instituted triple cropping on most fields receiving manure water, increasing the total N uptake by over 50 lbs N/acre. This has reduced the land area needed for manure water application by 47 acres. The values in Table 6 are also quite dependent on the assumptions of organic N availability.

Economic Evaluation

The main economic benefit to improved dairy manure management is savings in commercial fertilizer costs. Before the BIFS project, typical application to silage corn that also received manure water was on average 149, 71, and 45 lbs of N, P2O5, and K2O, respectively, at participating dairies (Table 7). This was reduced to zero commercial fertilizer in the improved treatments for the 2002 silage corn crop, an average savings of $63 per acre in N, P, and K fertilizer (Table 8).

Dairy	Land Area Needed (acres)
1	1064
5	260
6	198
7	88
9	259
10	347
11	464

Table 6. Total land area needed at BIFS dairies to utilize manure water nitrogen

Dairy	N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)
1	216	179	0
2	80	57	32
5	153	23	12
6	200	100	150
7	40	0	0
8	254	208	163
10	150	0	0
11	100	0	0
Average	***149***	***71***	***45***

Table 7. Commercial fertilizer application to silage corn fields receiving manure water, before BIFS project.

Dairy	Savings in 2002 ($/acre)	Total potential savings ($1000/year)
1	95	101.0
2	38	—
5	53	13.8
6	97	11.4
7	13	1.1
8	132	—
10	47	16.4
11	32	14.6
Average	***63***	***12.6[g]***

Table 8. Potential savings in commercial fertilizer costs for participating dairies, silage corn crop only.

This savings could be achieved on all the land area for which the manure water can meet all the crop nutrient needs (see Table 6), from 88 to over 1000 acres, depending on the dairy. Total annual savings in commercial fertilizer costs would be as low as $1,100 at Dairy 7 to as high as $101,000 at Dairy 1, with median savings of $12,600 at the six dairies in the BIFS project where data was available for total manure water nutrient output and the project focused on silage corn rotations. If fertilizer costs continue to increase along with rising energy costs, the potential benefits of this management system would be even greater.

The savings were lower at Dairy 7 than at other locations because commercial fertilizer use was conventionally minimal at this dairy and total acreage is smaller than any of the other sites. This may make it less feasible for smaller dairies already minimizing fertilizer inputs to justify the additional management time and investments necessary to install flow meters and implement the recommended practices. These smaller dairies also tend to have less time to focus on improvements because their management resources are responsible for many different aspects of the dairy production enterprise.

However, the other dairies in the BIFS project, able to save more than $10,000 per year in fertilizer costs, should be able to cover the costs of the improved management system. Although costs for improved manure management vary significantly from farm to farm because of different system set-ups, costs can be approximated based on the experiences of the BIFS participants. The set-up costs of a flow meter and control valve system are approximately $5000 to $10,000 within the first year. The ongoing costs of manure sample analysis ($500 to $1000/year Assume 6 samples with Ammonium N, TKN, EC, pH, P, K, and other salts analyses (~$100 each) and 6 samples with only Ammonium N and TKN (~$50 each) = $900. Cost varies significantly between laboratories, and can be reduced if rapid test method (EC meter or Hach quick test) is used on-site to be checked regularly with laboratory samples.(10)), extra time required by irrigators for sample and data collection ($1200 to $1800 Assume irrigator spend extra time of 8-12 hours per month @$12.5/hr to collect samples and data(11)) plus paying a manager or consultant for the record keeping and data analysis ($2400 to $3600 Assume consultant spends average of 8-12 hours per month @ $25/hour to compile and analyze data.(12)) could total between $4100 and $6400, still below the estimated potential savings in commercial fertilizer costs. The additional savings could cover other improvements that may be needed.

Costs may increase dramatically if land area for nutrient use is insufficient and additional land must be purchased or leased. Installation of pipelines and additional manure water storage capacity may also be necessary. However, some of these costs may be already required based on regulatory factors.

Other economic benefits of the improved manure management system include deferral of fines or other fees for not meeting regulatory guidelines. Dairies who balance farm nutrients will be less likely to pollute the environment and less likely to be implicated in lawsuits against polluters. Also, certification of environmental stewardship through a recognized program may give the dairy a competitive advantage as consumers preferentially purchase more environmentally friendly products. This has been found to be true for other environmental certification programs with some agricultural commodities.

Forage Crop Nutrient Uptake

Dairy BIFS participants can manage their manure nutrients more accurately with nutrient uptake measured over the course of the project (Table 9). Proper management of manure nutrients requires that crop nutrient uptake is known. This can vary significantly from site to site, and is largely dependent on yield, although a range of nutrient concentrations in the crop may also cause differences between sites. Average silage corn nutrient removal at harvest at the Dairy BIFS sites was 238, 104, and 325 lbs/acre of N, P2O5, and K2O, respectively. Uptake in the winter forage averaged 202, 82, and 373 lbs/acre of N, P2O5, and K2O, respectively. Winter forage crops tended to remove a greater proportion of K as a proportion of crop dry matter, making it less desirable forage than silage corn for the cattle that require low K feed (i.e. dry cows). Average N, P2O5 and K2O uptake in double crop silage corn/winter forage rotations totaled 439, 187, and 698 lbs/acre, respectively. The very large amount of K in harvested forage is not surprising, given the high K content of manures. High K content is associated with milk fever or milk-fever like problems in cows just before, during, and after pregnancy and is a problem worthy of further investigation.

Table 9. Yield and Nutrient Uptake in Forage Crops at Dairy BIFS Sites, Average 2000-2002.

Dairy	Crop Type	Yield (tons/acre @ 70% moisture)	N Uptake (lbs/acre)	P Uptake (lbs P_2O_5/acre)	K Uptake (lbs K_2O/acre)
1	silage corn	24.5	218	93	314
	winter forage	20.2	241	95	387
	TOTAL		***459***	***187***	***701***
2	silage corn	27.9	265	131	421
	winter forage	14.6	141	67	318
	TOTAL		***405***	***198***	***739***
5	silage corn	27.7	224	85	248
	winter forage	27.3	270	112	508
	TOTAL		***494***	***196***	***755***
6	silage corn	27.9	198	88	256
	winter forage	23.5	215	88	391
	TOTAL		***413***	***176***	***647***
7	silage corn	30.6	253	120	336
	winter forage	15.5	224	93	431
	TOTAL		***478***	***212***	***767***
8	silage corn	30.8	245	107	359
	winter forage	9.9	102	53	234
	TOTAL		***347***	***159***	***593***
10	silage corn	27.2	214	75	277
	winter forage	21.4	221	63	246
	TOTAL		***435***	***138***	***523***
11	silage corn	34.3	283	139	389
	winter forage	13.1	199	86	468
	TOTAL		***483***	***225***	***857***

Survey of Dairy BIFS Participants

Ten of the initial eleven project dairies were surveyed in October 2002 to assess their current dairy and manure management situations and determine how their actions and attitudes were affected by the BIFS project. One dairy milked Jersey cows while the rest were primarily Holstein operations. The median number of milking cows (the Jerseys, which are smaller than holsteins, were converted to an equivalent number of Holsteins) was 1150 animals (Table 10). About 64% of these milking cows are in flushed freestalls, while only 36% of the dry cows are in flushed freestalls. Assuming that 80% of manure in freestall housing and 60% of the manure in drylots with flushed lanes goes into the liquid manure system, we calculated that 51% of the total manure on the BIFS dairies is managed in the liquid manure system. This value varied from dairy to dairy and ranged from 15% to 78%.

Table 10. Dairy animals at BIFS locations, with housing types

Category of animal	Number of animals (median, equivalent # of Holsteins[13])	% of animals in each housing type (average for all 10 dairies, weighted for # of animals at each dairy)[14]			
		Flushed freestall	Scraped lanes	Drylot with flushed lanes	Scraped drylot (no flushed lanes)
Milking cows	1150	64	4	22	11
Dry cows	200	36	0	37	27
Bred heifers	212	6	0	49	45
Heifers, 1 yr to breeding	151	5	0	23	73
Calves, 3 mo to 1 yr	235	8	0	27	65
Calves, birth to 3 mo	50 (calves on site at only ½ of dairies)	7	15	0	78

The impact of managing the liquid manure on the total farm nutrient management depends on the nature of the manure handling system at each dairy. For some of the participating dairies, management of the manure water dealt with the majority of their manure nutrients, while for others solid manure presents a larger problem. However, since manure water is more limited by land area directly surrounding the dairy facility, the management of the manure water is in many cases the most pressing issue. The Dairy BIFS project has given these dairies tools to manage a significant portion of their manure nutrients.

When asked about whether they knew the capacity of their manure water storage ponds, eight respondents knew or estimated the storage volume (median of 19.0 million gallons) and seven knew or estimated the storage capacity in days (median of 105 days). The capacity in days is very dependent on the time of year and the weather. Five respondents planned to increase storage capacity in the next two years or had already increased capacity since July 1999. Eight out of ten respondents currently use a mechanical solids separator and/or settling basins to separate solid material from the liquid manure, and one plans to implement this practice in the next two years.

The median total crop acreage rented or owned by participants was 975 acres, with 345 of these available for manure water application. Of the manure water acreage 8% was single crop silage corn, 57% double or triple crop silage corn/winter forage, 21% alfalfa, and 14% other. Four of 10 had increased total land available for manure water application since July 1999, including two who had implemented agreements with neighbors that would accept manure water for their forage or cotton crops. Five of the ten plan to increase land area available for manure water application While four had increased land available since July 1999 and five planned to increase in next 2 years, some of this referred to the same respondents. Three of the 10 respondents neither increased land area nor planned to do so.(15) by purchasing or leasing more land Commercial fertilizer was applied to improved portion of the field due to miscommunication in 2001(2), adding pipelines to access more forage fields Year 1 – 23 meetings/11 participants = 2.1 per participant; Year 2 – 22 meetings/11 participants = 2.0 per participant; Year 3 – 11 meetings/10 participants = 1.1 per participant(4), giving/selling manure water to neighbors Commercial fertilizer was applied to improved portion of the field due to miscommunication in 2001(2).

While 7 of the 10 respondents stated that manure water was applied to meet crop needs, only 2 said that this had been the case on their facilities prior to the BIFS project.

Transportation of solid manure off the dairy seemed to be a constant practice, as the respondents said they either had practiced this for at least three years or didn't plan to start within the next five. Composting of the solid manure on-site, however, emerged as a relatively new phenomenon, as it was not practiced at any dairies before the BIFS project, but three facilities had adopted the practice within the past three years. All participants used (or planned to adopt within two years) a tailwater return system or some other method to control runoff of irrigation water.

Improvements promoted by the BIFS project were adopted during the course of the project. While only two participants used a valve to control manure water flow rates before July 1999, seven dairies were using valves by October 2002 and one more planned installation within the next two years. A flow meter was used at only one site before the project but permanent meters were installed at nine of the ten sites by October 2002. During the project, participating dairies also made improvements to mixing of fresh water and manure water, made changes to pipe sizes, and adapted irrigation systems to improve distribution and measurement of manure water application.

Much of the testing of samples during the BIFS project was performed by BIFS personnel, although by October 2002, four of the 10 were doing their own sample testing. Commercial laboratories and on-farm quick tests were all utilized. Five more dairies planned to implement such testing within two years, and only one respondent had no such plans. Three of the respondents were calculating nutrient application without aid of BIFS personnel and six more planned to do this within two years, some with the help of consultants. While two of the participants did not intend to set manure water flow rates to meet nitrogen targets, the others were evenly split between already doing so and planning to implement within the next two years.

Prior to the BIFS project, participants were already giving some nutrient credit to manure water, but this increased significantly after three years of monitoring manure water nutrient application. While average (median) commercial fertilizer application on silage corn fields that do not receive manure water was 200, 40, and 40 lbs/acre of N, P2O5, and K2O, respectively, application on manured fields in 1999 was 125, 13, and 18 lbs/acre of N, P2O5, and K2O, respectively. By 2002 this dropped to zero for all three commercial fertilizer constituents. At these rates and UCCE fertilizer cost estimates, the median savings per acre from adopting BIFS practices is $44. Earlier estimates used typical fertilizer values given by the participants at the beginning of the project and came up with median savings of $55/acre The mean savings is $63, since there were some participants with exceptionally high savings as they were using a lot more fertilizer prior to the BIFS project than were other growers.(16). The earlier estimates are likely more accurate because the participants may not remember as clearly their practices after three years have passed.

When asked who would perform the tasks required for improved manure nutrient management, respondents expected that dairy/farm personnel (owners, managers, irrigators) would collect the flow meter and irrigation data. The calculations, record keeping and decision-making tasks were more likely to be performed by higher level management such as owners Samples for Dairy 8 are from main storage lagoon; samples analyzed from settling basin are excluded(7), PCA's Commercial fertilizer was applied to improved portion of the field due to miscommunication in 2001(2), managers and office staff Assumes average retail fertilizer value for N, P2O5 and K2O of $0.32, $0.15, and $0.13/lb, respectively. Values from UC Davis cost studies for San Joaquin Valley crops (1998-2001).(1 each).

BIFS participants also expressed their opinions on a number of statements in the survey. 100% of respondents agreed or strongly agreed that forage crops would grow just as well or better with manure water as compared with commercial fertilizer. While most respondents (70%) said that regulatory action was a major incentive for improving manure management, one strongly disagreed, stating that regulatory action shouldn't be an incentive and instead efficiency and environmental stewardship were key incentives. 90% of respondents agreed or strongly agreed that managing manure nutrients required more time than managing commercial fertilizer, and 50% said that managing nutrients properly using a flow meter required more management time than they could provide with their current resources. In light of this 60% said they would be willing to pay someone else to keep track of manure nutrient balances. The main motivational factors for improving manure management were reducing input costs (100%) and maintaining a high level of land stewardship and dairy quality (70%), with regulations significantly less important.

BIFS project activities were generally deemed to be very useful, with farm visits for reviewing and planning (90% very useful), project data summaries by farm (70% very useful), and farm visits for technical assistance (70% very useful) the most appreciated. Field days (60% very useful) and printed technical information (60% very useful) were also valued. Guest speakers at lunch meetings, conversations with other growers during lunch meetings, and BIFS presentations at other conferences were less important (average of "moderately useful"), mainly because of the time required to attend these meetings. The project newsletter was also only moderately useful although it was intended mainly to increase awareness in non-participants.

Most participants appreciated being included in the BIFS project, and did not have many suggestions for improvement. However, some ideas included 1) looking at whole-farm nutrient balances, 2) addressing nutrient application in solid manure, and 3) having more funding available to pay for improvements to manure management systems.

While 20% of participants were reluctant to tell other dairy producers what to do, 80% said they would recommend that other dairies start managing manure nutrients using a flow meter system. Suggestions for other producers included "look at the cost savings rather than the regulations", "research it and look at the whole farm system", "talk to the BIFS people about installation guidelines", and "install the valve and read-out close enough so making adjustments is easy". They said that commercial fertilizer use can certainly be reduced, and the flow meter system will probably save money, but it has to fit in with the rest of the dairy/forage operation. They also said that small dairies should have to follow the same rules as larger dairies, and all dairies need to improve management or those who don't make the rest look bad.

All participants said that the BIFS project provided them with concepts that will enhance their business viability and help them deal with manure management. They said they "are no longer irrigating without thinking", that the project "enlightened [them] to the value of manure water nutrients" and "made [them] conscious about manure applications and nutrient requirements for crops". They also learned about the low value of pre-plant nutrient application, the importance of adequate fresh water supply, and the necessity of control valves. While some participants had initially thought that the University of California would be "imposing and not practical", they (UC project personnel) proved instead to be “practical and flexible”, especially in relating to farm employees. One participant concluded that “the fertilizer cost savings has to make anyone a believer!”

(6) All samples collected from the same dairy within 5 days where ammonium N was within 10% value were averaged together. Median value was calculated based on these composite samples. Samples from Dairy 3 are not included because all samples at that location were of mixed water (manure water diluted with fresh irrigation water)

(7) Samples for Dairy 8 are from main storage lagoon; samples analyzed from settling basin are excluded

(8) On some BIFS dairies, some of the land is single cropped corn, so if this is included in the calculation for total land needed, the acreage will increase accordingly. Also, some manure is applied to alfalfa, so that would reduce the silage corn/winter forage acreage needed for manure water application.

(9) Because of the high range in values, the average for annual savings in commercial fertilizer is stated as median rather than mean.

(10) Assume 6 samples with Ammonium N, TKN, EC, pH, P, K, and other salts analyses (~$100 each) and 6 samples with only Ammonium N and TKN (~$50 each) = $900. Cost varies significantly between laboratories, and can be reduced if rapid test method (EC meter or Hach quick test) is used on-site to be checked regularly with laboratory samples.

(11) Assume irrigator spend extra time of 8-12 hours per month @$12.5/hr to collect samples and data

(12) Assume consultant spends average of 8-12 hours per month @ $25/hour to compile and analyze data.

(13) Assumed that 1 Holstein is equivalent of 1.4 Jerseys

(14) Average number of animals in each housing type did not change much when weighted for number of animals at each dairy, indicating that the size of dairy did not seem to affect housing type at BIFS dairies.

(15) While four had increased land available since July 1999 and five planned to increase in next 2 years, some of this referred to the same respondents. Three of the 10 respondents neither increased land area nor planned to do so.

(16) The mean savings is $63, since there were some participants with exceptionally high savings as they were using a lot more fertilizer prior to the BIFS project than were other growers.

Conclusions and Discussion

This project, which lasted for three and one-half years, relied on traditional extension techniques, including small-group interactions between researchers and farmers, lunch meetings and field days to promote grower-to-grower communication, on-farm monitoring and data collection, and frequent (weekly and, during busy times, daily) communication between and among project participants, especially between the dairy farmers or their farm managers and Project Coordinator Alison Eagle, her assistants, and the Cooperative Extension farm advisors. Project achievements and findings are the following:

> 1. The project demonstrated that dairy farmers could install and use specialized flow meters (~$4,000 plus installation costs) designed for wastewater systems. These meters used in combination with manure water nutrient analysis made it possible for the participating farmers to quantify manure nutrient flows onto the selected fields or portions of fields. The expansion of this critical technology to an entire farm will work fairly well on dairies having one large storage pond, where the lagoon water is relatively homogeneous, and where all of it passes through a single manure pump before flowing to crop fields. This technology by itself is less useful where there are several ponds or several pumps (or gravity flow from ponds), where the distribution system to fields is complicated and not optimized, and where long irrigation set times are required. These problematic conditions are more likely to be found on fields with fine-textured or poorly

drained soils, on older dairies, and in the southern San Joaquin Valley.

2. All project farmers were able to eliminate use of commercial fertilizer on the field or portion of field selected by the farmer for the project without harming yield or forage quality. This practice, if extended to all dairies in the Central Valley and all fields receiving manure would result in significant dollar savings and would reduce the over-application of nutrients, especially nitrogen, which in turn would reduce nitrate contamination of groundwater.

3. Data are inadequate for estimating the number of dairies or the total crop acreage in the Central Valley that could benefit from this technology. We speculate that currently, manure water is applied to as much as 300-400,000 acres of dairy forage crop land in California and that manure metering and nutrient analysis could be implemented on half or more of this acreage within the next five years.

4. Even with project funds and personnel and with the most progressive dairy farmers as participants, a full three years was required for them to implement manure nutrient monitoring and feel confident that they could eliminate commercial fertilizer usage on the BIFS project acreage.

5. Most of the participating dairies found that after eliminating fertilizer applications, they were still applying manure nitrogen in excess (and in some cases, far in excess) of crop requirements. Most of the project dairies are now trying to reduce manure water application per acre rates, but before this can be done, land area and infrastructure improvements will need to be evaluated. The monitoring adopted by BIFS farmers will provide critical data for such an evaluation. For some dairies, due to irrigation system limitations and limited “head” (flow rate) of their fresh water source, it will be difficult to apply dairy manure water in small amounts or with adequate dilution.

6. There were not enough resources or time to help project farmers adopt improved practices on all their fields. Just because a farmer is able to reduce manure nutrient applications to one field or portion of a field does not mean it could be done over the whole farm. We recommend that demonstrations of a whole farm system be conducted. This has been done at a few dairies near Hilmar in Merced County, which are now well beyond the demonstration stage, but not on dairies with different soils and irrigation water flow rates than exist in the Hilmar area. Also, whole farm nutrient management would have to include the solid manure collected from corrals and during storage pond clean-out. Finally, the manure tracking will require a very large increase in the amount of on-farm recordkeeping. Certified bug-free, customizable software will be needed for implementation of the improvements at the whole-farm level. This was not needed for the BIFS project, because the data demands were smaller, and the project coordinator served as the central record keeper, although good records were kept by at least one of the participating dairies.

7. The project showed that by starting with a “menu” of individual practices, rather than with a list of so-called best management practices, dairy farmers could develop a package tailored to their farming operations. This is a major project finding, given the great variety of soils, dairy layouts, management styles, and dairy financial situations in the Central Valley.

8. Alternative cropping systems or rotations that will capture more of the manure nutrients were identified and demonstrated. Modest applications of manure water were applied by one project farmer to alfalfa, which did not result in yield loss, lower forage quality, or increase in weed populations, as is sometimes claimed. Use of annual ryegrass as a cool-season (fall planted) dairy forage with very high N uptake potential and tolerance of less-than-ideal soil conditions looks promising. Production of berseem clover, either alone, overseeded on alfalfa, or mixed with annual ryegrass was shown to be feasible. Production of berseem clover with feed quality at or very near good quality alfalfa was successful at two dairies, but practical problems, especially with stand establishment and the harvest operation may limit its acceptance as a dairy forage.

9. The project produced several newsletters, a popular farmer brochure on installation and use of manure water flow meters, handouts used at project-sponsored lunch meetings, statewide and national conference papers, and articles for trade magazines read by dairy farmers.

10. Several research and extension needs were identified during this project

- Testing of a simpler, less expensive on-farm method for estimating the concentration of ammonium in dairy manure water. The method would use a standard, inexpensive electrical conductivity meter, rather than the more expensive ammonium meter; • Development of an easy technique for estimating manure water organic N content or confirmation that the current, unpublished method (essentially a turbidity measurement) is sufficiently accurate;
- Development of practical guidelines on the rate of net mineralization of organic N contained in manure water that can be used at any time of the year, i.e., reflect the influence of temperature.
- Determination of mineralization rates for manure water that is surface-applied in the irrigation water, rather than incorporated.
- Production of farmer and crop consultant brochures on soil testing and plant analysis

There were additional findings related to the methods used in this project:

1. The ideal of a farmer-directed project was not achieved and appears not to be practical where the participating farms are spread over a large geographical area. Additionally, dairy farming is a complex enterprise involving facilities engineering, animal nutrition, forage production, irrigation engineering, and soil management. Dairy farmers, especially on the average- to below-average dairies, are incredibly busy year-round and in our project lacked time for more than a few off-farm activities. For these and other reasons, the participating farmers were not able to attend valley-wide project meetings; therefore such meetings were not planned. An exception was a near-end-of-project meeting held in May, 2002.

2. The project did not carry out the stated objective of development of an educational curriculum to be integrated with the California Dairy Quality Assurance Program's Environmental Stewardship Shortcourse. A separate project to do this with substantial funding from the State Water Resources Control Board has been approved and will begin in early 2004. This project will be carried out by Merced County and U.C. Davis in cooperation with several other organizations. The BIFS project findings and data set will be useful in this effort. Furthermore, the BIFS data and findings have contributed to development of a draft Comprehensive Nutrient Management Plan Technical Guide that is currently under revision by the state USDA-Natural Resources Conservation Service and its technical committee. Also, project data were used by the U.C. Committee of Consultants, which is advising the Central Valley Regional Water Quality Control Board on technical aspects of dairy manure and crop management.

3. The end-of-project survey indicated a high level of satisfaction among the dairy participants with project methods. A beneficial result of this project to the sponsoring organizations is the very high regard that the participating farmers have for the University of California, especially for the UC Cooperative Extension county farm advisors.