Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices

Deliverables 15.3 Final Report

SWRCB Agreement No. 03-165-555-0

March 8, 2006

Bachand & Associates,
Hydrofocus, Inc.,
University of California, Davis,
U.S. Geological Survey,
Ducks Unlimited,
& Contra Costa Water District

CONTRACT SUMMARY

This information will made available to the public on the State Water Resources Control Board's (SWRCB) Website (see address below).

Use the "tab" and arrow keys to move through the form. If field is not applicable, please put N/A in block.

Date filled out: August 17, 2004

A) Contract Information Please use complete phrases/sentences. Fields will expand as necessary a	
1. Contract Number: 03-165-555-0	
2. Project Title: Reducing Non-point Dissolved Organic Carbon and Nitrogen Exports from Delta Ric	
3. Project Purpose – Problem: To investigate and develop hydrologic best management practices (BMPs) production on experimental subplots in the Sacramento-San Joaquin Delta (Delta) to reduce dissolved organ disinfection byproduct precursors (DBPP) and nitrogen (N) export from rice fields.	
4. Project Goals:	
a. Short-term Goals: • Investigate and develop hydrologic BMPs for rice production on experimental subplots in order to reduce DOC, DBP precursors (DBPPs) and nitrogen export from the rice fields; • Convert corn fields to rice production; • Measure hydrologic, DOC, DBPP and nitrogen load from experimental subplots; and • Investigate how broadly these BMPs can be applied to rice production throughout the Delta.	
b. Long-term Goals: To determine if rice production is a viable land use option in the Delta and to focus on methods to grow r minimizes exports of DOC, DBPPs and nitrogen loading to the Delta.	
5. Project Location: San Joaquin Delta	
a. Physical Size of Project: (miles, acres, sq. ft., e **Year One** – Two 100-acre fields **Year Two** – One additional farm with an approxim 100-acre field	**b. Counties** included in the project: San Joaquin County
b. Legislative Districts: (Assembly and Senate) Contra Costa County **– 11 (Assembly), 7 (Senate)** San Joaquin County **– 10 & 17(Assembly), 5 (Sen**	
6. Which SWRCB program is funding this contract? Please put an "X" by the one that applies.	

__X_ Prop 13 ___ EPA 319(h) ___ Other	
B) Contract Contact: Refers to contract project director.	
Name: David A. Briggs	**Job Title:** Special Projects Manager
Organization: Contra Costa Water District	**Webpage Address:** ccwater.com
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C. Contract Time Frame: Refers to the implementation period of the contract.	
From: January 1, 2004	**To:** March 30, 2006
D) Project Partner Information: Name all agencies/groups involved with project. Bachand & Associates, Hydrofocus Inc., Ducks Unlimited Inc., University of California, Davis, United States Geological Survey	
E) Nutrient and Sediment Load Reduction Projection (if applicable):	Unknown at this time; focus of research is to investigate potential load reduction of dissolved organic carbon and nitrogen through application of hydrologic BMPs.

PLEASE PROVIDE A HARD COPY AND AN ELECTRONIC COPY TO YOUR CONTRACT MANAGER AND YOUR PROGRAM ANALYST WITH YOUR QUARTERLY/MONTHLY REPORT. ALL APPLICABLE FIELDS ARE MANDATORY. IF FIELD IS NOT APPLICABLE, PLEASE PUT N/A IN BLOCK. INCOMPLETE FORMS WILL BE RETURNED. THE ELECTRONIC VERSION OF THIS FORM CAN BE FOUND AT: http://www.swrcb.ca.gov/nps/319hproj.html.

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Executive Summary

Rice is a relatively new crop. Several factors suggest rice is an attractive crop alternative for the Delta:

- Recently developed rice varieties seem more suitable for the Delta climate then earlier varieties which required warmer conditions;
- Previous economic analyses (Appendix A.10) suggest rice is more profitable then corn, a dominant land use in the Delta;
- Recent studies on wetlands at Twitchell Island suggest rice production will help mitigate oxidative subsidence (Miller et al. 2000);
- The different oxidative states that result from flooding in rice as compared to those found in crops that require drained soils may help control crop specific weeds and nematodes when rice is incorporated into a crop rotation; and
- Providing flooded conditions during a greater part of the year than other crops may benefit water birds.

These many different factors have resulted in interest in implementing rice production in the Delta and several organizations such as the San Joaquin Cooperative Extension and Ducks Unlimited have begun to promote its implementation.

As pressure grows to expand rice through the Delta, there is a need to quantify surface and subsurface loads for dissolved organic carbon (DOC), disinfection byproducts (DBP's) and nitrogen; and to begin developing and understanding Best Management Practices (BMPs) available to reduce their export. Under this project, three 100-acre fields in the Delta were selected along a southeast-northwest gradient in the Delta and converted to rice production. Experimental plots were set up at Bouldin Island and Muzio Farm on Wright-Elmwood Tract to test the effects of the different hydrologic BMPs on DOC, DBP and nutrient loads from surface and subsurface flows:

- High drain water levels (a new BMP) is being tested against low drain water levels (current practices) to reduce the export of subsurface drain water from rice plots;
- Adjustable weir inserts to better control surface water flow and water level, and better utilization of weirs as opposed to pipes at field inflows were tested during the second year in an effort to develop BMPs to better control surface water flows.

For these different treatments, we have attempted to answer the following questions:

1. What are the concentrations and loads of key constituents of concern (COC - NO_3, NH_4, DOC, THMFP and TDS) in surface and subsurface drainage waters from rice plots under different land and water management practices, and how do they vary temporally and spatially under varying land- and water-management practices?
2. What are the factors and processes affecting variations in loads?

3. How can COC loads from rice fields be minimized?

Experimental plots were implemented during winter 2004. These plots were designed to test different hydrologic treatments (high water level in the drains vs. low water level in the drains), as well as to distinguish COC concentrations and loading from new rice and established rice fields, and from corn. Surface water and groundwater quality; flow; groundwater levels; and biomass production data were collected for the 2004 and 2005 growing seasons. Surface water quality and flow data were collected during winter 2005. Soil samples were collected during fall 2004 to generally characterize the soil carbon and nitrogen content.

On these participating farms and a third farm established in 2005, bird counts were conducted and economic data were collected from the farmers.

Findings

From these data we have drawn a number of findings related to water quality and loading, feasibility of growing rice in the Delta and wildlife effects.

Water quality and Loading

Trihalomethane Formation Potential (THMFP) concentrations in surface and subsurface waters were significantly and highly correlated with Dissolved Organic Carbon (DOC) concentrations. Loading of both were significantly and highly correlated with flows. These relationships had implications with regard to surface and subsurface loading of DOC and THMFP.

Increases and decreases in surface water flows led to similar changes in DOC loading. An increase in surface water flows at Bouldin Island between summer 2004 and summer 2005 led to an increase in DOC loading by 53%. A decrease of 68% in surface flows at Wright-Elmwood Tract during the same period resulted in a corresponding decrease in surface water DOC loading of 48%.

Changing water elevations in ditches had a similar effect on subsurface loading. Managing water levels high reduced the hydraulic gradient between groundwater elevations and drain water elevations. This reduced gradient would be expected to reduce subsurface flow to the drain. This effect was most evident at Wright-Elmwood Tract where managing the drainage ditch at a high water elevation greatly reduced subsurface DOC and THMFP loading. For instance, median subsurface DOC loads from rice fields into the drain managed at a low water elevation was about 121 g/Acre-day during the period of this project. That loading decreased to a median value of 0 g/Acre-d for drains managed at a high water elevation. Bouldin Island data showed similar effects. During Summer 2004 and Winter 2005, mean values for subsurface DOC loading values were lower for the rice treatment operated with a high water level in the drain then for the rice treatments (new and established) operated with low water levels

Surface DOC loading was similar at Bouldin Island and Wright-Elmwood Tract for rice though surface water THMFP loading was significantly (and an order of magnitude) less. Subsurface DOC and THMFP loads were both greater at Bouldin Island then at Wright-Elmwood Tract. At Bouldin Island, surface and subsurface loads from rice were both similar, with median values in the range of 210 – 230 g/Ac/d. At Wright-Elmwood, surface loads were an order of magnitude greater then subsurface loads (median of around 250 g/Ac/d vs. around 28 g/Ac/d). The differences between surface and subsurface loading between the two locations may have been in part due to difference in soils. Peat soils were deeper at Bouldin and had higher carbon content then the soils at Wright-Elmwood Tract.

In comparing DOC and THMFP loading from rice and corn, DOC loading for rice was generally larger then corn at Bouldin Island and Wright-Elmwood Tract. However, where drains were managed high, subsurface loads for rice greatly decreased and under some circumstances were reduced below those of corn. For instance, when managing drains at a high water level at Wright-Elmwood Tract, subsurface DOC and THMFP loads were significantly less then subsurface loads from corn.

There were some seasonal differences in DOC and THMFP loading with regard to surface and subsurface loading. Subsurface DOC loading at Wright-Elmwood Tract was significantly different between corn for the different seasons, winter and summer. At Wright-Elmwood Tract, subsurface DOC loading was lowest for all treatments (corn v rice, high v low drain) for rice operated at with a high drain level, during both winter and summer. For low drain management for corn and rice fields, corn had higher subsurface loads in the winter and lower subsurface loads in the summer then rice. For Bouldin Island, subsurface loading for all treatments was around 200 – 300 g/Ac/d during the winter. During the summer, corn had much lower subsurface loading then rice. Corn had no surface DOC loads in the summer because there was no surface runoff.

The seasonal differences in loading from the different crops and treatments reflect the different seasonal management. Surface water loading of DOC and THMFPs occurred with rice but not because corn had no surface runoff. Subsurface loading between rice and corn under low drain water management is similar though high drains were shown at Wright-Elmwood to be able to greatly reduce the subsurface loading.

Nitrogen loading differed between rice and corn. The corn field subsurface nitrogen loads were primarily as nitrate whereas the rice field subsurface loads were primarily as dissolved organic nitrogen. Subsurface nitrate loads for corn and Wright-Elmwood Tract rice where drain water levels were maintained low were significantly higher than the other treatments. The large subsurface nitrate exports from the corn fields occurred exclusively during the winter. Subsurface ammonia and dissolved organic nitrogen loads were similar across treatments with the previously farmed rice field on Bouldin Island exporting the greatest loads for both species.

Surface water outflow nitrogen loads were dominated by dissolved organic nitrogen with only small amounts of ammonia and nitrate.

Bird use

Bird counts were conducted at Bouldin Island, Wright-Elmwood Tract and Rindge Tract once during each season during the years each grower participated. Counts were also conducted at the Consumnes River Preserve. For the counts we conducted, rice provided on average better land bird habitat in the summer then the other two habitats (e.g. corn, managed wetlands), and this was do to high use at Bouldin Island. Rice and corn together provided better land bird use then managed wetlands alone. Water bird use in the summer was highest in the managed wetlands, being about two and a half times greater then for rice. No water birds used corn in the summer. In the winter, water bird use was lowest in the rice and highest in the corn. Winter use saw very high variability between the years and the locations. The mix of usage by land birds and water birds between the habitats during the different seasons suggest that continued integration of managed wetlands along with rice and corn fields will provide habitat for a variety of breeding and migratory waterfowl and water birds.

Economic and Agronomic Feasibility for Growing Rice in the Delta

Based on information presented here and from personal communications between the project team members and the project participants, rice production in the Delta at this small scale of approximately 300 acres has been profitable. Production expenses were less than those of estimated for the Sacramento River Valley, while yields remained comparable. Our analyses support the contention that rice can be grown throughout the Delta, from as far west as Twitchell Island to the eastern edge. Newer rice varieties seem to be able to successfully accommodate the small climate differences. Soils at Bouldin Island and Wright-Elmwood Tract were peat soils and were similar in organic content and carbon content. Nitrogen differences were small and all soils had similar C:N ratios.

Profits are a function of income and expenses. Though lower yields were achieved at Bouldin Island as compared to the other two farms, expenses were also lower. Thus, profits similar to those that can be achieved in the Sacramento Valley were achieved for all the farmers through two different strategies:

- A reduction in expenses, and
- A maximization of income.

For all growers, rice continued to be more profitable then growing corn.

Cultural practices appeared to be the key to maximizing yields. Good management of water levels during the early season to suppress weeds and later in the season to maximize the flowering of rice to seeds seemed important for optimizing yields. Being able to implement these practices required good leveling, which depends upon a number of factors including the design of the rice fields; the timing and implementation of leveling; and perhaps the thickness of peat. Complicated hydrologic networks, sometimes artifacts of historic draining and supply networks on the islands, also complicate water management and retrofitting water control structures to these systems may only be partially successful in achieving the goal of maximizing yields.

Weed control appears to be a very important requirement to achieve high rice yields. Good hydrologic management appears to be a good tool to control weeds. Crop rotation may also be useful in controlling weeds. A final tool is herbicides though the options for herbicides are limited by the Delta environment.

Finally, our data suggests that yields were higher when drain water level was kept high.

Managing Surface Flows and Loads

The following recommended practices are suggested for managing surface water flows and loading from rice fields in the Delta. These recommendations are discussed in greater detail in Chapter 3.

Minimize tidal effects on island water deliveries.

Daily tidal changes cause flow fluctuations which inhibit control of water flow to fields. Tidal effects can be minimized through the installation of water distribution ponds or the installations of standpipes at siphon structures.

Establish precision leveled areas between checks.

Large non-level fields prevent water distribution uniformity and precise water level management. Smaller, well-leveled fields resulted in high distribution uniformity. Non-uniformity results in a need for more inflow, lower yields and can result in more surface runoff.

Develop effective control of water between fields and basins and to islands

Structures for controlling water flow can be installed to precisely meter water onto fields and prevent surface-water runoff. Typical structures used for controlling flows and water levels onto Delta fields are rectangular weirs. Too many weirs from a single supply ditch complicate flow distribution and hinder effective hydrologic controls. Weir inserts that allow for more precise adjustments in water elevation improve hydrologic control and management. Reducing surface-water runoff will reduce loads.

Use evapotranspiration and seepage estimates to allocate flow to fields.

Surface-water outflow can be minimized by precisely allowing flow to meet crop water demand and seepage.

Install surface-water outflow structures to better control water levels

Water levels need to be adjusted throughout the growing season, first to suppress weeds and second to help prevent blanking. Weir inserts with adjustable levels can improve water level management. Better water level control can translate to lower surface water demands and reduced DOC, DBPP and nutrient loads.

Install drain outflow structures to raise drain water levels and reduce surface water requirements.

Raising drain levels raises groundwater levels. Higher groundwater levels should result in lower loss of surface water to groundwater through seepage. Reducing seepage should help simplify managing of surface water flows to offset evapotranspiration, which can be estimated from CIMIS data, and percolation, which cannot be estimated with a universally available dataset. Our data indicates that higher drain levels improve rice yields.

Managing Subsurface Flows and Loads

The following management practices are recommended to reduce subsurface flow and loads from rice in the Delta.

Install drain outflow structures to raise drain water levels and reduce subsurface flow and loading.

Higher drain water levels reduce the area contributing to subsurface flow to the drains and reduce the head between groundwater and drain water elevations. Both these factors should reduce subsurface flow into the drains and the accompanying loads.

Reduce the drain length to area ratio

A low ratio between drain length and field area reduces the available area for the flow of subsurface water from the island through the drain network. This reduction in area acts as a funnel for subsurface flow and should result in lower subsurface loads of constituents of concern.

Island water management strategies

The following management strategies are recommended to reduce loading of DOC and other constituents from Delta islands and tracts. Implementing water management practices throughout an island or tract is much more complicated then implementing crop specific practices. These strategies thus realistically reflect longer term goals and objectives.

Reapply drain waters from rice fields onto other crops

Water from drains can be reapplied onto other crops during the summer to minimize pumping of drain water.

Release drain water high in DOC in the summer

DOC loads from rice are lower in the winter then corn. Rice allows for lower winter discharges of DOC as compared to corn. Winter is the time in which the water supply is most sensitive to higher DOC concentrations.

1 Introduction

The Sacramento – San Joaquin Delta is the hub of California's water supply system. Drinking water for over 22 million Californians flows through the Delta channels from water-rich northern California to water-poor southern California. Sacramento-San Joaquin Delta waters are impacted by organic carbon and nutrients (primarily nitrogen) discharged in drainage waters from agricultural lands.

High concentrations of dissolved organic carbon (DOC) in Delta export waters can be problematic due to formation of disinfection byproducts (DBP's) such as trihalomethanes (THMs) upon chlorine addition. Agricultural drainage from delta island organic soils contributes approximately 20% of the THM formation potential (THMFP) at Delta export pumps (Amy et al.,1990). A recent investigation by Fleck et al. (2004) showed that management differences could affect DOC concentrations in water exported from Delta Islands.

Dissolved organic carbon from soil organic matter is a mixture of organic compounds whose reactivity to form DBP's depends on land- and water-management practices and biogeochemical, hydrologic and soil forming processes. The predominant Delta crops (primarily corn and other field and vegetable crops) require aerated root zones and continuous drainage through networks of drainage ditches and pumping of drainage water to Delta channels. Root zone aeration results in biochemical oxidation of the soil organic matter, which results in DOC production and subsidence. DOC produced during the spring, summer and fall is mobilized by flooding of Delta islands during the winter and early spring which results in large island drainage-water DOC loads and increased DOC concentrations in Delta channel waters.

While various physical and chemical variables have been found responsible for controlling DOC formation and release in the laboratory (Kalbitz *et al*., 2000; Aguillar and Thibodeaux, 2005; Moore and Dalva, 2001; Moore, 1998; Christ and David, 1996), hydrology has consistently been shown to be the dominant control on DOC formation, release, and export under field conditions (Kalbitz *et al*., 2000; Hope *et al*., 1994; Urban *et al.*, 1989; Hogg *et al.*, 1992) and field-based experiments are suggested (McDowell, 2003). At the outset of the study, we hypothesized that by reducing hydraulic gradients between water on the field and water in adjacent drains (Figure 1), subsurface seepage will be reduced (Hillel, 1998) and in conjunction with good water management (Doorenbos, 1979; DeDatta and Williams, 1968; Herdt and Wickham, 1984; Kandiah, 1985), exports of DOC would be reduced thereby improving water quality at the source.

Nitrogen is large component of organic soils and there is evidence that nitrogen is discharged to Delta channels in agricultural drainage. Application of N may also lead to the export of other nutrients and exacerbate export of dissolved organic carbon (DOC). Nitrogen enrichment in Delta channel waters leads to greater algal blooms, which cause increases in DOC, dissolved oxygen (DO) depletion, and taste and odor problems. For example, data for the DWR Municipal Water Quality Investigations monitoring station at the Banks pumping plant indicate titrate concentrations are in the 2 to 3 mg-N L^{-1} range, with highs in the range of 5 to 8 mg-N L^{-1}.

One possible option to minimize DOC export to Delta waters is through conversion of cornfields to rice production. Rice, unlike other crops, can be grown under flooded conditions. These conditions may help improve export water quality. This hypothesis is supported by data on subsidence in the Delta. Subsidence in the Delta is primarily results from a net soil carbon loss. More carbon is lost due to oxidation of peat than is gained from crop residues. USGS research shows the carbon loss increases with temperature. There is no data for the effects of rice growing on subsidence. However, data from Twitchell Island experimental plots indicates that hydrologic management similar to that for rice may stop subsidence.

Specifically, Miller et al (2000) compared different water management regimes, permanently, seasonally and reverse flooded. The reverse flooded treatment was intentionally flooded to about 30 cm from early spring to midsummer to simulate brood habitat for waterfowl, and is subject to seasonal conditions from August until March. Rice flooding would probably keep the soils flooded for longer periods of time than the reverse flooding treatment. Analysis of the reverse flooding data indicates carbon inputs were about equal to carbon losses indicating a potential for stopping subsidence. The reduction of organic soil oxidation because of flooding may also reduce the export of DOC from drainage water. Further, rice offers opportunities to hold water on the islands and thus reduce water export through irrigation water recycling.
Rice potentially offers other benefits as well such as providing ecosystem restoration benefits through benefits to waterfowl, and enabling growers a more profitable crop option to corn. Because of the potential economic advantages of rice over corn and its potential to improve water bird habitat, Ducks Unlimited and local farmers have been converting cornfields to rice production, pursuing funding opportunities for that purpose.

1.1 Project Information

This project is from PIN 645 (Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic and Straw Management BMPs). The total budget for this project was $899,715 with $869,715 funded through the Drinking Water Quality Program and $30,000 provided as in-kind services from the growers.

This project was submitted to address a number of Drinking Water Program priorities:

Organic carbon is one of the CALFED Drinking Water Quality Program's (DWQP's) constituents of most concern because of the DOC/DBP issue; one of the DWQP's specific targets is to achieve average concentrations of 3.0 mg/L TOC at drinking water intakes. Organic carbon falls into one of the four broad categories identified in CALFED's Drinking Water Quality Improvement Strategy: reduce contaminants that impair Delta water quality. Organic carbon also is included as one of the four major objectives of CALFED: provide good water quality for all beneficial uses. Agriculture runoff is an important source of DOC and managing rice production to minimize DOC export through runoff may be a less expensive alternative and will be more community-based action than its downstream treatment.

Nitrogen (N) export is another potential water quality problem. Nutrients, including nitrogen species, are a water quality parameter of concern to beneficial uses. Nitrogen is often a limiting nutrient in aquatic systems. If these exports significantly increase nitrogen concentrations within the Delta or off-stream drinking water reservoirs, the problems associated with nitrogen enrichment will be exacerbated. These problems lead to greater algal blooms, which cause increases in DOC, dissolved oxygen (DO) depletion, and taste and odor problems. Nitrate can be translated to carbon and taste and odor. These problems are likely to be greatest in the reservoirs that have a mean residence time of 4 months and thus offer opportunities for algal blooms.

Additionally, this project addressed other CALFED Bay-Delta Program objectives outside of the Drinking Water Quality Program. Because of the long periods of flooding and the return of approximately 3 to 5 tons of carbon to the soils with 40 – 60% of the mass persisting the following year, conversion to rice production is likely to either mitigate or reverse **subsidence** in a similar fashion as wetlands. The prolonged flooding period that occurs during the summer and is unique to rice among agricultural crops should also benefit water birds and thus provide a **benefit to the Delta ecosystem**.

These priorities are discussed in the project's Statement of Purpose.

1.2 Statement of Purpose

Rice is a relatively new crop in the Delta. There is a need to quantify loads for DOC, DBP's and nitrogen and to understand Best Management Practices (BMPs) available to reduce export of DOC, DBP's and nitrogen. This project sets to develop and test different hydrologic BMPs to reduce the export of these constituents and to investigate how broadly these BMPs can be applied to rice production throughout the Delta. These investigations were done at experimental rice plots on Bouldin Island and at Wright-Elmwood Tract (Figure 1-1). Specifically, this project tested BMPs to control the export of both surface and subsurface loads:

A high drain water level (a new BMP) is being tested against low drain water levels (current practices) to reduce the export of subsurface drain water from rice plots;
Adjustable weir inserts to better control surface water flow and water level, and better utilization of weirs as opposed to pipes at field inflows were tested during the second year in an effort to develop BMPs to better control surface water flows.

For these different treatments, we have attempted to answer the following questions:

1. What are the concentrations of key constituents of concern (COC) (NO_3, NH_4, DOC, THMFP and TDS) surface and subsurface drainage waters from rice plots under different land and water management practices?
2. What are the surface and subsurface COC loads and how do they vary in time and under varying land- and water-management practices?
3. What are the factors and processes affecting variations in loads?
4. How can COC loads from rice fields be minimized?

In addition to these studies of water quality effects, this project has sought to quantify rice production rates, the associated economics, and its wildlife benefits to waterfowl. These components were conducted at Bouldin Farms on Bouldin Island, Muzio Farm on Wright-Elmwood Tract, and Jack Klein Trust on Rindge Tract (Table 1-1). At each of these farms, 100-acres were converted to rice production from corn or other terrestrial crops. These farms represent and southeast-northwest gradient through the Delta.

Table 1-1. Farms used during Delta Rice Study

Farm	Location	Coding used in figures and tables
Muzio Farm	Wright-Elmwood Tract	MU
Bouldin Farms	Bouldin Island	BI
Jack Klein Trust	Rindge Tract	not applicable

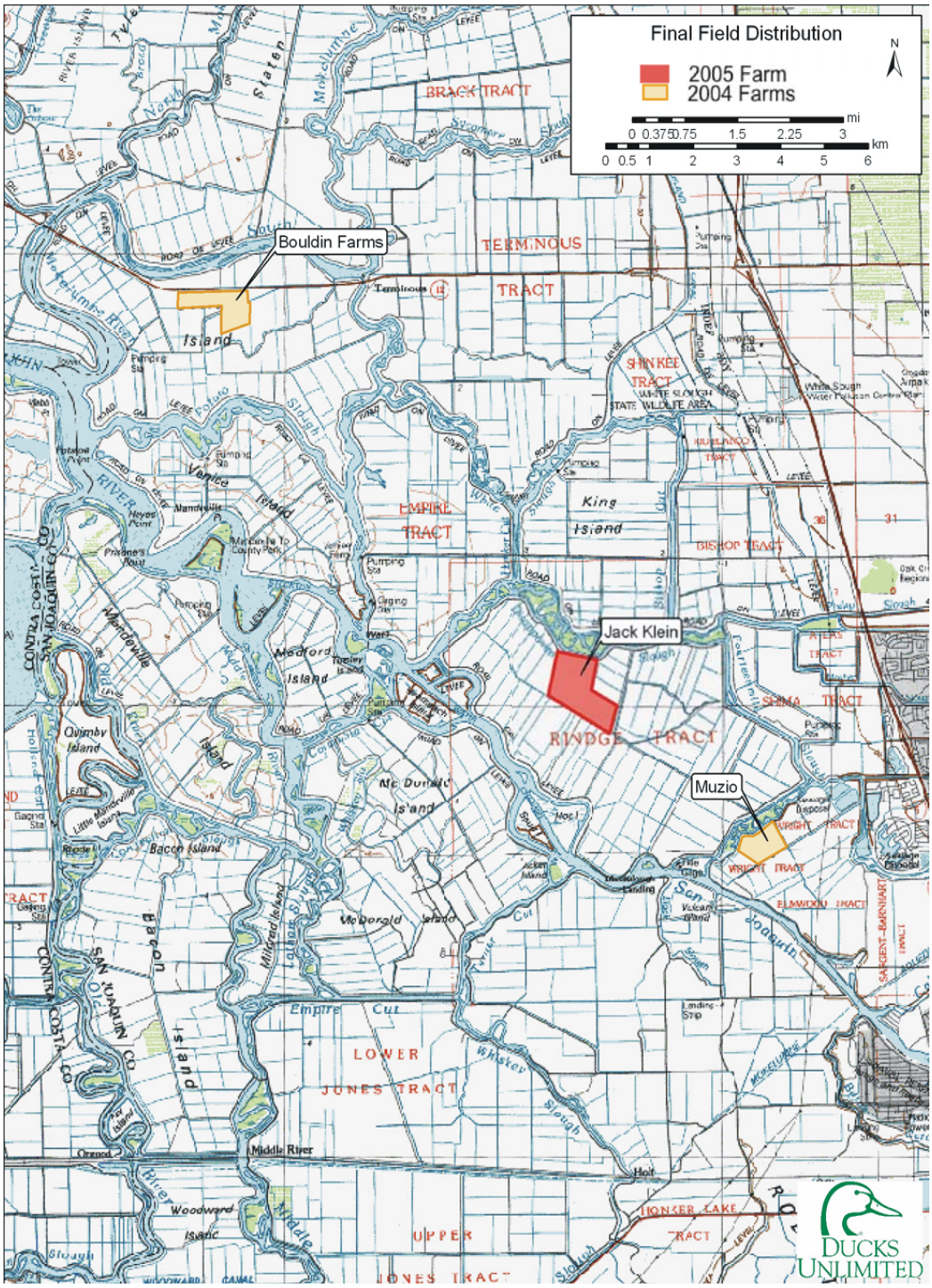

Figure 1-1. Delta Map including locations of the selected farms.

Bouldin Farms on Bouldin Island and Muzio Farm on Wright-Elmwood Tract were selected in 2004 for testing hydrologic BMPs. Jack Klein Trust on Rindge Tract was added in 2005 to this group to quantify rice production and the economic of growing rice in the Delta.

1.3 Project Scope

For this project, three 100-acre fields in the Delta were selected along a southeast-northwest gradient in the Delta and converted to rice production. Experimental plots were set up on Bouldin Island and on Wright-Elmwood Tract to test the effects of the different hydrologic BMPs on DOC, DBP and nutrient loads from surface and subsurface flows. In the original SOW, three farmers were to be selected in 2004 and the study plots were to be distributed over their farms. However, only two farmers qualified from that initial applicant pool in 2004 so the experimental plots were distributed over their fields. A third farmer was selected in 2005. This third farmer was new to rice production and was selected in part to document that experience. All farmers participated in the wildlife and economic components of this study. The rational and documentation for the selected farmers are found in Deliverables 6.4 and 6.4B for this project. The subsequent experimental design and monitoring plan for this project reflected the modification in the approach from the original concept of selecting three farms in 2004 to our approach of selecting two farmers in 2004 and one farmer in 2005.

Table 1-2 describes the different technical tasks associated with the scope of work. Under these tasks, a number of project activities were implemented. Below are a list of those activities and any relevant *technical* project deliverables that have been previously submitted:

- Assisted three farmers with the conversion to rice (Tasks 6 – 8; Table 1-2). This assistance included both financial assistance to help with conversion costs, and technical input and guidance from the project's rice expert and from the San Joaquin Cooperative Extension (Task 14, Table 1-2).

    - Deliverable 6.4 - Farmer Selection Summary, SWRCB Agreement No. 03-165-555-0, September 29, 2004
    - Deliverable 6.4B - Farmer Selection Summary for 2005 Growing Season, SWRCB Agreement No. 03-165-555-0, April 29, 2005
    - Deliverable 07.3 – Rice Conversion Plan, Final, SWRCB Agreement No. 03-165-555-0, October 15, 2004
    - Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots, SWRCB Agreement No. 03-165-555-0, November 1, 2004

- Implemented study plots and hydrologic treatments on two of the three farms and conducted associated water quality, flow and soil sampling (Tasks 9 & 10; Table 1-2). Statistical analyses of these data were used to determine the effects of the different BMPs on the surface and subsurface export of DOC, DBPs and nutrients (Task 13; Table 1-2).

    - FINAL QUALITY ASSURANCE PROJECT PLAN VERSION 1.0, December 2, 2004. (QAPP includes monitoring plan and experimental plan.)
    - Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots, SWRCB Agreement No. 03-165-555-0, November 1, 2004

  - Deliverables 5.4 – Technical Advisory Committee Comments on Experimental Design, SWRCB Agreement No. 03-165-555-0, April 19, 2005

- Conducted summer and winter wildlife surveys at the three selected farms. Bouldin Farms on Bouldin Island and Muzio Farm on Wright-Elmwood Tract were implemented in 2004 and Jack Klein Trust on Rindge Tract was implemented in 2005.
- Developed economic analyses for rice production at the three farms and discussed those economics as they relate to growing rice in the Delta.

Table 1-2 SOW Summary

Task		Description	Comments and Notes	Contract Due Date	Estimated Task Completion Dates	Deliverable Documentation Submitted
6	Field Selection	Select 3 fields for conversion to rice for implementation of experimental plots to assess water quality affects and for documentation of rice	Two farms were selected for 2004 as only two applicants met technical requirements of the project.	4/15/2004	3/15/2004	09/29/04
			Third farmer was selected in 2005. Farmer new to rice production.	NA	12/1/2004	04/29/05
7	Rice Conversion Plan	Develop specifications for conversion of agricultural fields to rice production.	Experienced farmers were selected in 2004 and did not need formal rice conversion plan. Worked with 2004 growers to develop formal rice conversion plan for farmer selected in 2005. October 2004 submitted deliverable was referenced by the third farmer in converting to rice in 2005.	6/5/2004	10/15/2004	10/15/2004
8	Rice Conversion Implementation	Implement conversion to rice production.	2004 farmers completed conversion to rice by May 2004, including all field preparation and planting.	9/5/2004	5/1/2004	11/01/04
			2005 farmers completed conversion to rice by May 2005, including all field preparation and planting.	NA	5/1/2004	NA
9	Implementation of Study Plots	Design and implement 6 approximately 20-acre rice plots to implement hydrologic BMPs and to assess their affects on the export of DOC, DBPP, and N from rice fields.	Study plots were implemented by early June, 2004. Modifications were made in the second year to improve water management and these modifications were completed by May, 2005	9/5/2004	6/1/2004	11/01/04
10	Water and Soil Sampling	Implement water and soil sampling on rice plots and adjacent corn fields.		1/10/2006	10/1/2005	01/17/06
11	Wildlife Surveys	Quantify wildlife benefits.		2/10/2006	12/1/2005	01/18/06
12	Rice Production Rates	Quantify economics of rice production.		1/10/2006	1/18/2006	01/18/06
13	Data Analysis	Analyze water and soil data to quantify the export of DOC, DBPP and N from rice fields, to compare to export from corn fields, and to identify export seasonal and annual trends.		1/10/2006	3/1/2006	NA
14	Technical Assistance and Outreach	Provide technical assistance to growers. Conduct outreach to interested growers, planners and agency personnel.		3/5/2004	Throughout the project	Throughout the project as needed
15	Reports			3/1/2006	3/1/2006	03/01/06

1.4 Approach and Methods

This project moved forward on several fronts as discussed above:

- Assisted three farmers with the conversion to rice (Tasks 6 – 8; Table 1-2). This assistance included both financial assistance to help with conversion costs, and technical input and guidance from the project's rice expert and from the San Joaquin Cooperative Extension (Task 14, Table 1-2).
- Implemented study plots and hydrologic treatments on two of the three farms and conducted associated water quality, flow and soil sampling (Tasks 9 & 10; Table 1-2). Statistical analyses of these data were used to determine the effects of the different BMPs on the surface and subsurface export of DOC, DBPs and nutrients (Task 13; Table 1-2).
- Conducted summer and winter wildlife surveys at the three selected farms. Bouldin Island (Bouldin Farms) and Wright-Elmwood Tract(Muzio Farm) were implemented in 2004 and Rindge Tract (Jack Klein Trust) was implemented in 2005.
- Developed economic analyses for rice production at the three farms and discussed those economics as they relate to growing rice in the Delta.

This section briefly discusses the approach used for each.

1.4.1 Rice conversion

At the beginning of this project in January 2004, farmers were solicited for participation in this project. Two farmers were selected and 100 acres were converted on each farm to rice. Beginning prior to the growing season in May 2004 plots were constructed by performing one or more of the following: laser leveling, surveying, shallow disking, construction of check levees as necessary, and installation of irrigation and drainage structures. These fields were for placement of smaller experimental plots, for wildlife surveys, and for the economic and feasibility analyses. A third farmer was selected in 2005 and 100 acres were converted on that farm as well.

Both farmers who were selected in 2004 had grown rice previously and thus had experience with converting to rice. Under this project, we developed a rice conversion plan and documented the conversion process in two deliverables:

- Deliverable 07.3 – Rice Conversion Plan, Final, SWRCB Agreement No. 03-165-555-0, October 15, 2004
- Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots, SWRCB Agreement No. 03-165-555-0, November 1, 2004

These documents were provided in 2005 to the third grower who was unfamiliar with rice production to help provide guidance.

Jay Dee Garr, the agricultural specialist for Ducks Unlimited regularly worked with the participating growers to assist with their conversion to rice and to provide input on their practices for growing rice. Mr. Garr has extensive experience in agricultural outreach, He is a former rice

grower and manages Ducks Unlimited Technical Assistance Program and rice production in the Delta, promoting wildlife friendly agricultural programs. He has worked closely with growers, the Farm Bureau and the Colusa County RCD over the last decade.

Assistance was also provided by the San Joaquin County Cooperative Extension.

Rice was dry seeded and paddies were flooded as soon as rice was approximately 6" high. Fields were drained by the end of September and harvested as soon as fields were dry enough to safely drive farm equipment on them. Post-harvest, fields were re-flooded by December, and the winter rains helped maintain flooded conditions for the duration of the winter. Prior the following growing season fields were drained (around late March) and dried to prepare for planting. An unusually wet fall in 2004 prevented harvest until mid-late October, and likewise an unusually wet spring in 2005 prevented planting until mid-May. Water sampling began promptly as soon as paddies were flooded each growing season and during the winter months.

1.4.2 BMP testing at Study Plots

To test different BMPs, we implemented study plots on Bouldin Farms on Bouldin Island and at Muzio Farm on Wright-Elmwood Tract. In all six experimental plots totaling slightly less then 170 acres with four treatments (e.g. new rice with low drain water management, new rice with high drain water management; corn with low drain water management; and established rice with low drain water management) were implemented on Bouldin Island, and 4 plots totaling about 33 acres with three treatments (e.g. new rice with low drain water management, new rice with high drain water management; and corn with low drain water management were implemented on Wright-Elmwood Tract. Table 1-3 summarizes the experimental design used for this project. Together these treatments tested several effects:

- The effects of low (standard practice) and high (tested BMP) drain management on the export of DOC, N and DBPPs from new rice fields;
- The differences in DOC, N and DBPPs exported from new rice fields, established rice fields and corn fields under low drain management;
- The effects of improved weir configurations on the export of surface loads of DOC, N and DBPPs.

Management practices within sites (straw management, cover crop, seeding, harvest) were otherwise kept as uniform across all plots such that changes in water quality, production, and other practices could be more easily related to hydrologic management practices and not confounded by other BMPs.

Table 1-3 Experimental Design for investigating land uses and hydrologic BMPs.

Farm/Plot	Treatment				
	Land Use			Drainage	
	Rice		Corn		
	New	Established		Low	High
Bouldin Island					
Plot/Area 1	X				X
Plot/Area 2	X			X	
Plot/Area 3		X		X	
Plot/Area 4			X	X	
Wright Elmwood Tract					
Plot/Area 1	X				X
Plot/Area 2	X			X	
Plot/Area 3			X	X	

The above experimental design reflected our decision in 2004 to only select the two farmers who met the technical requirements for the project and to defer the third farmer selection until 2005. This experimental design focused on not only testing hydrologic BMPs for drain water management, but also to test the effects of established versus newly planted rice, and to better test the effects of corn as opposed to rice. In the original SOW, only drain water management was to be experimentally tested. The SOW allowed flexibility in finalizing the experimental plan and that flexibility was written into the contract to allow for modifications in the experimental implementation of the project based upon unforeseen or pragmatic considerations.

On these field sites we implemented a number of activities as summarized below that fall into the categories of water flow and elevation monitoring and management; water quality monitoring; soils characterizing; plant rice production; and data management and analyses. Below we describe the various activities and identify the Chapters in this report that greater detail can be found on the methods used:

- Water flow and elevation monitoring and management. (See Chapter 5 for more detail on methods.)

    - Installed a piezometer (wells) grid at Bouldin Island and Wright-Elmwood Tract in the 2004 growing season within the new and established rice experimental plots. The purpose of these grids was to map groundwater contours that occur during the growing season and to define the contributing areas to the drains . This grid was installed immediately after tractor work was completed to prepare and seed the fields and removed immediately before the fall tractor work to harvest the rice. A subset of piezometers in this grid was continuously monitored during the 2004 growing season to show temporal variability in groundwater elevations and the temporal groundwater responses to drain and surface water management. The temporal monitoring on the subset of piezometers was repeated during the

2005 growing season to determine if the groundwater responses were similar from year to year.
- Installed weirs in 2004 and 2005 to better manage surface water on the experimental plots and installed weir inserts at Wright-Elmwood Tract to provide an even higher level of surface water management.
- Installed weirs in drains and field outflows, and instrumented those locations with pressure transducers and gauge plates to measure and monitor water elevations. A relationship was developed and calibrated at each location correlating water level elevation with flow through the weir and this relationship was used to estimate flows.
- On a subset of wells we installed pressure transducers. These transducers in combination with the surface water transducers showed the temporal trends for surface and subsurface waters and the effects of changing surface water regimes on subsurface water elevations.
- Worked with farmers to provide guidance on desirable surface water management.
- Improved sampling and maintenance methods in 2005 to obtain higher quality water level and flow data.

- Water quality monitoring. (See Chapter 5 for more detail on methods.)

  - Sampled inflow and outflow locations at each experimental plot and drain locations biweekly during the summer and winter periods in which there were flow (Table 1-4). In all, approximately 20 sampling events occurred. Grab samples were collected primarily for carbon and nitrogen species, and THMFP determinations. Field measurements of dissolved oxygen, temperature, electroconductivity and pH were also taken.
  - Piezometers were sampled during a synoptic study during 2004 for isotopes and anions and cations help characterize subsurface water characteristics.

- Soil Sampling and Characterization. (See Chapter 5 for more detail on methods including sampling design, laboratory handling and laboratory analyses.)

  - Soils were sampled during October 2004 after the fields were drained and the rice harvested. Composite (non-intensive) and discrete (intensive) soil samples were collected at each location. Composite soils included no less then four soil cores composited by horizon. Soils were characterized for total nitrogen and total carbon, and bulk density. Thickness of peat was measured at each location and the core lithology described. A minimum of three soil horizons for each location were characterized (e.g. 0-15 cm, 15-30 cm, 30-60 cm). For deeper peat soils, deeper soil horizons up to a depth of about 200 cm were characterized.

- Rice Production. (See Chapter 7 for more detail on methods.)

  - Rice plants were harvested at each experimental plot during 2004 and 2005. Rice seed was separated from straw and total nitrogen and total carbon were

determined for both the straw and the seed. Additionally, total silica was determined for the seed.

- Data management and statistical analyses

    - All water quality, flow, elevation, survey, soils and biomass data were entered in the database. QAQC was done on all data before its entry into the database and once the data was entered in the database, additional queries were run to check data quality. Queries were used to calculate and extract surface and subsurface flow estimates; calculate and extract surface and subsurface load estimates for nitrogen and carbon species and for THMFP; calibrate pressure transducers to ft-NAVD and relate those measurements to other measures of water level elevation (e.g. heights over the weirs, gauge plate measurements); extract soil chemistry and lithology relationships; and other relationships. Parametric and non-parametric statistics were used to analyze the data as needed.

Laboratory methods used followed those detailed in the QAPP. Table 1-4 summarizes the number of samples and their frequency planned for this study. Table 1-5 provides a summary of the analyses completed for this study. The number of analyses targeted and conducted differed slightly for a number of reasons:

- As the project progressed and data was reviewed, the project and its focus slightly evolved. For instance, more data was collected for soils to better characterize the system then was originally planned, the export of particulates from the fields was measured in surface waters, and biomass sampling was conducted in 2004 and 2005 to test the effects of the different tested BMPs on crop production in the Delta.
- Groundwater was sampled only during the summer seasons as compared to the year around sampling that was planned. During the other periods of the year, tractor work, access issues or logistics made it impossible for the project team to install the wells and monitor them.
- During the winter, many of the locations did not have any flow. For instance, Bouldin Island had no surface water flow from their fields throughout the winter. Thus, even though sampling trips were made, during the winter many fewer samples were taken for each sample event then were taken during the summer.

These changes were driven by an adaptive management approach on the project in which collected data and new questions based upon our experiences and those data resulted in slight modifications to our approach. Figures 1-2 and 1-3 show the experimental sampling locations and structures at Bouldin Island and Wright-Elmwood Tract respectively.

Table 1-4 Estimated Sampling Locations, Frequency and Total Numbers.

Actual number of samples taken are slightly different are slightly different but numbers below reflect the level of activity for the different project components.

Constituents	In-plot Sample Locations[1,2]	Planned No. of samples per experimental treatment/plots[5]						Frequency (Times/Year)	Years	Total Number[3]
		Bouldin			Muzio		Total			
		NR	OR	CO	NR	CO				
Water Quality Sampling[4]:										
Grab Sample: DOC, POC, NO_3^-, NH_4^+, Diss Org N **Field Measurement:** pH, DO, EC, Temperature	SWI	2	1	0	3	0	6	13	1.5	**117**
	SWO	4	1	0	3	0	8	13	1.5	**156**
	DDO/DDI	2	2	1	2	2	9	13	1.5	**176**
	PIZ	4	2	2	4	2	14	4	1.5	**84**
	Total									**533**
Isotopes	SWI	0	0	0	0	0	0	1	2	**0**
	SWO	0	0	0	0	0	0	1	2	**0**
	DDO/DDI	0	0	0	0	0	0	1	2	**0**
	PIZ	4	2	2	4	2	14	1	2	**28**
	Total									**28**
THMFP, DOC Quality (UVA, UV-Vis, flourescence)	SWI	1	1	0	3	0	5	13	1	**65**
	SWO	4	1	0	3	0	8	13	1	**104**
	DDO/DDI	2	2	1	2	2	9	13	1	**117**
	PIZ	4	2	2	4	2	14	4	1	**56**
	Total									**342**
Major cations: Ca^{2+}, Mg^{2+}, Na^+, K^+ **Major Anions:** SO_4^{2-}, Cl^-, CO_3^{2-}	SWI	0	0	0	0	0	0	1	2	**0**
	SWO	0	0	0	0	0	0	1	2	**0**
	DDO/DDI	0	0	0	0	0	0	1	2	**0**
	PIZ	4	2	2	4	2	14	1	2	**28**
	Total									**28**
Soil Sampling[6]										
Intensive: Bulk density, ash, TN, TC	SCO 0-15	20	5	0	15	0	40	1	1	**40**
	SCO 15-30	20	5	0	15	0	40	1	1	**40**
	SCO 30-45	20	5	0	15	0	40	1	1	**40**
	SCO 45-60	20	5	0	15	0	40	1	1	**40**
	SCO 60-200[9]	20	5	0	15	0	40	1	1	**40**
	Total									**200**
Non-intensive: Ash, TN, TC[8]	SCO 0-15	20	5	0	15	0	40	1	1	**40**
	SCO 15-30	20	5	0	15	0	40	1	1	**40**
	SCO 30-60	20	5	0	15	0	40	1	1	**40**
	Total									**120**
Flow										
Planned unattended monitoring	SWI	0	0	0	0	0	0	8736	1.5	**314,496**
	SWO	4	0	0	0	0	4	(hourly)		
	DDO/DDI	2	2	0	2	0	6			
	PIZ	4	2	2	4	2	14			
	Total[7]						24			
Planned manual monitoring	SWI	4	1	1	3	1	10	13	1.5	**800**
	SWO	0	1	0	3	0	4			
	DDO/DDI	0	0	1	0	2	3			
	PIZ	8	4	0	8	4	24			
	Total[7]						41			

Notes

1. SWI = Surface Water In; SWO = Surface Water Out; DDO = Drainage Ditch Out; PIZ = Piezometer sample; SCO = Soil Core
2. Surface water samples including drainage ditches will be collect from flow over the boards or from pipes at the outlet of the riser.
3. Total number does not include field QAQC samples.
4. Water Quality Sampling will be conducted by UCD staff. Pis from other team organizations will provide training support and method verification
5. NR = New Rice Plots; OR = Old or established Rice Plots; CO = Corn.
6. "SCO 0-30" = soil core depth of 0 - 30 cm; "SCO 30-60" = soil core depth of 30 - 60 cm; "SCO 60-150+" = soil core depth of 60 cm to 150 or
7. Approximatley 60 piezometers will be installed for the seven experimental areas (NR plots are comprised of a low water treatment and a high
8. Non-intensive samples are composited samples from five sample points.
9. Samples taken to clay layer. More samples sometimes taken if transitional zone is identified in boring log.

Table 1-5. Tally of Analyses and Measurements

Total Sampling Events Per Farm		Total	Target
Surface Water		19	19
Groundwater	(Groundwater wells only in place during the growing seasons)	2	6
Soils		1	1
Groundwater (Piezometer)			
Laboratory			
Cations			
	Ca	29	28
	Mg	29	28
	Na	29	28
	K	29	28
Anions			
	SO4	29	28
	HCO3	29	28
	Cl	29	28
DOC		25	84
Nitrogen			
	TDN	20	84
	NH4	28	84
	NO3	24	84
Isotopes		36	28
Total Laboratory Measurments & Analyses		**336**	**560**
Field			
	Eh	22	84
	EC	22	84
	Temperature	22	84
	DO	22	84
Total Field Measurements		**88**	**336**
Surface Waters			
Laboratory			
Carbon			
	PIC (Particulate Inorganic Carbon)	404	0
	POC (Particulate Organic Carbon)	482	0
	DOC (Dissolved Organic Carbon)	582	342
	THMFP & Constituents (CHBR3, CHCl2Br, CHCl3, CHClBr2)	228	342
	UV254	239	342
	STHMFP	225	342
Nitrogen			
	NO3	477	533
	NH4	471	533
	TDN	476	533
Solids			
	TSS	482	0
Total Laboratory Measurments & Analyses		**4066**	**2967**
Field Measurements			
	DO	355	533
	pH	361	533
	Temperature	360	533
	EC	363	533
Total Field Measurements		**1439**	**2132**
Soils			
Laboratory Measurements			
	% Carbon	395	200
	% Nitrogen	395	200
	Total Laboratory	790	400
Total Laboratory Measurments & Analyses		**1580**	**800**
Field Measurements			
	Bulk Density	270	0
	Depth of Peat	270	0
Total Field Measurements		**540**	**0**
Biomass		85	0
Physical Parameters			
Discrete Sampling			
	Water level and elevations	300	
	Discrete Water Flow Determinations for grab samples	360	
Unattended Monitoring			
	Unattended Monitoring Stations Locations (15 minute sampling intervals)	28	24
	Data points	508340	314496

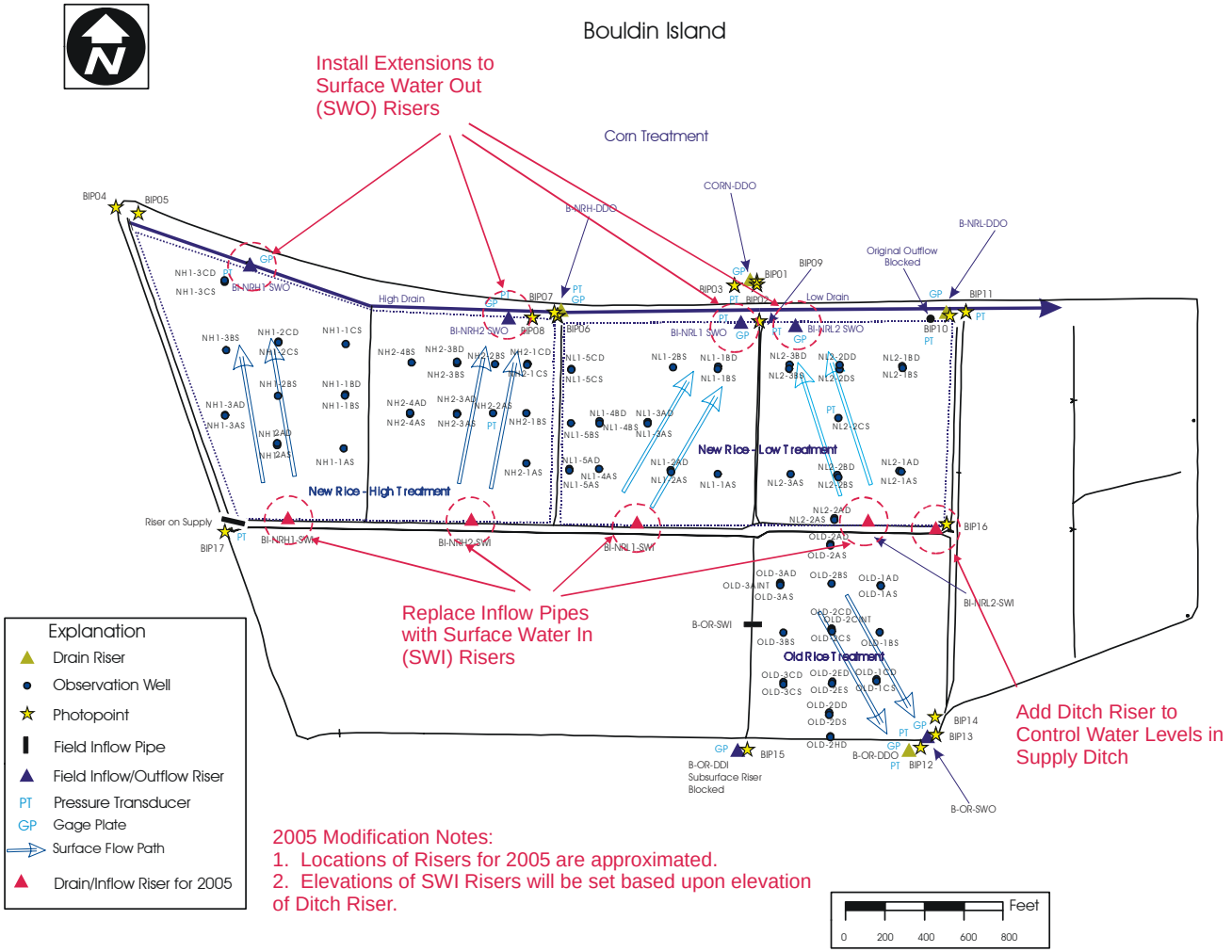

Figure 1-2. Modifications implemented for 2005 to improve water management at Bouldin Farms experimental plots.

Figure shows equipment and sampling locations for 2004 and 2005. Modifications (in red) for 2005 include replacing inflow pipes with risers, adding a riser in the supply ditch for better water level control and adding extensions onto outflow risers. Gauge plates were installed for recording water levels at the field inflows. Pressure transducers were installed in the supply ditches during the 2005 growing season.

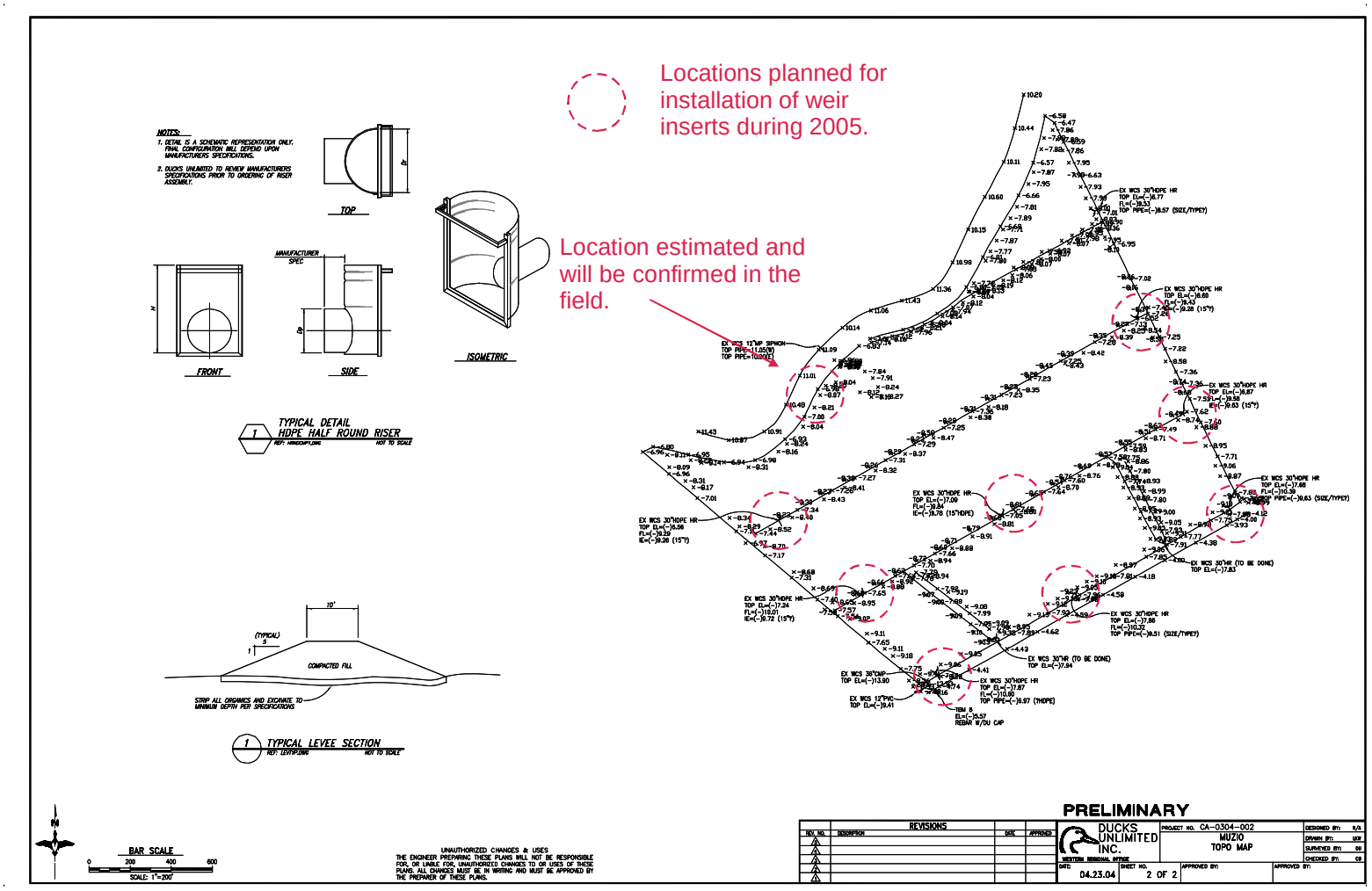

Figure 1-3. Modifications implemented in 2005 to improve water management at Wright-Elmwood Tract experimental plots and hydrologically connected upstream rice fields.

Figure shows equipment and sampling locations for 2004 and 2005. Used inserts in the surface water weirs located in the fields during 2005 (in red). Inserts allowed better control of surface water elevations and flow. All risers had gauge plates.

1.4.3 Wildlife surveys

Wildlife surveys were conducted on the rice fields that were implemented for this study, adjacent corn fields and managed wetlands in the nearby Consumnes Reserve. Each field was approximately 100 acres. Surveys were conducted using point counts and these point counts were conducted on one visit to each farm or site during each of the seasons shown: Summer 04 (June/July 2004), Fall 04 (November 2004 – January 2005), Summer 05 (June/July 2005) and Fall 05 (November/December 2005). Chapter 6 provides more details on the methods used.

1.4.4 Economic analyses and Feasibility Assessment

As part on the feasibility assessment, an economic analysis was conducted. Our team provided to each participating farmer a spreadsheet to identify the costs and economics associated with growing rice. Economic costs were determined by year. These costs were determined for Bouldin Island and Wright-Elmwood Tract for 2004 and 2005, and for Rindge Tract in 2005. Jack Klein Trust of Rindge Tract began participating in the project in 2005. Chapter 7 provides more details on the economic analysis methods.

1.5 Report Summary

The following describes the outline for this report.

Executive Summary

This chapter summarizes the project's methods and findings. This chapter discusses the water quality effects of growing rice in comparison to corn; water management practices that can be implemented to improve discharge water; the economics of rice grown for the project at the different locations in the Delta; and the wildlife benefits of the rice fields implemented under this project.

Chapter 1. Introduction

This chapter provides a statement of purpose, the scope of the project, and a description of the approach and techniques used during the project. This chapter references appropriate technical deliverables.

Chapter 2. List of Task Deliverables

This chapter provides a tabular list of the deliverables for this project and when they were completed.

Chapter 3. Recommendations

This chapter recommends management and design practices to improve water quality as it relates to DOC, N, and DBPPs in the discharge from rice fields in the Delta.

Chapter 4. Evaluating Measures of Effectiveness

This brief chapter summarizes the effectiveness of the project. This chapter restates the goals and measurable objectiveness for this project, briefly discusses the different effectiveness evaluations, and references chapters that provide a more detailed analysis of the evaluation measures and related findings.

Chapter 5. Comparing the discharge of N, DOC and DBPP loads between rice and corn in the Delta and for different hydrologic management practices.

This chapter compares the water quality impacts of different hydrologic management practices and different crops as they relate to N, DOC, and DBPP. It identifies differences in export loads and develops recommendations for management practices to be used in rice. This chapter compares data from these experimental plots with that of Twitchell Island to help put these data in perspective to the Delta as a whole.

Chapter 6. Comparing wildlife usage of rice fields with corn

This chapter documents bird and waterfowl usage of the converted rice fields and adjacent corn fields for the three farms and compares their usage to that of regional managed wetlands.

Chapter 7. Assessing the feasibility of rice production along an east-west gradient in the Delta

This chapter quantifies rice production and summarizes the economics for rice grown for each of the participating farms. It provides guidance information for converting to rice production in the Delta.

Chapter 8. Project management performance evaluation for the Delta rice project.

This brief chapter discusses implementation of the Delta rice project with regard to farmer participation, success in conversions, and outreach. This chapter includes a discussion of several measures of effectiveness related primarily to project management and implementation, and references appropriate appendices where the different measures are included, if not included with this chapter:

- Evaluation of following the schedule as outlined in the original SOW.
- Evaluation of compliance with the original SOW.
- Document identifying farmers participating in project.
- Conversion document including maps describing rice field conversion.
- Photo documentation showing one season of rice production in the Delta for converted fields.
- Implementation plan including maps showing experimental plot implementation.
- Outlines for eight workshops and list of participants

Appendices

Data

- Water quality data
- Water flow data
- Soils data
- Wildlife counts
- Productivity data
- CD's with photo documentation of study plots and converted fields

1.6 Chapter References

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2 List of Task Deliverables

Table 2-1 shows the deliverables for this project. For this project, all the deliverables except for a handful have been completed by the completion of this draft report. Deliverables shaded in yellow are those deliverables completed for this report. Deliverables shaded in green are those that will be completed after completion of the draft and before or with the completion of the Final Report.

Table 2-1. List of Deliverables

Task	Deliverable	Due Date	Date Submitted
1	Project Administration		
1.2	Progress Reports	4/10/04 and quarterly thereafter	6/25/04, 8/27/04, 12/7/04, 6/30/05, 8/22/05, 11/17/05, 2/16/06
1.5	Contract Summary Form	Within (3) three months of Agreement execution	08/27/04
1.6	Subcontractor Documentation	03/05/04	06/25/04
1.7	Expenditure Projections	4/10/04, 10/10/04, 4/10/05, 10/10/05	8/27/04, 12/7/04, 6/3/05, 11/17/05
1.8	Project Survey Form	03/01/06	03/01/06
2	CEQA/NEPA Documents		
2.1	CEQA/NEPA Documentation	03/31/04	6/25/04, 11/17/05
2.2	Permits	06/05/04	None required
3	Quality Assurance Project Plan		
3.1	Approved and signed QAPP	06/05/04	070/9/2004, QAPP signed Dec. '04
3.2	Monitoring Plan	06/05/04	07/09/2004
4	Project Assessment and Evaluation Plan		
4.1	Project Assessment and Evaluation Plan	07/10/04	12/04, Draft 4/29/2005, Final with revisions re-submitted 6/1/05
5	Technical Advisory Committee		
5.1	Copies of Solicitation Letters	03/05/04	06/25/04
5.2	TAC Member List	03/05/04	06/25/04
5.4	TAC Comments on Experimental Design and Study Plots	06/05/04	06/01/05
5.5	TAC Comments on Draft Report Comments	2/5/2006 as prepared	2/13/06, 2/21/06

	5.6	Meeting Minutes and Notes (to SWRCB's Project Representative Only)	2/5/2006 as prepared	2/13/06, 2/21/06
6		Field Selection		
	6.1	Application for Interested Farmers	03/15/04	06/25/04
	6.2	List of Workshop Attendees	04/15/04	08/27/04
	6.4	List of Farms Selected and Memorandum Documenting Criteria Used	04/15/04	11/10/04
	6.5	Selection Memorandum	04/15/04	8/27/04, Informally notified selection by telephone.
	6.6	Written Landowner Agreements	04/15/04	8/27/2004 for 2004 farmers. 8/22/05 for third farmer.
7		Rice Conversion Plan		
	7.3	Final Rice Conversion Plan	06/05/04	11/10/04
8		Rice Conversion Implementation		
	8.1	Photodocumentation	09/05/04	06/01/05
	8.3	Conversion Documentation	09/05/04	11/10/04
9		Implementation of Study Plots		
	9.1	Final Experimental Design	04/05/04	8/27/04 draft, December 2004 final. Submitted as part of QAPP
	9.3	Implementation Plan	04/05/04	11/10/04
	9.5	Photodocumentation	09/05/04	06/01/05
	9.6	Documented Implementation of Study Plots	09/05/04	11/10/04
10		Water and Soil Sampling		
	10.4	Report Summarizing Water and Soil Sampling Results	01/10/06	01/17/06
11		Wildlife Surveys		
	11.1	Wildlife Survey Comparison Results	02/10/06	01/17/06
12		Rice Production Rates		
	12.1	Cost/Income Analysis and Annual Production Rates	01/10/06	01/17/06
13		Data Analysis		
	13.1	Hydrologic Budget	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/06
	13.2	DOC, DDBP and Nutrient Budgets	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/07
	13.3	Regression Analyses as Appropriate; Plots of Seasonal and Annual Trends; ANOVA	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/08

	13.4	Soil Effects Analysis	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/09
	13.5	Qualitative Comparison of Rice Production with Corn Production and Wetlands	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/10
	13.6	Proof of Hypotheses	01/10/06	1/10/2006 - submitted as Chapter 5 of Draft Final Report. SWRCB Rep requested that deliverables be submitted individually and not part of Draft Final Report - re-submitted on 1/12/11
14		Technical Assistance and Outreach		
	14.2	Memorandum with Extension Contacts and List of Technical Publications and Information on their Availability	02/28/04	06/25/04
	14.3	Initial Database List of Interested Parties	03/05/04	06/25/04
	14.4	Workshop Mission Statement	02/28/04	06/25/04
	14.5	Workshop Announcements	2/20/04, 4/20/04, 6/20/04, 9/20/04,12/20/04,3/20/05, 6/20/05,9/20/05	Workshop announcement for April Kickoff meeting for 3rd farmer
	14.6	Signed agreements with Landowners for Private Property Access	3/5/04, 5/5/04, 7/5/04, 10/5/04, 1/5/05, 4/5/05, 7/5/05, 10/5/05, as needed	8/27/04 for first two farmers, 8/22/05 for third farmer
	14.7	Survey/Questionnaire	03/05/04	06/25/04
	14.8	Workshop Presentations (to SWRCB's Project Representative Only)	3/5/04, 5/5/05, 7/5/04, 10/5/04, 1/5/05, 4/5/05, 7/5/05, 10/5/05	6/25/04, 8/27/04, 11/10/04, 6/1/05
	14.9	Survey Summary Responses	01/10/06	01/17/06
15		Reports		
	15.1	Draft Project Report	01/10/06	1/13/06 - Chapters 1,2&5 submitted, 1/13/06 Chapter 4 & 8 submitted, entire Draft submitted 1/19/06
	15.3	Final Project Report	03/01/06	

Notes

1. Deliverables shaded in light yellow are those completed by this report.
2. Deliverables shaded in light green are those deliverables to be completed before or with the Final Project Report.

3 Recommendations

This chapter list recommended management and design practices for improving water quality as it relates to DOC, N, and DBPPs in the discharge from rice fields in the Delta. Each of these recommendations is discussed and potential effects on yield, economics and wildlife are included.

3.1 Managing Surface Flows and Loads

The following recommended practices are suggested for managing surface water flows and loading from rice fields in the Delta. These recommendations are based upon our experience and findings unless otherwise noted.

3.1.1 Minimize tidal effects on island water deliveries.

Daily tidal changes cause flow fluctuations which inhibit control of water flow to fields. Tides in inflow ditches can vary by nearly one foot in these Delta locations. Inflow weirs reduce tidal inflows to rice fields. Tidal effects can also be minimized through the installation of water distribution ponds which have a larger hydrologic capacity then ditches or through the installations of standpipes designed to maintain a set head despite tidal changes at the siphon structures.

3.1.2 Establish precision leveled areas between checks.

Precise leveling between checks and maintenance of that leveling is recommended for growing rice in the Delta. Large fields on Bouldin Island which were not as well leveled as those at Wright-Elmwood Tract prevented water distribution uniformity on Bouldin Island and precise water level management. Smaller, well-leveled fields at Wright-Elmwood Tract resulted in high distribution uniformity. Non-uniformity results in a need for more inflow, lower yields and can result in more surface runoff.

3.1.3 Develop effective control of water between fields and basins and to islands

Structures for controlling water flow can be installed to precisely meter water onto fields and prevent surface-water runoff. Typical structures used for controlling flows and water levels onto Delta fields are rectangular weirs. Too many weirs from a single supply ditch complicate flow distribution and hinder effective hydrologic controls. Weir inserts that allow for more precise adjustments in water elevation improve hydrologic control and management. Reducing surface-water runoff will reduce loads. Inserts for this project were constructed for about $100 each and reduced associated labor costs for managing water.

3.1.4 Use evapotranspiration and seepage estimates to allocate flow to fields.

Our findings provide estimates of seepage and these estimates are similar to seepage rates estimated in other Delta studies. Using these estimates of seepage for different drain management regimes in combination with estimates of evapotranspiration for the region provide an estimate of the surface water demand for the crop. Evapotranspiration rates can be estimated from the Twitchell Island and Lodi CIMIS stations

Surface-water outflow can be minimized by precisely allowing flow to meet crop water demand and seepage.

3.1.5 Install surface-water outflow structures to better control water levels

Water levels need to be adjusted throughout the growing season, first to suppress weeds and second to help prevent blanking. Weir inserts with adjustable levels can improve water level management. The inserts for this project were constructed for about $100 each. This project showed that better water level control can translate to lower surface water demands and reduced DOC, DBPP and nutrient loads.

3.1.6 Install drain outflow structures to raise drain water levels and reduce surface water requirements.

Raising drain levels raises groundwater levels. Higher groundwater levels should result in lower loss of surface water to groundwater through seepage. Reducing seepage should help simplify managing of surface water flows to offset evapotranspiration, which can be estimated from CIMIS data, and percolation, which cannot be estimated with a universally available dataset.

3.2 Managing Subsurface Flows and Loads

The following management practices are recommended to reduce subsurface flow and loads from rice in the Delta.

3.2.1 Install drain outflow structures to raise drain water levels and reduce subsurface flow and loading.

Higher drain water levels reduce the area contributing to subsurface flow to the drains and reduce the head between groundwater and drain water elevations. Both these factors should reduce subsurface flow into the drains and the accompanying loads.

3.2.2 Reduce the drain length to area ratio

A low ratio between drain length and field area reduces the available area for the flow of subsurface water from the island through the drain network. This reduction in area acts as a funnel for subsurface flow and should result in lower subsurface loads of constituents of concern.

3.3 Island water management strategies

Island water management strategies were not investigated for this project. The following management strategies are recommended to reduce loading of DOC and other constituents from Delta islands and tracts.

3.3.1 Reapply drain waters from rice fields onto other crops

Water from drains can be reapplied onto other crops during the summer to minimize pumping of drain water. The logistics and the impacts on farm operation have not been studied for this project. Reapplying drain water should reduce DOC and nutrient loading from the island and pumping costs at the pump stations from the island through more efficient water use. PIN 9234 proposes studying these strategies to reduce DOC and nutrient loading from Delta Islands to demonstrate the reduction in loading that can be achieved and determine economic costs. Recycling summer waters would need to be coordinated with rice drydown periods necessary for harvesting or weed management.

3.3.2 Release drain water high in DOC in the summer

DOC loads from rice are lower in the winter then corn. Rice allows for lower winter discharges of DOC as compared to corn. Winter is the time in which the water supply is most sensitive to higher DOC concentrations.

4 Evaluating Measures of Effectiveness

This chapter summarizes the effectiveness of the project. It restates the goals and measurable objectiveness for the project; briefly discuss the different effectiveness evaluations; and reference chapters that provide more detailed analyses of the evaluation measures and related findings.

4.1 Project Goals and Measurable Objectives

This project has three goals:

- Investigate and develop hydrologic BMPs for rice production on experimental subplots in order to reduce DOC, DBP precursors (DBPPs).
- Investigate and develop hydrologic BMPs for rice production on experimental subplots in order to reduce nitrogen (N) export from rice fields.
- Investigate how broadly these BMPs can be applied to rice production throughout the Delta.

There were a number of measurable objectives for this project to achieve these goals. Table 4-1 shows these measurable objectives, the actions taken to meet those objectives and the chapters and deliverables discussing the objectives.

4.2 Different Evaluations of Effectiveness and Referenced Chapters

Table 4-2 shows the different measures of effectiveness used to evaluate the project and the chapters which discuss the different measures. Chapters 5 and 7 discuss the measures related to the effectiveness of the project in reducing and/or preventing nonpoint source pollution. This effectiveness includes not only a discussion of the changes in water quality concentrations and loads resulting from the management practices tested but also the economic feasibility of implementing rice within the San Joaquin-Sacramento Delta.

Chapters 6 and 8 relate to measures of effectiveness less directly related to the technical objectives and goals related to improving water quality. Chapter 6 relates to the effects of implementing rice on waterfowl in contrast to corn and managed wetlands. Chapter 8 focuses strictly on project management evaluations as they relate to the scope, schedule and budget for the project.

Table 4-1. Measurable Objectives, Actions Taken and Reference Chapters and Deliverables

	Measurable Objective	Actions towards Meeting Objectives	Reference Chapter from Report (Deliv 15.2 & 15.3) and other	
			Chapters from Deliv 15.2 & 15.3	Other Deliverables
Tasks 7 and 8 – Rice Conversion Plan and Implementation				
Project Management				
	Convert each of three (3) approximately one hundred (100)-acre farms from corn production to rice production.	Two farms converted in 2004 and one farm converted in 2005	1, 5	7.3 Final Rice Conversion Plan 8.1 Photodocumentation 8.3 Conversion Documentation
Task 9 – Study Plot Implementation				
Project Management				
	Implement six approximately 20-acre study plots	Implemented four treatments (e.g. established rice with low drain water level; new rice with low drain water levels, new rice with high drain water levels, corn with old drain water levels) on six plots at Bouldin Island and 4 plots on Muzio's Farm rangin	1, 5	9.1 Final Experimental Design 9.3 Implemetation Plan 9.5 Photodocumentation 9.6 Documentated Implementation of Study Plots
	Implement two hydrologic BMPs on study plots		1, 5	
Tasks 10 and 13. Water and Soil Sampling and Data Analyses				
Water Quality Improvements				
	Post-implementation water quality sampling for specified parameters in study plots	Completed water quality sampling	5	3.1 Final QAPP 10.4 Report Summarizing Water and Soil Sampling Results
Pollution Load Reduction				
	DOC, DBPP and nutrient mass budgets and export calculations in study plots as compared against the control treatment and between corn and rice	Completed hydrologic, DOC, DBPP and nutrient budgets for each treatment for surface and subsurface waters.	5	13.1 Hydrologic Budget 13.2 DOC, DDBP and Nutrient Budgets
	Seasonal trends for export of DOC, DBPP and nutrients from corn and rice study plots and in comparison with control treatment	Completed assessment of winter and summer water quality changes.	5	13.3 Seasonal and Annual Trends
Tasks 11, 12 and 14 – Outreach and Related Technical Assistance Issues (e.g. Wildlife Surveys, Rice Production Rates, Workshops)				
Project Management				
	Develop list of interested parties to keep informed on upcoming workshops and discussion of water quality affects of implementing BMPs	Completed list.		14.1 Farmer Information Memo 14.2 Memo with Extension Contacts and List of Technical Pubs and Information on their Availability. 14.3 Initial Database List of Interested Parties
	Conduct eight workshops to assist with regard to implementing rice and coordinating study plot activities to test BMPs and to provide technical information on project to interested parties.	Completed two solicitation workshops; four technical presentations at conferences and local regional workshop; and over twelve meetings with each farmer to provide information on growing rice and on improving water quality and flow management.		14.1 - Farmer Information Memorandum 14.5 Workshop Announcements 14.9 Survey Summary Responses
	Create file of relevant outreach handouts on benefits (water quality, wildlife, economics) and issues of converting to rice for distribution to interested parties in electronic format	Completed deliverables for project and distribution to interested parties.	5, 6, 7	11.1 Wildlife Survey Comparison Results 12.1 Cost/Income Analysis and Annual Production Rates 14.8 Workshop Presentations

Table 4-2. Measures of Effectiveness Evaluation and Status of Each Measure.

	Measures of Effectivenss Evaluation	Status and Notes
Effectiveness in reducing and/or preventing nonpoint source pollution		
Chapter 5. Comparing the discharge of N, DOC and DBPP loads between rice and corn in the Delta and for different hydrologic management		
	Comparison of nitrogen and DOC loads (seasonal and annual) for different rice treatments and management practices (i.e. new rice v. established rice, high drain level v. low drain level) in study plot and with corn. Estimate of N and DOC load reduction f	Completed
	Estimate of disinfection byproduct precursor load reduction for different rice treatments and management practices in comparison to corn and rice operated under current hydrologic management practices. Will use measured THMFP data and correlations with D	Completed
	Hydrologic budgets and nitrogen, DOC and DBPP mass budgets for rice and corn study plots and associated drains.	Completed
	Quantify surface and subsurface DOC and N loads to drains under different hydrologic regimes and identify area contributing subsurface flows to drains.	Completed. For Bouldin unable to directly quantify subsurface loads for New Rice Study Plots in 2005. Assessed data using 2004 data for study plots and using 2004/5 data for other treatments.
Chapter 7. Assessing the feasibility of rice production along an east-west gradient in the Delta.		
	Productivity measurements and economic analyses for rice grown at three locations along an easterly gradient to identify areas in the Delta rice can be implemented as a feasible crop with hydrologic management practices to minimize the export of nutrients	Northwesterly to southeasterly gradient.
Evaluation for measuring project management performance (Scope, schedule, budget)		
Chapter 6. Comparing wildlife usage of rice fields with corn.		
	Wildlife surveys of converted rice fields and comparison to area corn and managed wetlands.	Completed
Chapter 8. Project management performance evaluation for the Delta rice project.		
	Evaluation of following the schedule as outlined in the original SOW.	Completed
	Evaluation of compliance with the original SOW.	Completed
	Document identifying farmers participating in project.	Completed
	Conversion document including maps describing rice field conversion.	Completed
	Photo documentation showing one season of rice production in the Delta for converted fields.	Completed
	Implementation plan including maps showing experimental plot implementation.	Completed
	Outlines for eight workshops and list of participants.	One-on-one workshops with farmers not always have formal outline.

5 Processes and Factors Affecting Carbon and Nitrogen Concentrations and Loads

5.1 Introduction

The Sacramento – San Joaquin Delta is the hub of California's water supply system. Drinking water for over 22 million Californians flows through the Delta channels from water-rich northern California to water-poor southern California. Sacramento-San Joaquin Delta waters are impacted by organic carbon and nutrients (primarily nitrogen) discharged in drainage waters from agricultural lands.

High concentrations of dissolved organic carbon (DOC) in Delta export waters can be problematic due to formation of disinfection byproducts (DBPs) such as trihalomethanes (THMs) upon chlorine addition. Amy et al (1990) estimated that agricultural drainage from delta island organic soils contribute 20 % of the THM formation potential (THMFP) at Delta export pumps. Understanding the factors and processes contributing to DOC and THMFP on delta islands is pivotal to developing management strategies to minimize the THMFP in exported drinking water.

Previous investigations elucidated processes affecting DOC and THMFP in soil, groundwater and drainage water. Fujii et al. (1998) reported on the concentrations and nature of DOC in relation to THMFP on Twitchell Island. Their work illustrated the influence of spatially varying organic soil conditions and decomposition on DOC and THMFP. Aromatic compounds, which are generally considered the primary THM precursors were higher in the deeper, saturated, anoxic deposits relative to the shallow, variably saturated, oxidized deposits. Fleck et al (2004) evaluated the effects of soil chemical and management differences among different areas on Twitchell Island. They found higher DOC concentrations associated with more recently cultivated and higher organic-matter soils.

In a study of carbon fluxes on three delta islands (Jersey, Sherman and Orwood Tract), Deverel and Rojstaczer (1996) reported the highest DOC concentrations in drainage water from poorly drained Jersey Island. The Jersey Island DOC was predominantly acidic and hydrophilic. In contrast, DOC concentrations were lower and more hydrophobic on two well drained islands. California Department of Water Resources (DWR) (1997) data consistently shows the highest DOC concentrations in Delta channels during high flows in winter and early spring. Also, Deverel and Rojstaczer (1996) showed high drainage concentrations and loads associated with groundwater level highs in winter and early spring.

Dissolved organic carbon from soil organic matter is a mixture of organic compounds whose reactivity to form DBP's depends on land- and water-management practices and biogeochemical, hydrologic and soil forming processes. The predominant Delta crops (primarily corn and other field and vegetable crops) require aerated root zones and continuous drainage through networks of drainage ditches and pumping of drainage water to Delta channels. Root zone aeration results

in biochemical oxidation of the soil organic matter, which results in DOC production and subsidence. DOC produced during the spring, summer and fall is mobilized by flooding of Delta islands during the winter and early spring which results in large island drainage-water DOC loads and increased DOC concentrations in Delta channel waters.

While various physical and chemical variables have been found responsible for controlling DOC formation and release in the laboratory (Kalbitz *et al*., 2000; Aguillar and Thibodeaux, 2005; Moore and Dalva, 2001; Moore, 1998; Christ and David, 1996), hydrology has consistently been shown to be the dominant control on DOC formation, release, and export under field conditions (Kalbitz *et al*., 2000; Hope *et al*., 1994; Urban *et al.*, 1989; Hogg *et al.*, 1992) and field-based experiments are suggested (McDowell, 2003). At the outset of the study, we hypothesized that by reducing hydraulic gradients between water on the field and water in adjacent drains (Figure 1), subsurface seepage will be reduced (Hillel, 1998) and in conjunction with good water management (Doorenbos, 1979; DeDatta and Williams, 1968; Herdt and Wickham, 1984; Kandiah, 1985), exports of DOC would be reduced thereby improving water quality at the source.

Nitrogen is large component of organic soils and there is evidence that nitrogen is discharged to Delta channels in agricultural drainage. Application of N may also lead to the export of other nutrients and exacerbate export of dissolved organic carbon (DOC). Nitrogen enrichment in Delta channel waters leads to greater algal blooms, which cause increases in DOC, dissolved oxygen (DO) depletion, and taste and odor problems. For example, data for the DWR Municipal Water Quality Investigations monitoring station at the Banks pumping plant indicate titrate concentrations are in the 2 to 3 mg-N L^{-1} range, with highs in the range of 5 to 8 mg-N L^{-1}.

Higher hydraulic gradients resulting from continued subsidence will increase seepage onto Delta islands and increase the need for drainage. Together with delta water supply and water quality concerns, these issues necessitate better understanding of processes affecting nitrogen, DOC and disinfection byproduct formation in Delta channel water and related agricultural drainage effects especially as related to growing rice in the Delta. Rice is a relatively new crop in the Delta and there is a need to quantify loads for DOC, DBP's and nitrogen.

There is evidence that growing rice can benefit the Delta by:

1. Offering the opportunity to minimize export of high DOC drainage water through recycling or holding irrigation waters on the islands,
2. Stopping oxidation of organic soils,
3. Reducing nitrogen exports to Delta channels by minimizing export of drainage water and through recycling and holding irrigation water on islands.
4. Reducing oxidation of organic soils and DOC production during spring, summer and fall which can benefit Delta water quality by minimizing winter DOC export from Delta islands.
5. Providing ecosystem restoration benefits to waterfowl and,
6. Enabling growers a more profitable crop option to corn

Available data indicate rice may stop and reverse the effects of subsidence in Delta organic soils. Subsidence in the Delta is primarily results from a net soil carbon loss. More carbon is lost due to oxidation of peat than is gained from crop residues. USGS research shows the carbon loss increases with temperature. There is no data for the effects of rice growing on subsidence. However, data from Twitchell Island experimental plots indicates that hydrologic management similar to that for rice may stop subsidence.

Specifically, Miller and others (2000)[1] compared different water management regimes, permanently, seasonally and reverse flooded. The reverse flooded treatment was intentionally flooded to about 30 cm from early spring to midsummer to simulate brood habitat for waterfowl, and is subject to seasonal conditions from August until March. Rice flooding would probably keep the soils flooded for longer periods of time than the reverse flooding treatment. Analysis of the reverse flooding data indicates carbon inputs were about equal to carbon losses indicating a potential for stopping subsidence.

During the conduct of this study, we attempted to answer the following questions:

1. What are the concentrations of key constituents of concern (COC) (NO_3, NH_4, DOC, THMFP and TDS) surface and subsurface drainage waters from rice plots under different land and water management practices?
2. What are the surface and subsurface COC loads and how do they vary in time and under varying land- and water-management practices?
3. What are the factors and processes affecting variations in loads?
4. How can COC loads from rice fields be minimized?

We collected data on two islands, Bouldin Island in the central Delta and Wright-Elmwood Tract in the southeastern Delta (Figure 5.1). These islands have different land and water management practices and soil characteristics. During 2004 to 2005, we collected physical data for drain flow, groundwater levels. We collected and analyzed water samples from wells, surface outlets, irrigation water and drainage ditches for inorganic and organic constituents. We integrated and analyzed the data to develop an understanding of processes resulting in the observed variability in COC concentrations and loads and to answer the four questions posed above.

In the following sections we present field and laboratory methods; summarize concentration data for surface water, drain water samples and groundwater samples and for soil samples; present and discuss carbon, DBP and nitrogen load data; and present reasons for variation in loads.

[1] Hydrologic Treatments Affect Gaseous Carbon Loss From Organic Soils, Twitchell Island, California, October 1995–December 1997, USGS Water Resources Investigations Report 00-4042

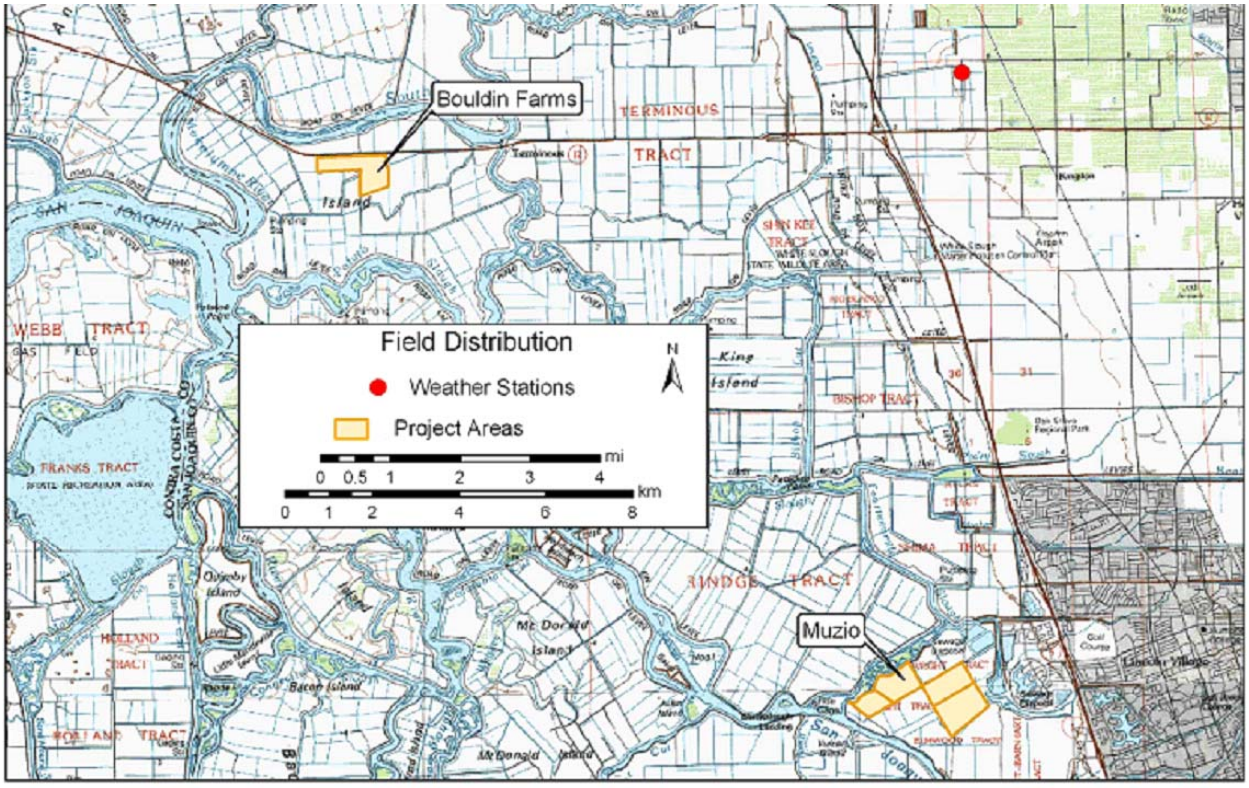


Figure 5-1. Locations of Bouldin Farms on Bouldin Island and Muzio Farm on Wright-Elmwood Tract.

5.2 Methods

5.2.1 Field Descriptions, Water Management and Study Plot Designs

The Bouldin Farms study site is located on Bouldin Island (38.104 °N, 121.534 °W) in San Joaquin County approximately 15 miles east of Rio Vista, CA, just south of Highway 12, near the northern edge of the Sacramento-San Joaquin River Delta. The island is bordered by the South Mokelumne River to the north, Mokelumne River to the west (where it joins the San Joaquin River), and Potato Slough to the south and east. Six treatment areas, totaling slightly less than 170 acres, were developed and included two new rice fields under high drain management, two new rice fields under low drain management, a rice field that was planted to rice during 2003 under low drain management, and a cornfield under low drain management. The predominant soils are the high organic matter (10-55% organic matter) Rindge mucky silt loam, muck. These are classified as Euic, thermic Typic Medisaprists (US Department of Agriculture, 1992). Water from the nearby San Joaquin River is siphoned on the fields through a network of inflow ditches, exits the fields as surface and/or subsurface flows, and is returned to the river through a network of drainage ditches.

The Muzio Farm study site is located on Wright-Elmwood Tract (38.0 °N, 121.35 °W) in San Joaquin County, approximately 15 miles west of Stockton, CA. The Wright-Elmwood Tract is bordered by the San Joaquin River to the south-southwest and Fourteen Mile Slough to the north-northwest. Four treatment areas were established totaling just less than 33 acres as follows: an existing corn field under low drain management, a new rice field under low drain management, a new rice field under high drain management, with a new rice field as a buffer/spacer between the two (high and low) drain treatments. The predominant soil is the Kingile (muck), a clayey, mixed, euic, thermic Terric Medisaprist (35-45% organic matter). Other soils include a large proportion of Peltier (mucky clay loam, 10-25% OM), and some Egbert (silty clay loam, sandy substratum, 2-10% OM), which are both fine, mixed, thermic Cumulic Haplaquolls.

Water management for rice is generally similar for both Bouldin Farm on Bouldin Island and Muzio Farm on Wright-Elmwood Tract and differs seasonally. On both farms during the summer, water for flooding of rice fields is siphoned into ditches for distribution to the individual fields. Water is distributed to the fields from ditches via flash board risers. For our study plots, we denoted these as the surface-water input (SWI) measurement locations (Figures 5-2 and 5-3). Ponded water on rice fields (paddies) flows to surface-water outflow measurement sites which were also flashboard risers. These were denoted as SWO sites. Water from the rice fields also seeps through the subsurface to drainage ditches where it flows to main collector drainage ditches and from these pumped from the island to adjacent channels. We measured flow in drainage ditches that were immediately downstream of the specific treatment fields described below. These were denoted as DDO sites.

During the fall, the sites are drained for rice harvesting. During draining, all ditches are operated very low to dry out the fields sufficiently for harvesting. Ponds are re-flooded in the winter for waterfowl, with minimal or no surface water runoff. Ponds are again drained for bed preparation for seeding.

The seasonal differences in water management are reflected in the seasonal differences in loading that are discussed later in this chapter.

There are some differences in the design of the sites that affect irrigation implementation. At Bouldin Island, several hundred of acres and several different fields are fed from a central irrigation ditch that gets the water from a single siphon. The supply ditch for the converted rice fields received a slip stream of water over a rectangular weir from that central irrigation ditch. Water flows down the supply ditch and inlets along the north-side of the ditch feed the rice fields in parallel (Figure 5-2). In 2004, pipes on the northern side of the ditch provided irrigation water to the converted rice fields. In 2005, weirs were added. Additionally in 2005, the supply ditch for the rice fields for this study also was used to supply the rice fields on the southern side of the ditch, requiring the installation of four more weirs on the southern side of the ditch.

For the converted rice fields at Wright-Elmwood Tract, a siphon provided water only to the rice fields and no other fields. Water flowed in serial through the fields requiring only two weirs off the supply ditch (Figure 5-3).

Figures 5.2 and 5.3 show the experimental plots in greater detail. These different treatments are summarized in Table 5-1. Experimental codes for the different treatments and hydrologic structures are shown in Table 5-1.

Table 5-1. Experimental Design for investigating land use and hydrologic treatments.

Farm/Plot	Treatment				
	Land Use			Drainage	
	Rice		Corn		
	New	Established		Low	High
Bouldin Island					
Plot/Area 1	X				X
Plot/Area 2	X			X	
Plot/Area 3		X		X	
Plot/Area 4			X	X	
Wright-Elmwood Tract					
Plot/Area 1	X				X
Plot/Area 2	X			X	
Plot/Area 3			X	X	

Table 5-2. Treatment Code Summary for Rice Project

Treatment Code	Treatment Description	Field Subcodes as applicable	General Description
Treatment Codes			
Bouldin Island			
NRH	New Rice High		Fields and Drains associated with high drain management
		NRH1	Western field associated with high drain.
		NRH2	Eastern field associated with high drain.
NRL	New Rice Low		Fields and Drains associated with low drain management
		NRL1	Western field associated with low drain.
		NRL2	Eastern field associated with low drain.
OR	Old Rice		One field with rice established before project commencement and associated drain
CORN	Corn		One field with corn at project commencement and associated drain
Wright-Elmwood Tract			
NRH	New Rice High		Fields and Drains associated with high drain management
NRL	New Rice Low		Fields and Drains associated with low drain management
NRM	New Rice Mid		Middle Field between both treatments. Shares High and Low drains with NRH and NRL respectively
Structure Codes			
DDO	Drainage Ditch Outflow		Outflow typically over weir from drain ditches
SWO	Surface Water Outflow		Surface water outflow from field
SWI	Surface water inflow		Surface water inflow to field.

On both islands, rice was dry seeded and fields were flooded as soon as seedlings were approximately 6" high. Fields were drained by the end of September and harvested as soon as fields were dry enough to safely drive farm equipment on them. Post-harvest, fields were re-flooded by December. Prior to the following growing season fields were drained (around late March). An unusually wet fall in 2004 prevented harvest until mid-late October, and likewise an unusually wet spring in 2005 prevented planting until mid-May. Water sampling began as soon as possible after flooding each growing season and during the winter.

We attempted to improve water management at both farms for summer 2005. Specially designed water control structures were added at inflow and outflow locations established on Wright-Elmwood Tract in order to allow a greater control. We obtained positive feedback from the farmer on their use. At Bouldin Island, flashboard risers identical to those at outflow locations were installed at all inflow locations for all fields. Previous inflow locations supplied water via shallow ditches and/or pipes with no way to carefully regulate flow rates. Changes made at both farms were intended to facilitate on-farm water management and improve farm water-use efficiency. At Bouldin Island, we were not able to achieve improved supply water control during 2005 due to increased demand on the water supply ditch for the experimental plots. We achieved greater water supply and outflow control at Wright-Elmwood Tract during 2005. Specifically, we added control structures to the flashboard risers to allow the grower to adjust inflows to more precisely meter water onto the fields. Additionally, we used ET estimates and seepage estimates to estimate water demand. We estimated seepage based on data from Twitchell Island for permanently flooded wetlands from Gamble and others (2003).

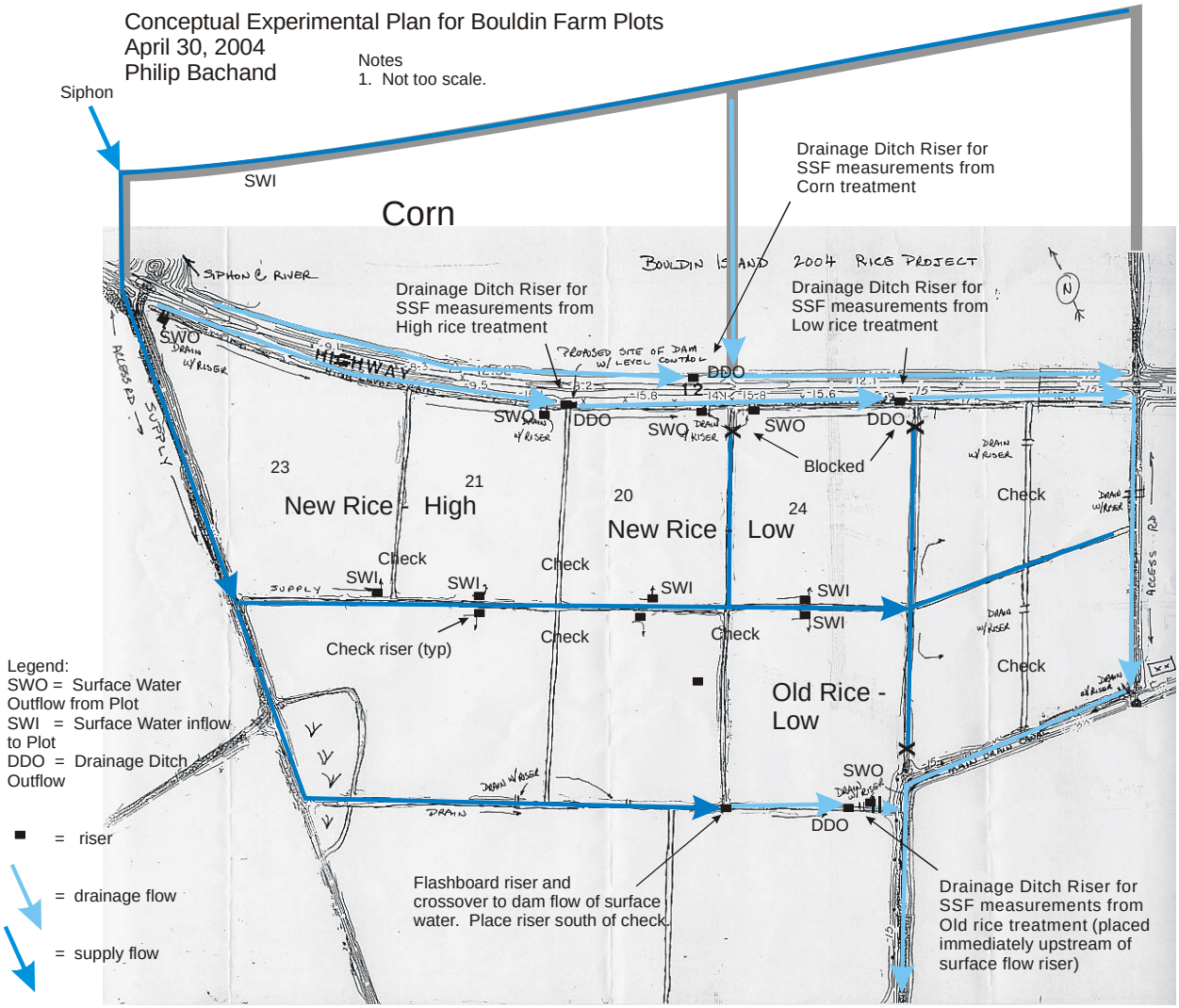


Figure 5-2. Experimental plots at Bouldin Farms on Bouldin Island.

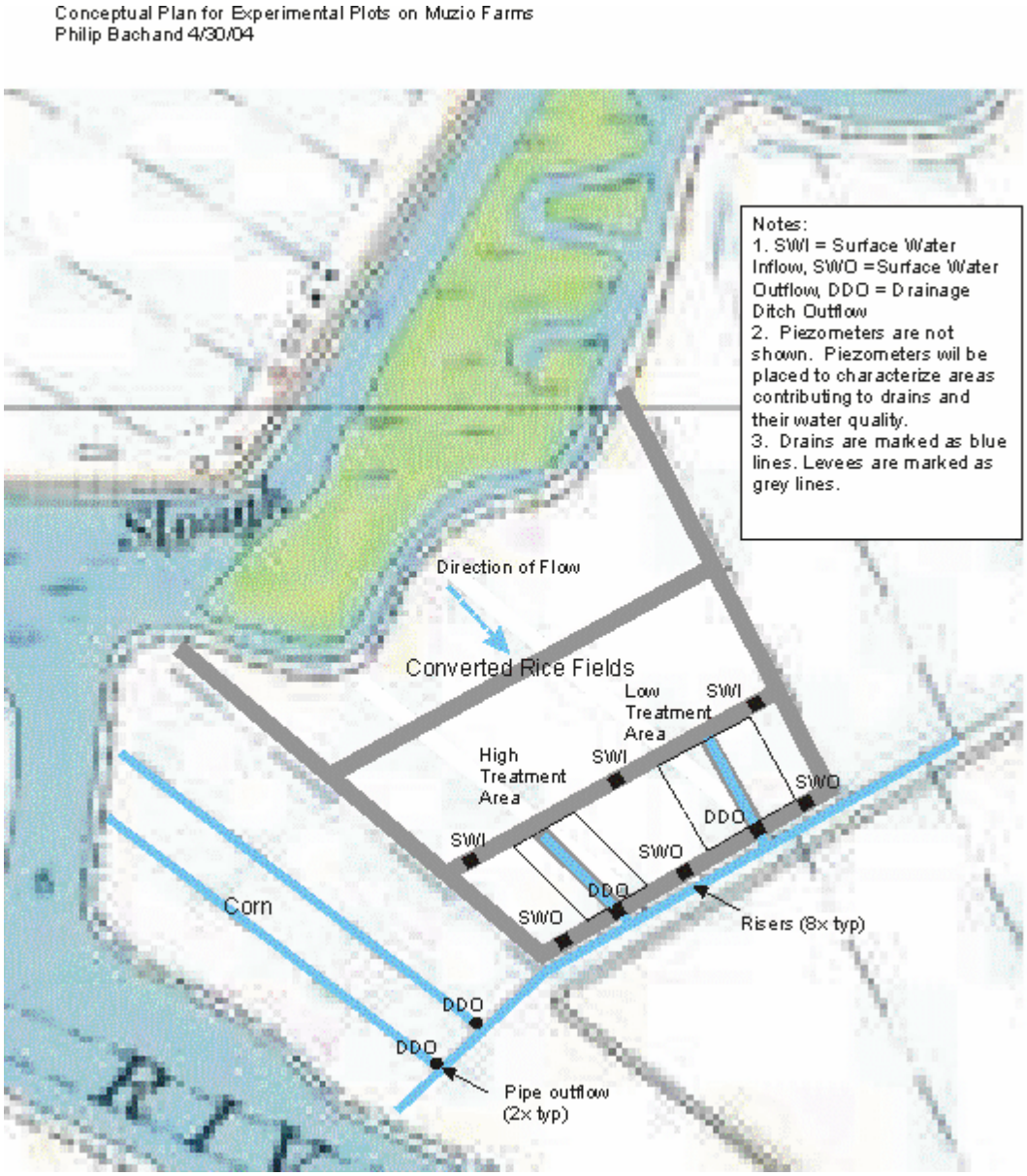


Figure 5-3. Experimental plots at Wright-Elmwood Tract.

5.2.2 Field methods and Sample Processing

5.2.2.1 Monitoring Installations

To allow monitoring of irrigation water, subsurface drain flow and surface runoff and groundwater levels of field plots, we installed piezometers, flash board risers and pressure transducers. In 2004, we installed weirs in subsurface drainage ditches to measure and restrict flow. Surface water outflows were measured over boards in the flash board risers. Risers and pipes were installed at the inflows of the experimental plots to control the water level of the supply ditches feeding the experimental plots. Within each field, we evaluated flow in and to agricultural drains with manual measurements of flow with velocity meters, buckets and stop watches as frequent as every other week during the growing season and while water was present in the drains and less frequently during the remainder of the year. We also used standard equations calibrated against bucket measurements to estimate flow over weirs. For the corn fields, we measured subsurface drain flow at weirs installed in drainage ditches.

The experimental rice plots were bordered and traversed by agricultural field drainage ditches that we monitored for flow and water quality to determine flow volumes and TMFP and DOC loads in drainage water. We continuously monitored flow stage into and from fields and from the drainage ditches with pressure transducers. We also installed pressure transducers in selected wells to monitor groundwater-level changes. We used monitoring-well clusters in the field and adjacent to the drainage ditches to evaluate groundwater flow to the drainage ditches.

Monitoring wells were installed by hand using augers. In spring 2004, we installed 1.25 inch PVC wells to about 4 feet and 6 feet in four-inch diameter boreholes. Boreholes were backfilled with sand adjacent to and about 1 foot above the 2.5-foot screens and bentonite grout from the sand to near land surface. The wells were designed to decouple about 1 foot below land surface so that they could be capped and buried to allow for harvesting and field preparation. Selected wells were unburied and risers were reinstalled in spring 2005. We selected and unburied wells in 2005 where transducers were placed during 2004.

5.2.2.2 Water and soil sampling and flow measurements

We collected water samples at each inflow, outflow, and drain site in labeled 1.0 L amber glass bottles which we stored on ice until return to the laboratory. Electrical conductivity (EC) and pH were measured using a YSI Model 63/25 FT pH, salinity, conductivity, and temperature meter at each sample location every time samples were collected. Dissolved oxygen (DO) measurements were also obtained at each location during each sampling event using a YSI Model 55/25 FT DO meter. All field instruments were calibrated at the start of each sampling day using standardized solutions, and calibrations were checked for accuracy at the mid-point and finish of each day. Upon return to University of California, Davis, samples were immediately filtered through stacked 0.45 and 0.60 µm glass fiber filters that were first combusted at 500˚C (initial post-combustion mass recorded). Filters were then dried at 103˚C for total suspended solids (TSS), then combusted again at 500˚C and re-massed to determine particulate organic carbon (POC).

The filtrate was then acidified to pH <2 by adding 2 drops of 1:1 DI:H_2SO_4 to ~40 mL of sample, and refrigerated at 4˚C until needed for analysis.
Additionally, flows were measured at each hydrologic structure during each sampling event (Figures 5.2 and 5.3). Flows were estimated at each weir location using standard V-notch and rectangular weir equations (Cameron Hydraulic Data, 2002). At all locations where it was possible, flow rates were determined filling a bucket of known volume and measuring time. At all stations, the height over the weir, the pressure transducer elevation data converted to ft-NAVD, and the water elevation as shown on a gauge plate were measured. Standard weir equations were calibrated against flow measurements and these equations were then used to estimate flow at all stations when critical flow existed. These estimated flows are used in the database for all hydrologic and water quality parameter load estimates and budgets.
During 2004, velocity measurements were also taken using a Marsh-McBirney FloMate Model 2000 Portable Flowmeter. Under non-critical flow conditions it was used to estimate flow rates. Under this approach, the dimensions of the cross-sectional area of flow were measured and recorded, then later multiplied by average velocity to obtain flow rate in cubic feet per second (cfs) which was then converted to liters per second in the database.

For bucket measurements, the average time required to fill a bucket was multiplied by the bucket volume in order to obtain flow rate in cubic feet per second. Due to difficulty with water management and obtaining accurate flow measurements, water control inserts were constructed for use during the second summer of sampling (2005) for use at Wright-Elwood Tract. Improvements to water management at Bouldin Island included adding weir structures at the inflow locations at all fields during the summer 2005.

Identification information for each sample was recorded on the field data sheets when the sample was collected. To prevent contamination of the sample from sample container, sampling containers were washed with dilute Liquid-Nox soap and rinsed with copious amounts of organic carbon free water then followed with an acid wash.

Water samples were collected from pipes or risers at the surface water inflow and outflow of the studied plots, from the inflow and outflow of the drainage ditches, and from piezometers. When necessary to wade into the water, the sample collector sampled downstream of the sample location. DO, EC, pH and Temperature were measured at the same locations using field instruments calibrated twice at each field location. All sampling equipment was rinsed with carbon-free deionized water between sampling locations. Approximately 1,000 ml was collected from each sample location in amber glass bottles, stored immediately on ice and taken to the lab for processing and transfer. The Chain of Custody (COC) was stored in a Ziploc bag and packed within the ice chest during transport. Water samples were transferred from UCD to the USGS for THMFP and optical analyses and to DANR for analyses of major ions and cations. When samples are transferred from one organization to another, a Chain of Custody form was used.

We collected soil samples in October 2004 at no less than 5 sample locations per field. At each sample location there was one central intensive sampling point, and four non-intensive sampling points located at random points radially outward from the central sampling point. Intensive sampling refers to a discrete location for analysis of bulk density (D_b) and total carbon and total nitrogen (TC/TN). Non-intensive sampling consists of composite samples from the same

horizons (similar depths) in the four non-intensive sampling points. Soil samples were collected using a 2cm diameter stainless steel AMS (McCauley) soil probe designed to collect samples at 30cm increments. The 30cm cores were then removed through a slot on the side of the probe, separated by horizon, and stored in Ziploc bags. Samples were collected at 0-15, 15-30, and 30-60cm increments for both intensive and non-intensive sampling. Samples at 60-90, and 90-200cm were also obtained when possible at intensive sampling points.

Bulk density was determined using a specially designed probe 4.4cm in diameter and 15cm deep, and was collected at 0-15, 15-30, 30-45, and 45-60cm intervals at the central intensive sampling point and stored in Ziploc bags. Each sample was labeled with depth, date, time, and type of sample, and boring logs were kept for all intensive soil pits recording depth to water table, soil/peat name or type, color, odor, soil structure, and additional comments. Upon arrival at UCD, the soils were then dried at <50˚C (to prevent loss of carbon) for 4-6 days. Samples were immediately placed in the ovens on arrival at UCD to prevent soil microbes from mineralizing soil organic matter (SOM) that can lead to less accurate TN results. Note that NH_4^+-N is only a minute fraction of TN and its volatilization during the drying process may not significantly affect the TN results. After bulk density samples were dried, final mass was recorded and bulk density calculated. All other soil samples were ground in metal canisters containing 5/8 inch diameter stainless steel balls until the soil could easily pass through a 100-140 μm mesh sieve, and a 5-10mg sub-sample was massed in foil tins and analyzed on the Carlo Erba for TC/TN.

Pressure transducers were deployed at all drain flow measurement locations and at most surface water inflow and outflow locations from fields such that flows could be calculated and hydrologic budgets calculated for the fields and the drains. Pressure transducers were also installed in a subset of deep and shallow well locations. All pressure transducers were standardized against NAVD elevations by surveying in the well casings and staff gauges used for calibrating the pressure transducers. Weir, staff gauge, pressure transducer and staff gauge locations are shown in Figures 5-4 and 5-5.

5.2.2.3 Filtration, Splitting and Preservation

Samples were processed in the UCD lab with 24 hours of collection. Samples were filtered, treated and transferred in aliquots to the appropriate lab for analysis. All glass bottles were shaken before splitting the sample in order to homogenize the sample. Aliquot size and allocation was dependent upon sample size and method of analysis. Part of the sample filtrate was preserved through acidification and further analyzed for ammonia, nitrate/nitrite, DON, major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+), major anions (SO_4^{2-}, Cl^-, CO_3^{2-}) and DOC quality. All aliquots were refrigerated in the dark at 4°C until analysis. Table 5-3 describes sample preservation and containers.

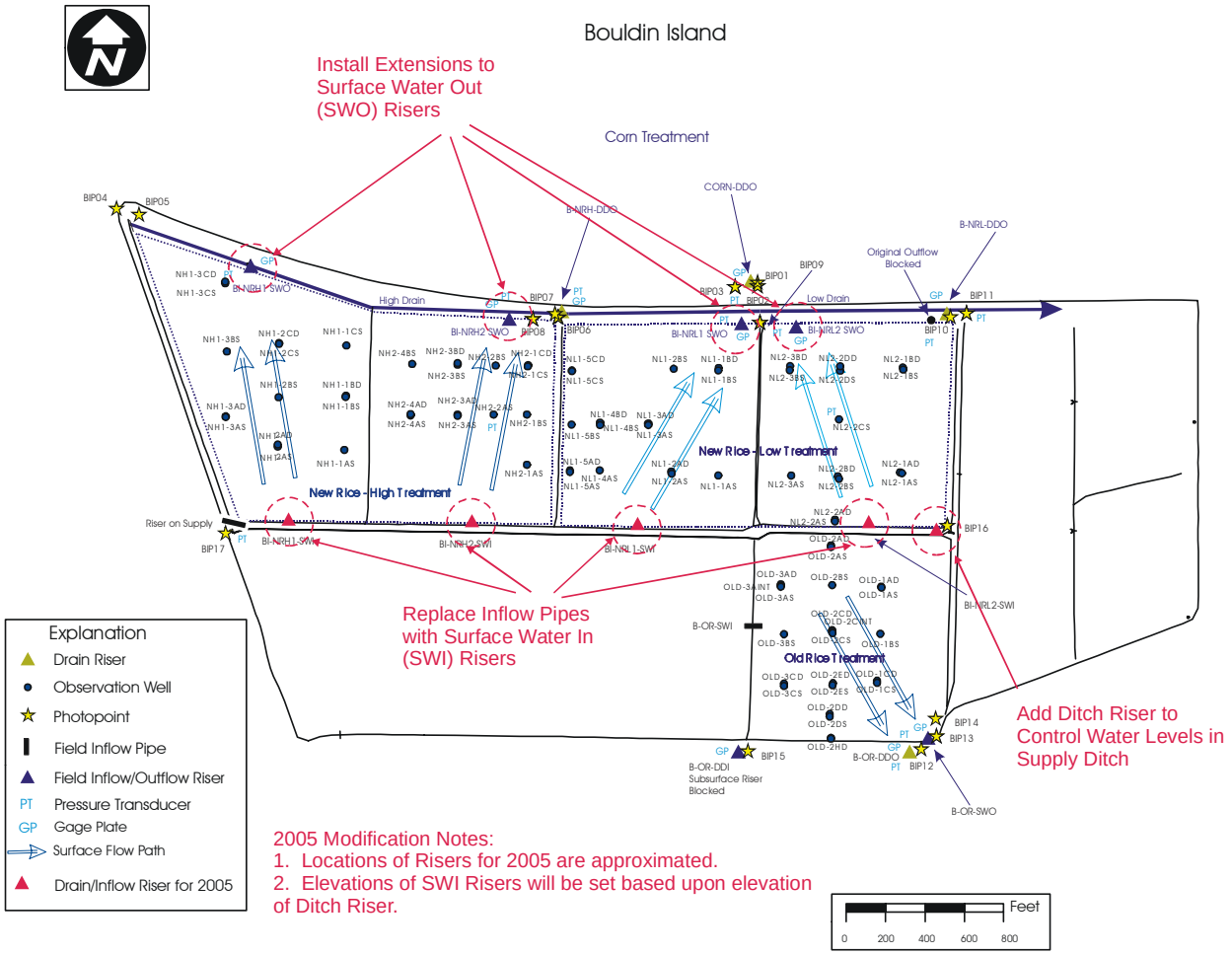


Figure 5-4. Modifications implemented for 2005 to improve water management at Bouldin Island experimental plots.

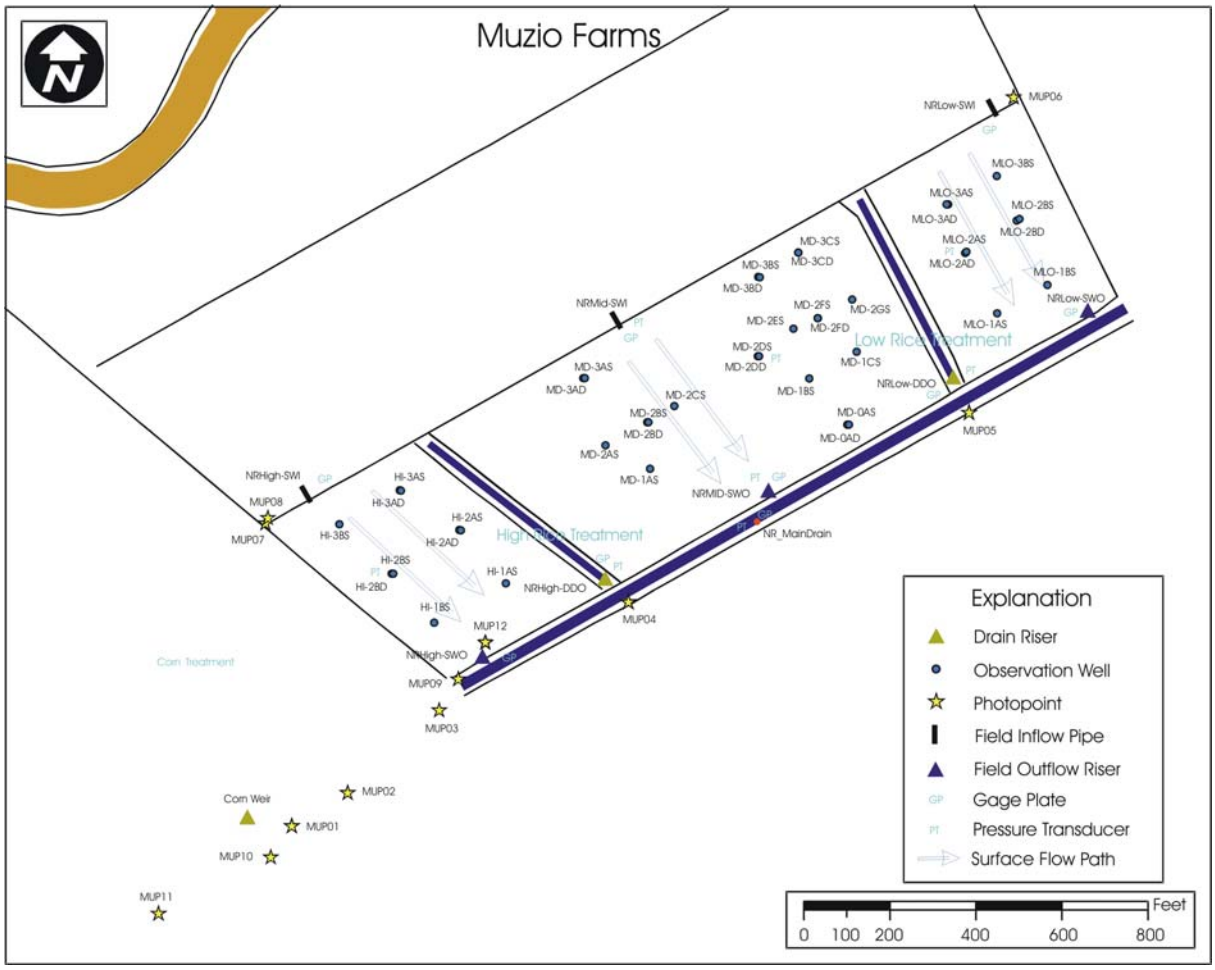


Figure 5-5. Monitoring locations at Wright-Elmwood Tract.

Table 5-3. Water Sample Handling and Preservation

Determination	Container	Minimum Sample Size(mL)	Preservation	Maximum Storage
Water				
DOC	G	5	analyze immediately	7 d
POC				
CO_3^-				
TSS				
NH4+	P,G	5	f,a*,r	28 d
NO3-/NO2-	P,G	5	f,a*,r	28 d
DON	P,G	50	f,a*,r	28 d
Major cations: Ca^{2+}, Mg^{2+}, Na^+, K^+ (dissolved)	G	10	f,a**,r	28 d
Major Anions:SO_4^{2-}, Cl^-	G	10	f,r	28 d
Isotopes	G	100	NA	NA
THMFP	G	100	analyze immediately	7 d
DOC quality (UVA, flourescence)	G	25	f,a,r	7 d
Soil				
TN				
TC				

* sulfuric acid

**1:1 nitric acid

f= filtered, a= acidified, r= refrigerated

The USGS supplied baked 250 mL amber glass bottles for an aliquot for THM and optical analyses. The aliquot for THM was filled to the top with no headspace and no preservation, and put on ice. These samples were transported to the USGS lab with chain of custody (COC) and results of DOC analysis. Within 7 days from time of collection, the USGS dosed the samples for THM formation.

5.2.3 Analytical Methods

Analytical methods included both field measurement of water quality parameters. Table 5-4 details the methods. We used standard methods where possible. Methods to characterize organic carbon quality are from peer review journals or developed by the USGS. Details on methods used by the UCD laboratory are described in the QAPP and briefly described here. After sample filtration as described above, the acidified filtrate was then used to determine dissolved organic carbon (DOC), nitrate (NO_3^-), and ammonium (NH_4^+), using methods described by EPA Standard Methods for the Examination of Water and Wastewater, 20th Edition. Samples used for determining total dissolved nitrogen (TDN) must remain unacidified and therefore samples were digested as soon as possible, usually the following day, and analyzed for NO_3^- as soon as possible thereafter on the Lachat Quickchem 8000 auto-analyzer. $NO_3^-$was similarly run on the Lachat. DOC was measured on a Dohrmann Model Phoenix 8000, UV-Persulfate TOC Analyzer. NH_4^+ was determined by standard methods.

Water samples were collected from wells in September 2004 and sent out to the DANR Laboratory on UCD campus for analysis of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{-}, Cl^{-}) and were subject to similar QAQC standards.

5.2.4 Quality Assurance

Quality assurance procedures were described in detail in the QAPP and are briefly described here. Quality Assurance/Quality Control (QAQC) procedures developed for this project specifies a minimum holding time for samples prior to analysis, and are fully outlined in the project Quality Assurance Procedure Plan (QAPP). Internal and external standards were included with every analysis and were required to fall within +/- 10% of expected values for data to be accepted. Field and laboratory duplicates also were required to fall within +/- 10% of one another. DOC was also determined at a USGS laboratory and used for interlaboratory comparison. The project required the lab at UCD complete the Environmental Laboratory Accreditation Program (ELAP) for analysis of DOC and NO_3^{-}. All requirements for ELAP certification were met, including onsite inspection of facilities and performance evaluation tests run by an independent laboratory, and our lab was designated EPA lab number: CA 01514. All required QA samples were collected and all samples were analyzed within the required hold times.

Table 5-4. Analytical Methods

Analyte/Procedure	Organization[2]	Units	Method of Analysis	Digestion	Color Determination
Lab Analyses - Water					
DOC	UCD	µg/L	Standard Methods 5310-C, Phoenix 8000 (Teledyne-Tekmar, Mason, OH)	Persulfate	NA
POC	UCD	µg/L	Mass Loss on High Temp Combustion	Persulfate	NA
Nitrate + Nitrite	UCD	mg N/L	Standard Methods 4500-NO3- I, Flow Injection Analysis Colorimetry, QuikChem Method 10-107-04-1-B	copperized cadmium reduction	sulfanilamide, magenta color sensed by flow-through detector
Ammonia	UCD	mg N/L	Salicylate method. From methods for the Chemical Analysis of Water and Wastes, March 1979, Method 351.2.	NA	salicylate
DON	UCD	mg N/L	Standard Methods, 4500-N C	Persulfate	molybdate blue
Total Nitrogen	UCD	mg N/L	Standard Methods, 4500-N C,	Persulfate	molybdate blue
Major cations: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}	DANR[1]	mg/L	ICP-AES	NA	NA
Major Anions:SO_4^{2-}, Cl^{-}, CO_3^{2-}	DANR[1]	mg/L	ICP-AES, flow injection, and titration	NA	NA
Isotopes: O-18, deuterium	UCD	del in per mil	Dave Harris, UCD isotope lab, (530) 754-7517, dharris@ucdavis.edu	NA	NA
UV/Vis scan	USGS		Modified APAH Standard Methods - 5910B	NA	NA
UVA, 254nm	USGS	1/cm	APHA Standard Methods - 5910B	NA	NA
Flourescence	USGS		Peer Reviewed Journal Articles	NA	NA
THMFP	USGS	µg/L	USGS SIR 04-5003	NA	NA
Lab Analyses - Soils					
TN/TC	UCD	mg/L	Dry combustion/GC	NA	NA
bulk density	UCD	g/cc	gravimetric	NA	NA
Field Measurements					
EC	UCD	µS/cm	CDM83 Conductivity Meter	NA	NA
pH	UCD	range	EPA 150.1	NA	NA
Temperature	UCD	deg C	EPA 170.1	NA	NA
DO	UCD	mg/L	EPA 360.1	NA	NA
Flow	HF/B&A	liters per second	pressure transducer correlated with flow over a weir or manual sampling with a bucket, stop watch and flow meter	NA	NA

Notes

1. Division of Agricultural and Natural Resources, UCD
2. UCD = UC Davis; USGS = USGS Sacramento Carbon Group; HF = Hydrofocus; B&A = Bachand & Associates

5.2.5 Data analysis methods

All data was managed in an ACCESS database. With the database we were able to calculate loading of different parameters using measured analyte concentrations and calculated flow rates. Flow rates were calculated using standard rectangular and V-notch weir equations with the equation constants calibrated against bucket measurements made at selected locations at Bouldin Island and Wright-Elmwood Tract where bucket measurements of flow were possible. We developed hydrologic and mass budgets for the fields and drains based on calculated load data into and from the fields and the drains, and utilizing evapotranspiration data from CIMIS stations in Lodi and on Twitchell Island. We statistically analyzed flow, load and concentration data using MINITAB and Statistica statistical software packages and EXCEL, MINITAB and Statistica for regression analysis. We displayed data for locations, treatments and for different time periods using box plots. To determine statistical differences among treatments and locations, we used non-parametric comparisons. This included the use of the Kruskal-Wallis test to determine differences among more than two populations and the Mann-Whitney (Wilcoxon Rank Sum) test for comparison of two populations. Non-parametric tests were used on water quality and load data because the data did not meet the requirements for parametric tests (ANOVA and t-test) of equal variance and normal populations. When discussing significance, the 95% level is always implied unless otherwise stated.

5.3 Results

5.3.1 Flow Estimates

Flow for each location was estimated using standard weir equations for v-notch weirs and rectangular weirs, with constants calculated from data for this project. Where bucket measurements could be made, these measurements of flow were related to the height over the weir.

Table 5-5 show the constants calculated for this project and the correlation coefficients for both. For the range of heights for which flow were calculated, these estimates accounted for about 85 to 95% of the variance, depending upon the type of weir for which the constant was calculated. Figure 5-6 shows that estimated flows were nearly always within 25% of the actual flows for the calibration range of heights over the weir less then 2.8 inches. Rectangular weir calculations were slightly better, with estimated flows being within around 15% of the measured flows for a calibration range of heights over the weir less then 2.3 inches.

The constants calculated from this study were slightly different then published constants (Table 5-5, Ingersoll-Rand, 1981). For the rectangular weir, the calculated constant from this study was within 5% of the published constant. However, for the v-notch weir, the calculated constant was about 20% higher then the published constant, 2.91 versus 2.44 (Ingersol-Rand).

Table 5-5. Calibration Constants Developed for Weir Estimates of Flow

Weir	Constant Calculated	Typical Constant[1]	R^2	Height Range (in)[2]
90 deg V-notch	2.90	2.44	0.8587	0 - 2.8
Rectangular	3.21	3.33	0.9394	0 - 2.3

[1]Published constants (Ingersol-Rand, 1981)

[2]Height ranges used for which bucket measurements of flow were taken.

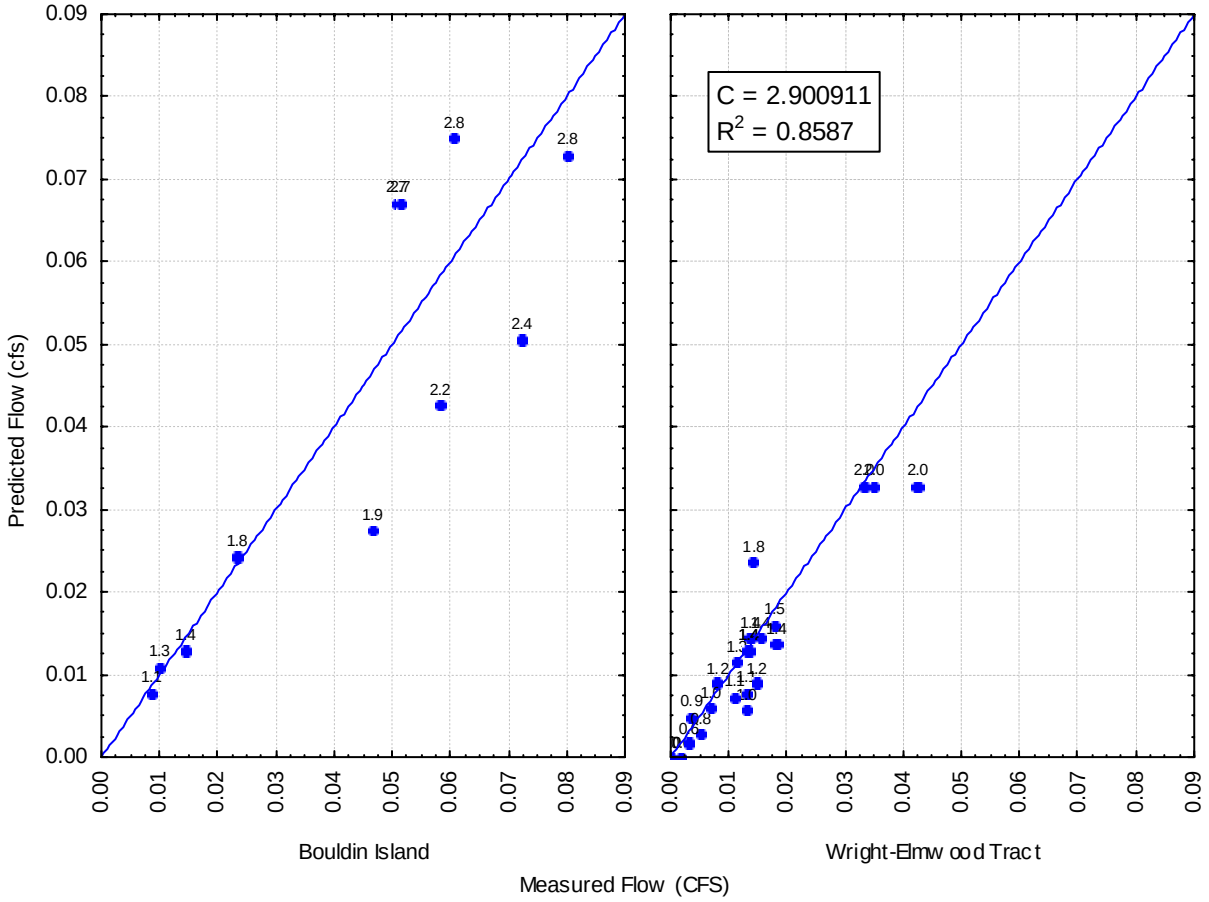


Figure 5-6. Predicting Flow across a V-notch Weir

Label values are corresponding heights over the weirs (inches).

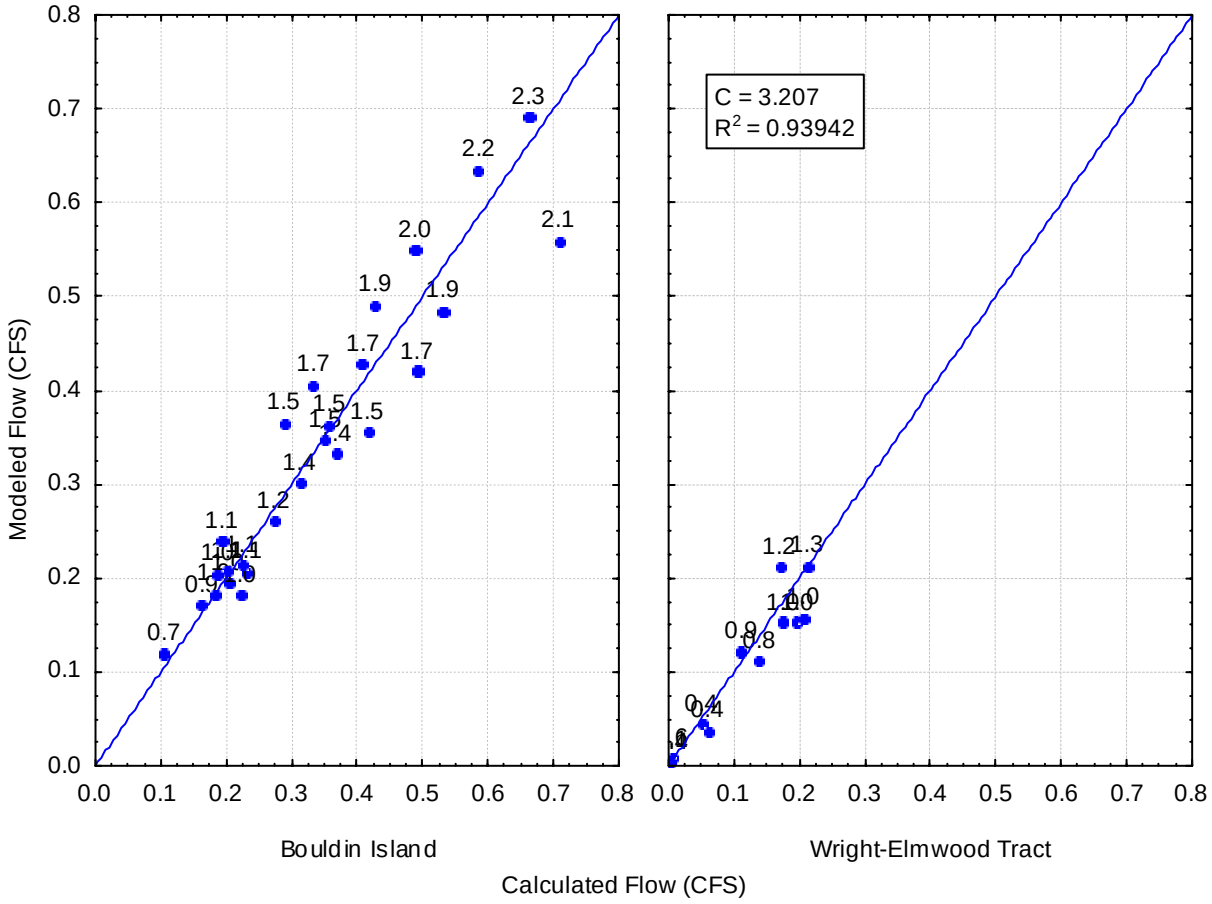


Figure 5-7. Predicting Flow across a Rectangular Weir

Label values are corresponding heights over the weirs (inches).

5.3.2 Hydrologic Budgets and Relationships

5.3.2.1 Surface Water Hydrologic Budgets

Table 5-6 summarizes the hydrologic budgets calculated at both Bouldin Island and Wright-Elmwood Tract with means and standard deviations calculated by treatment, season and year using casewise deletion. The contribution of subsurface flow to the fields as a hydraulic loading rate (in/d) was calculated with a mass budget that included measured inflow, outflow and precipitation, and estimated ETO rates using local CIMIS stations at Lodi and at Twitchell Island in combination with rice crop coefficients. Positive values of groundwater contribution may indicate that groundwater was positively contributing to the field through either exfiltration from groundwater to surface water or through providing a water source to the plants to help meet evapotranspiration needs. A negative value may indicate that surface water was being lost to

groundwater through seepage to drainage ditches. For the new rice plots at both Bouldin Island and Wright-Elmwood Tract, the median estimated contribution to groundwater is shown in Figure 5-6.

For all treatments except Bouldin Island NRH1, NRH2 and OR, the median value for groundwater contribution was negative generally indicating a loss of water to seepage. However, there is large variance in groundwater contribution numbers which points to the error in the different components of the water budget. Specifically, ET estimates can be in error by plus or minus about 15 % and outflow and inflow measurements for this study are generally within 15 % to 25% depending upon the weir used (Figures 5-6 and 5-7). The magnitudes of the median groundwater contribution estimates in Table 5-6 and Figure 5-8 are generally close to or less than 15 % of ET and inflow and outflow values. Groundwater data shown in section 5.3.5 clearly show groundwater flow towards the drainage ditches and we expect that this generally the case.

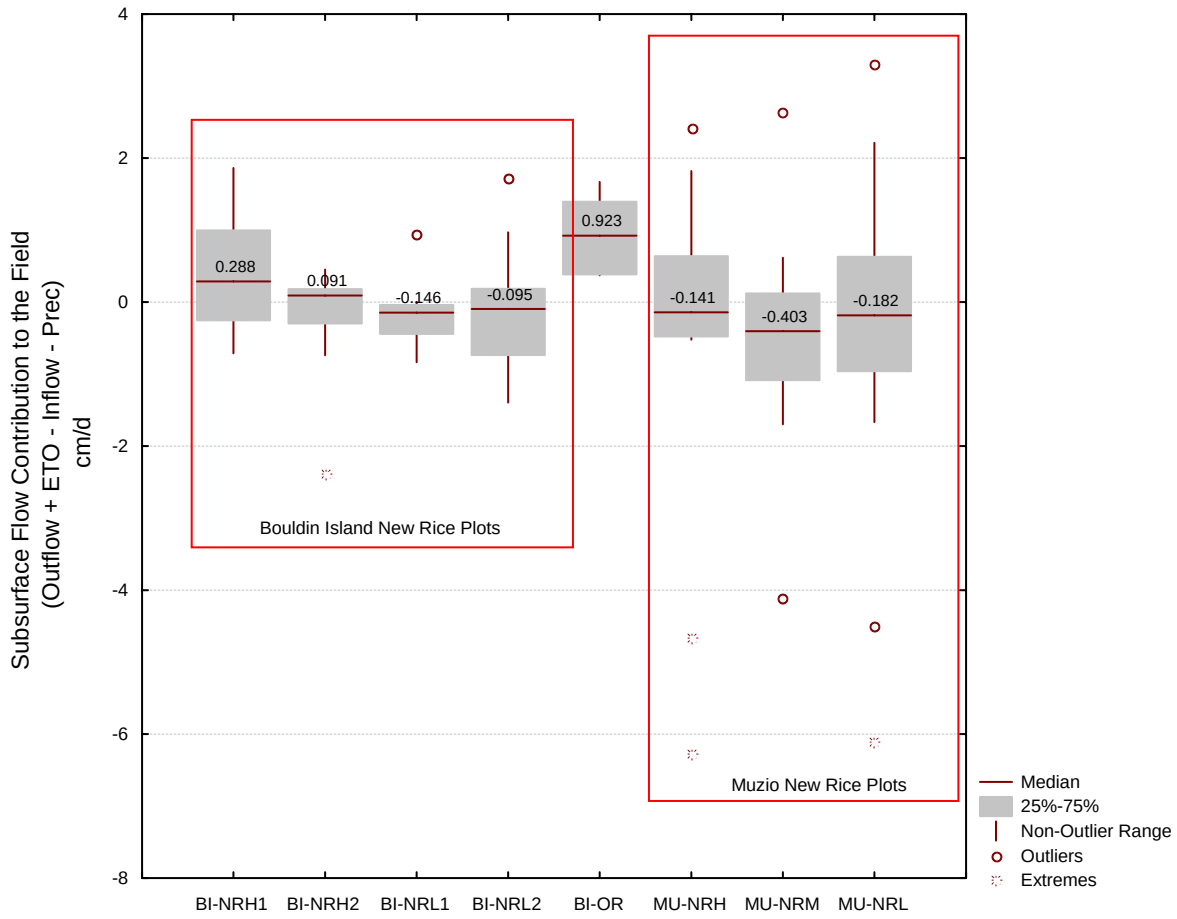


Figure 5-8. Estimated groundwater contribution to the different experimental plots.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract. Negative values indicate the surface water is being lost to groundwater or seepage to drainage ditches.

Table 5-6. Hydrologic Budget for Bouldin Island and for Wright-Elmwood Tract

Farm	Treatment	YearSeason	Inflow LPS				ETO LPS				Precipitation LPS				Outflow LPS				Outflow +ETO-Inflow -Prec LPS				Outflow + ETO - Inflow - Prec cm/d			
			Means	N	SD	Median	Means	N	SD	Median	Means	N	SD	Median	Means	N	SD	Median	Means	N	SD	Median	Means	N	SD	Median
Bouldin Island	NRH	04-Summer	12.6	8.0	10.3	11.0	8.6	8.0	1.2	8.6	0.0	8.0	0.0	0.0	6.2	8.0	6.7	4.6	2.1	8.0	15.7	1.6	0.1	8.0	1.3	0.1
		05-Summer	21.2	9.0	7.8	20.2	10.6	9.0	1.9	11.0	0.0	9.0	0.0	0.0	10.8	9.0	5.0	9.8	0.3	9.0	5.5	1.4	0.0	9.0	0.5	0.1
		05-Winter		0.0				0.0				0.0				0.0				0.0				0.0		
	NRL	04-Summer	26.3	7.0	10.1	21.8	7.6	7.0	0.6	7.1	0.0	7.0	0.0	0.0	12.8	7.0	10.2	7.4	-5.9	7.0	3.2	-7.2	-0.5	7.0	0.3	-0.7
		05-Summer	16.3	10.0	6.4	15.8	9.5	10.0	1.4	9.7	0.0	10.0	0.0	0.0	9.3	10.0	8.2	5.9	2.5	10.0	9.2	0.8	0.2	10.0	0.8	0.1
		05-Winter		0.0				0.0				0.0				0.0				0.0				0.0		
	OR	04-Summer	9.1	2.0	11.9	9.1	8.4	2.0	0.3	8.4	0.0	2.0	0.0	0.0	13.6	2.0	8.5	13.6	12.8	2.0	3.7	12.8	1.2	2.0	0.3	1.2
		05-Summer	14.3	5.0	4.6	14.7	9.5	5.0	1.6	9.8	0.0	5.0	0.0	0.0	13.9	5.0	4.8	12.1	9.2	5.0	6.0	7.6	0.8	5.0	0.5	0.7
		05-Winter		0.0				0.0				0.0				0.0				0.0				0.0		
Wright-Elmwood Tract	NRH	04-Summer	11.2	8.0	5.9	10.4	1.2	8.0	0.3	1.2	0.0	8.0	0.0	0.0	9.3	8.0	5.2	8.2	-0.7	8.0	4.6	0.0	-0.3	8.0	2.0	0.0
		05-Summer	8.8	6.0	4.9	8.4	1.5	6.0	0.2	1.5	0.0	6.0	0.1	0.0	5.2	6.0	3.3	5.2	-2.0	6.0	6.3	-0.5	-0.9	6.0	2.8	-0.2
		05-Winter	3.7	4.0	3.7	3.7	0.2	4.0	0.2	0.2	0.4	4.0	0.5	0.3	4.8	4.0	2.0	5.4	1.0	4.0	2.3	0.5	0.4	4.0	1.0	0.2
	NRM	04-Summer	19.6	7.0	10.2	13.8	3.1	7.0	0.8	3.1	0.0	7.0	0.0	0.0	11.7	7.0	5.5	10.3	-4.7	7.0	8.5	-1.9	-0.8	7.0	1.5	-0.3
		05-Summer	13.9	5.0	8.7	11.4	3.6	5.0	0.4	3.5	0.1	5.0	0.1	0.0	6.6	5.0	13.0	1.0	-3.7	5.0	4.5	-5.6	-0.7	5.0	0.8	-1.0
		05-Winter	4.5	4.0	4.7	4.3	0.5	4.0	0.4	0.6	1.0	4.0	1.2	0.6	6.2	4.0	7.8	3.8	1.2	4.0	10.1	-0.3	0.2	4.0	1.8	-0.1
	NRL	04-Summer	11.1	8.0	9.4	7.5	1.2	8.0	0.3	1.2	0.0	8.0	0.0	0.0	9.6	8.0	5.4	6.3	-0.3	8.0	6.4	0.2	-0.1	8.0	2.8	0.1
		05-Summer	6.9	6.0	5.1	8.0	1.5	6.0	0.2	1.5	0.0	6.0	0.1	0.0	3.1	6.0	2.1	3.3	-2.3	6.0	4.6	-2.1	-1.0	6.0	2.0	-0.9
		05-Winter	1.5	4.0	2.0	1.0	0.2	4.0	0.2	0.2	0.4	4.0	0.5	0.3	1.2	4.0	2.4	0.0	-0.5	4.0	1.3	-0.5	-0.2	4.0	0.6	-0.2
	OR	04-Summer		0.0				0.0				0.0				0.0				0.0				0.0		
		05-Summer		0.0				0.0				0.0				0.0				0.0				0.0		
		05-Winter		0.0				0.0				0.0				0.0				0.0				0.0		

5.3.2.2 Estimated Subsurface Flows

At Bouldin Island, we used water budgets to calculate subsurface flows into the drains. This method was used because Bouldin Island had both surface water and subsurface water feeding the drains which were monitored for this study. This design was unavoidable given the field layouts, field slopes and hydrologic network at Bouldin Island. The subsurface flow was calculated using the following equations:

$$Q_{NRH,Subsurface} = Q_{SWO,NRH1} + Q_{SWO,NRH1} - Q_{DDO,NRH} \qquad \textit{Equation 5-1}$$

$$Q_{NRL,Subsurface} = Q_{SWO,NRH1} + Q_{SWO,NRH1} + Q_{DDO,NRH} - Q_{DDO,NRL} \qquad \textit{Equation 5-2}$$

Subscripts in equations 5-1 and 5-2 are as follows: SWO is surface water outflow and DDO is subsurface drainage outflow.

This method introduced sources of error which were not present for Wright-Elmwood Tract.

5.3.2.2.1 Nature of flow system and propagation of error in hydrologic budget calculations

There were several sources of error in our flow measurements and calculations which we describe in this section. The first source of error resulted from the nature of the flow system. Specifically, surface-water from the NRH1 and NRH2 fields flowed into the drainage ditch and contributed to drainflow at the NRH weir. The surface-water outflow from the NRL1 and NRL2 plus the drainflow from the NRH weir contributed to the flow at NRL weir (Figure 5-4). At Bouldin Island, groundwater flow was estimated using a hydrologic budget for the drains (Equations 5-1 and 5-2), where Q equals flow:

Though we estimated flow using the weir formula which we verified and calibrated by measuring the time to fill a known volume, a correlation of these measurements with estimates of flow using the formula for flow over a rectangular or V-notch weir (Ingersoll-Rand, 1981) indicates our flow estimates for the calibration range of this study were in error by up to 15 to 25 % (Table 5-5). This resulting error propagated in our estimates for subsurface drain flow and loads for the NRL and NRH weirs. This is demonstrated by the equations. The subsurface flow error in the NRH drain includes the errors of the measurements at the NRH SWO and DDO locations. The error at the NRL drain includes of the errors at all the NRH and NRL SWO and DDO locations.

5.3.2.2.2 Systematic error at higher flows through the v-notch weir

At higher flows, a systematic error in our estimation of flows through the v-notch weirs may have also contributed to error. A v-notch weir was installed at NRH DDO (the weir in the NRH portion of the drain) and a rectangular weir was installed at NRL DDO (the weir in the NRL

portion of the drain). The v-notch weir was installed in the NRH drain in anticipation of lower flows. (V-notch weirs are the preferred weir configuration at lower flows). For higher flows over the weir (outside of our calibration range), Table 5-5 suggests that our weir equation consistently overestimated flows from the high drain by about 20%. During summer and winter 2004, the height over the weir at NRH DDO averaged 1.6 and 2.8 inches respectively, within the calibration range for the equations used. However, during summer 2005, the height over the weir averaged 7.3 inches, and sometimes was as high as 9 inches. Flows were too high and the logistics too difficult to do bucket measurements of flow. In comparing our calibration constant with the published constant, and understanding that our constant was developed for a height over the weir up to about 3 inches, there is reason to believe that our flows over v-notch weirs at the higher flow condition that existed only at this location were regularly overestimated on the order of 20%. This overestimation would mean that in 2005, subsurface flows from the NRH drain at Bouldin Island were overestimated and, consequently, the NRL subsurface flows were underestimated.

5.3.2.2.3 Contributing area of subsurface flow

Finally, at Bouldin Island, we believe we underestimated the contributing areas for rice fields for subsurface flows to the drains. This was due to the well distribution and is discussed in more detail in section 5.3.6, the groundwater results. We estimate that we underestimated the contributing area on the order of 20 to 50 % for the new rice fields. Thus, the per acre estimates of groundwater loads may be 20 to 50 % high. We believe the contributing area at Wright-Elmwood Tract has minimal error. Thus, in comparing Bouldin Island to Wright-Elmwood Tract, Bouldin Island subsurface loading rates may always be relatively high.

All these factors were unique to Bouldin Island and contributed to larger error in flow measurements and the resulting calculation of subsurface flow for Bouldin Island as opposed to Wright-Elmwood Tract.

5.3.2.3 Relationships between Surface Water and Drain Water Elevations and Subsurface Flows

Another important hydrologic consideration was the effect of raising drain water levels on drain flows. The hydrologic goal of this project was to raise drain levels to suppress subsurface flows to the drains. Our hypothesis was that raising drain levels would reduce subsurface flow and the carbon and nitrogen constituents that would be loaded from that source.

Figure 5-9 shows that raising drain water levels at the study plots at Wright-Elmwood Tract suppressed subsurface flows. Subsurface flows were measured at this sight directly from the drainage ditch (Figure 5-5). Raising drain levels accounted for just over 50% of the variance in drain flow rates. At very high drain water elevations where differences were below 1 foot on the x axis in figure 5-9, drain flows were stopped.

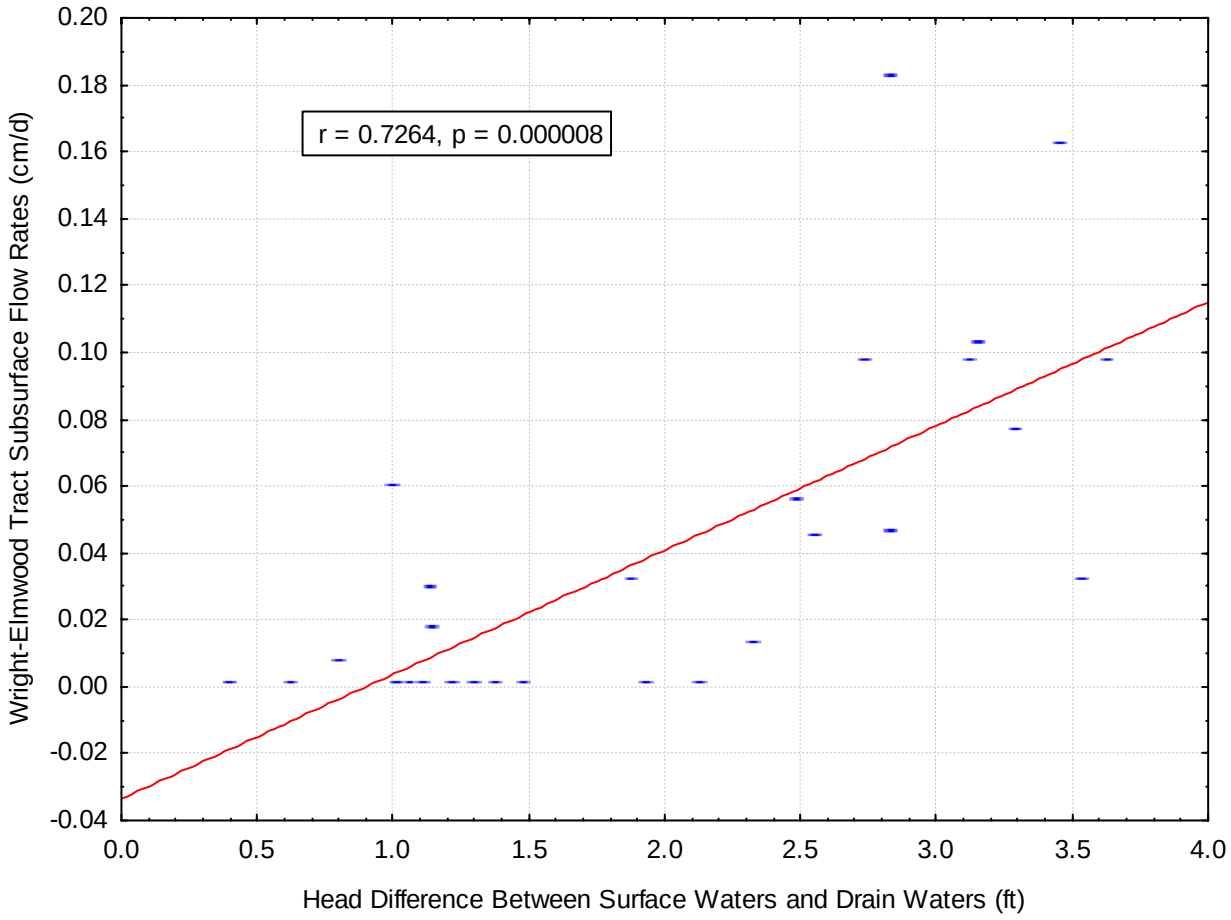


Figure 5-9. Relationship between Drain Ditch Water Elevation and Subsurface Flow

Thus, elevating drain-water elevations stopped drain flows at Wright-Elmwood Tract. Lower ditch water elevations resulted in higher flow rates. For Bouldin Island, the analysis is more complicated because of the method used to calculate flows and the greater inherent uncertainty. As is shown Figure 5-10 , subsurface flows from the fields in 2004 do not differ significantly based upon the Kruskal-Willis nonparametric test. However, in 2005 the subsurface flows do differ.

Based upon our error analyses in Section 5.3.2.2, we believe that because the v-notch weir separating the drain into NRH and NRL sections flowed well above the calibration range, our estimates of subsurface flow in 2005 for NRH were high and our estimates of NRL subsurface flows were low. After eliminating NRL and NRH data from 2005, all subsurface flows do not differ statistically (p=0.938).

These data from Wright-Elmwood Tract and Bouldin Island suggests that at Wright-Elmwood Tract, drain water elevations affected and stopped subsurface flows whereas at Bouldin Island, the data suggests that drain water elevations did not affect subsurface flows.

Our analyses of shallow groundwater (Section 5.3.6) shows raising the drain levels greatly decreased the gradient between the groundwater and the drain and also reduced the contributing area for that groundwater. This reduced gradient results in reduced flows based upon Darcy's Law. Thus, raising the drain water levels reduced the contribution of shallow groundwater.

A possible explanation to explain the data between Bouldin Island and Wright-Elmwood is that the raised drain levels did not suppress deeper groundwater as much. Bouldin Island is much lower then Wright-Elmwood Tract elevations (fields at about -13 to -14 ft-NAVD as compared to -8 to -9 ft-NAVD). This lower elevation and thus the relatively greater head differential between deeper groundwater and the drainage ditch water may be one possible reason why managing drains may not have suppressed drain flow at Bouldin Island as it did at Wright-Elmwood Tract.

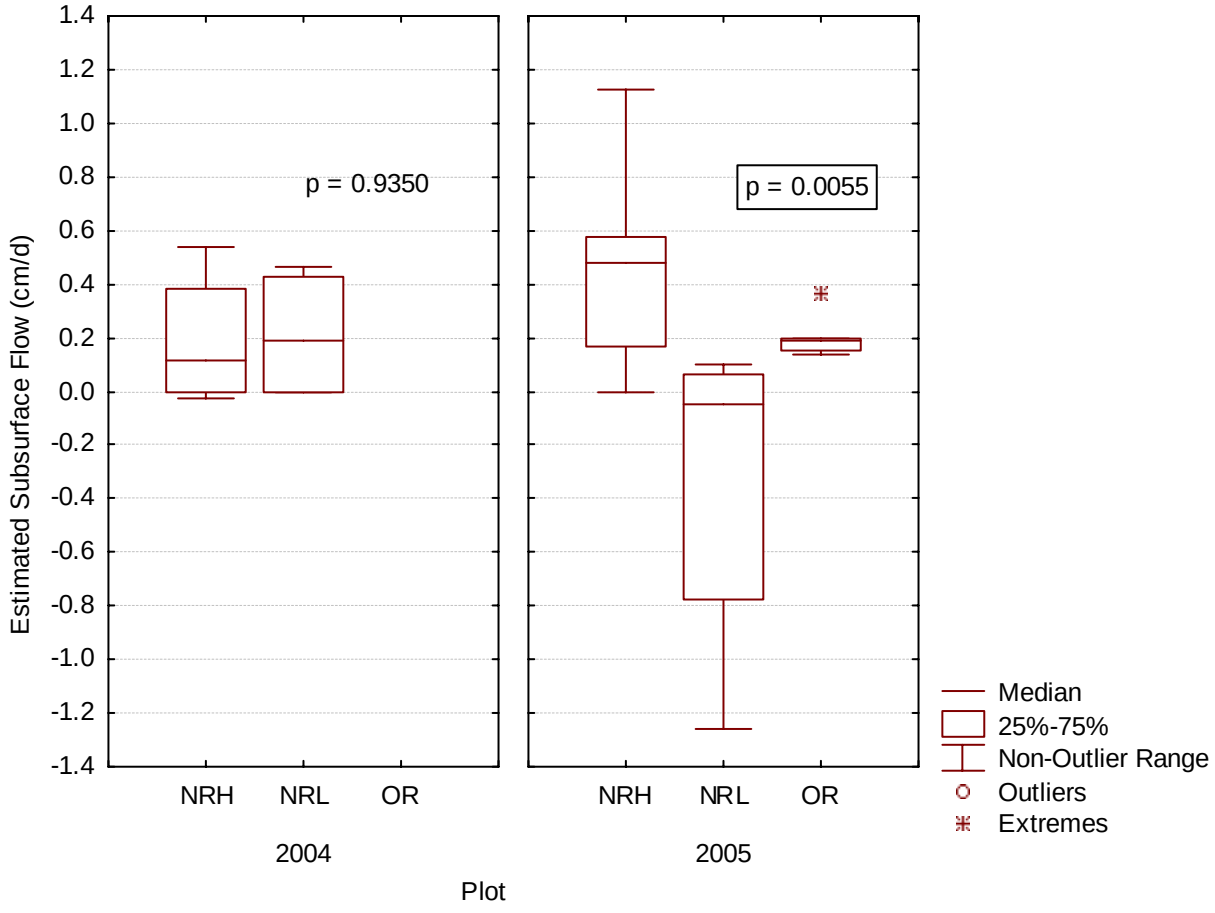


Figure 5-10. Subsurface Flows at Bouldin Island during 2004 and 2005 for Rice Fields

Estimated subsurface contributions were statistically different in 2005 but not 2004 between the different rice plots at Bouldin Island. When excluding NRH and NRL data from 2005 because of measurement and propagation errors, the subsurface flows between NRH 2004, NRL 2004 and OR 2005 were not statistically different.

5.3.3 Subsurface and Surface Loads

Our originally stated proposal goal for this project was to explore the possibility of growing rice for limiting DOC export from delta agriculture in light of its potential economic and subsidence-mitigation benefits. Consistently, in the analysis and discussion of subsurface and surface loads, we focused on dissolved organic carbon and disinfection byproduct precursors because of the high interest in these parameters related to drinking water. Tables 5-7 and 5-8 show the averages and ranges of concentrations of these and other constituents for surface water outflows (SWO) and drainage ditch outflows (DDO).

5.3.4 Concentration and Field Parameter Data

Concentrations of other analyzed constituents were generally below levels of concern relative to most restrictions in the Central Valley Regional Water Quality Board basin planning documents. Specifically, pH values were generally within the pH range specified in Regional Board documents; values were generally greater than 6.5 and always less than 8.5. Some subsurface drainage samples had pH values slightly less than 6.5 but the drainage volume is such that we do not expect effects on channel-water pH. Moreover, pH values for rice drainage (surface and subsurface) samples were not significantly different from corn subsurface drainage samples. Corn is the predominant delta crop.

Electrical conductivity values for surface water outflow samples were always less than 700 μS/cm for both farms. For subsurface drain flows, most values were less than the water quality objective of 1,000 μS/cm. Most electrical conductivity values were within the range of values measured in the San Joaquin River and other delta channels. Larger average electrical conductivity values which were as high as 1,800 mS/cm were measured in rice subsurface drainage water collected on Wright-Elmwood Tract. Rice subsurface drainage water samples on Wright-Elmwood Tract did not have significantly higher electrical conductivity values than those collected in corn subsurface drainage samples.

Average dissolved oxygen concentrations for subsurface and surface-water outflow samples were generally below the water-quality objective of 6.0 mg/L for the San Joaquin River. We did not analyze how waters with these dissolved oxygen values could affect receiving waters as this was beyond the primary project purpose. Average dissolved oxygen concentrations for rice subsurface drain samples were not significantly different than those measured in corn drain samples. Nitrate-nitrogen concentrations were universally and substantially below the drinking water standard of 10 mg-N/L nitrogen (Tables 5-7 and 5-8). Nitrate-nitrogen concentrations were also substantially below the concentrations measured at the Banks pumping plant which ranged from 0.5 to 8 mg-N/L from 1994 to 2004. They were also below the nitrate nitrogen concentrations that ranged from 2 to 12 mg-N/L in the San Joaquin River at Highway 4. Low nitrate concentrations are probably the result of denitrification that occurs under reducing conditions in delta organic soils. Average dissolved organic carbon concentrations in all samples

were above the 3 mg/L target concentration for drinking water proposed by the CALFED Bay Delta Authority.

This section presents results of seasonal and treatment comparison of DOC, THMFP and nitrogen subsurface and surface loads. Loads were estimated from concentration and flow data collected at the surface and subsurface drain outlets approximately every 2 weeks during the 2004 and 2005 growing seasons and during winter 2005. Tables 5-9 and 5-10 present the summary statistics for the instantaneous measurements of subsurface drains and surface water outflows. Table 5-9 presents surface water and subsurface loads and budget for Bouldin Island. Subsurface hydrologic and analyte loads at Bouldin Island were calculated by a mass budget using the measured inflows and outflows from the various weirs associated with each drain. Table 5-10 presents both surface and subsurface hydrologic and analyte loads at Wright-Elmwood Tract. Subsurface hydrologic loads at Wright-Elmwood Tract were measured directly with a weir and had no additional surface water inputs. Thus, these loads are considered more accurate estimates then those subsurface loads calculated at Bouldin Island.

Table 5-7. Surface water outflow concentration and field parameters summary.

Farm	Year	Season	PlotID	DO (mg/L)				pH				EC				Temp (deg-C)			
				In		Out		In		Out		In		Out		In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	NRH1	7.73	0.46	6.05	0.92	7.45	0.07	6.80	0.20	166	25	171	22	22.97	0.44	19.22	1.26
			NRH2	6.02	1.15	4.17	0.86	7.14	0.07	6.66	0.12	168	27	261	18	23.07	0.36	19.30	1.33
			NRL1	7.00	1.02	5.11	0.45	7.12	0.16	6.79	0.12	167	24	171	20	22.91	0.43	19.67	2.21
			NRL2	4.72	1.00	4.50	1.52	6.97	0.13	6.81	0.14	515	687	242	33	22.36	0.63	19.06	2.94
			OR	3.29	0.52	4.69	0.31	6.46	0.12	6.61	0.09	197	13	215	33	20.92	1.70	20.85	1.89
	2005	Summer	NRH1	2.50	4.07	4.52	2.70	7.16	0.13	6.41	0.17	146	7	150	15	23.22	1.29	21.02	0.88
			NRH2	7.34	1.27	9.46	8.05	7.03	0.27	6.57	0.28	144	9	187	29	23.45	1.21	21.58	1.60
			NRL1	8.23	1.38	3.10	2.78	7.05	0.37	6.44	0.13	166	44	189	46	23.68	1.06	21.16	1.63
			NRL2	5.62	2.17	1.31	0.51	7.00	0.25	6.49	0.24	151	13	231	51	23.42	0.63	20.82	1.86
			OR	7.12	1.54	6.55	1.24	6.91	0.19	6.65	0.22	152	16	174	13	23.78	0.79	23.72	3.51
Wright	2004	Summer	NRH	5.15	2.60	4.51	2.62	6.83	0.22	6.94	0.28	492	65	535	75	21.06	2.74	21.56	3.30
Elmwood			NRL	4.54	2.28	3.86	3.03	6.85	0.20	6.70	0.15	488	49	516	62	20.23	2.41	20.71	1.90
Tract			NRM	5.18	2.17	4.25	3.53	6.72	0.13	6.77	0.20	547	121	602	133	21.11	2.39	22.09	3.49
	2005	Winter	NRH	4.44	2.48	3.73	3.08	7.18	0.19	7.00	0.42	483	52	512	23	13.39	4.61	10.82	2.22
			nrl	3.63	2.17	2.83	3.12	7.14	0.33	7.05	0.35	477	23	471	7	12.65	4.67	11.17	2.45
			nrm	4.08	2.38	4.16	3.22	7.20	0.18	7.35	0.16	501	17	488	23	12.03	5.14	10.91	2.18
		Summer	NRH	3.64	1.89	6.93	7.30	6.51	0.25	6.34	0.17	385	65	406	59	23.62	4.59	21.20	2.37
			NRL	5.43	3.65	3.31	2.11	6.84	0.49	6.52	0.13	398	78	382	54	23.36	5.60	22.72	4.24
			NRM	3.44	3.30	4.19	4.08	6.42	0.15	6.75	0.25	423	69	419	51	21.70	4.23	21.03	3.22

Farm	Year	Season	PlotID	DOC (mg/L)				THMFP (ug/L)				TSS (mg/L)			
				In		Out		In		Out		In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	NRH1	1.66	0.16	7.20	1.35					8.44	2.88	2.03	38.04
			NRH2	1.81	0.09	13.47	3.14					6.53	3.68	0.24	7.89
			NRL1	1.94	0.09	3.66	0.46					12.55	18.96	1.46	9.04
			NRL2	2.60	0.38	11.99	4.44					2.86	2.47	1.89	3.82
			OR	6.60	2.59	8.95	3.94					3.88	2.95	0.29	6.56
	2005	Summer	NRH1	1.71	0.08	8.81	2.71	147	8	830	250	10.50	6.10	4.12	36.17
			NRH2	1.77	0.02	9.49	3.20	151	13	830	279	7.60	4.19	2.77	35.40
			NRL1	1.93	0.07	13.22	3.55	167	10	1261	354	6.67	4.84	3.25	85.57
			NRL2	2.50	0.18	12.21	5.99	206	9	1178	535	5.76	4.63	6.72	27.74
			OR	2.06	0.15	6.78	2.96	184	8	696	290	2.02	3.88	3.78	53.71
Wright	2004	Summer	NRH	7.62	2.38	9.60	3.23					4.22	6.76	5.44	103.89
Elmwood			NRL	6.63	0.82	11.83	2.90					3.74	4.83	5.52	90.48
Tract			NRM	9.91	3.88	16.85	10.69					5.19	8.85	4.82	86.61
	2005	Winter	NRH	11.33	2.79	11.39	2.38	1133	293	1207	163	5.34	1.24	5.18	14.46
			nrl	18.28	2.22	23.04	11.44	1718	252	2081	601	21.94	18.10	11.36	25.94
			nrm	13.82	2.21	12.97	0.89	1292	255	1222	91	9.87	3.32	6.34	36.26
		Summer	NRH	9.86	6.00	13.49	6.81	1022	582	1428	580	3.43	3.32	4.07	19.86
			NRL	6.38	1.74	12.66	9.70	672	146	1213	725	2.89	6.11	6.14	13.21
			NRM	16.75	11.80	17.43	5.71	1666	883	1825	508	3.51	4.50	8.63	143.63

Farm	Year	Season	PlotID	NH4-N mg-N/L				NO3-N (mg-N/L)				TDN (mg-N/L)			
				In		Out						In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	NRH1	0.05	0.02	0.01	0.00	0.32	0.15	0.13	0.16	0.66	0.30	0.66	0.10
			NRH2	0.04	0.01	0.02	0.01	0.33	0.15	0.09	0.14	0.66	0.22	0.94	0.13
			NRL1	0.03	0.01	0.01	0.01	0.33	0.14	0.10	0.18	0.65	0.37	0.43	0.16
			NRL2	0.02	0.00	0.01	0.02	0.33	0.13	0.07	0.16	0.58	0.19	0.92	0.21
			OR	0.01	0.01	0.00	0.00	0.09	0.19	0.09	0.19	0.66	0.09	0.80	0.25
	2005	Summer	NRH1	0.12	0.08	0.22	0.45	0.21	0.04	0.01	0.03	0.60	0.18	0.85	0.40
			NRH2	0.10	0.05	0.02	0.01	0.22	0.05	-0.02	0.01	0.60	0.19	0.78	0.29
			NRL1	0.11	0.06	0.02	0.02	0.22	0.06	-0.02	0.02	0.76	0.28	1.33	0.59
			NRL2	0.06	0.02	0.03	0.02	0.24	0.07	-0.02	0.01	0.60	0.14	1.22	0.63
			OR	0.05	0.04	0.16	0.34	0.25	0.03	-0.02	0.02	0.70	0.16	0.61	0.29
Wright	2004	Summer	NRH	0.01	0.01	0.03	0.05	0.08	0.15	0.08	0.15	0.80	0.23	0.95	0.29
Elmwood			NRL	0.03	0.02	0.04	0.02	0.12	0.17	0.08	0.16	0.80	0.21	1.14	0.29
Tract			NRM	0.01	0.01	0.05	0.06	0.09	0.16	0.10	0.15	1.00	0.35	1.57	0.80
	2005	Winter	NRH	0.01	0.01	0.03	0.03	0.01	0.09	0.00	0.05	0.86	0.13	0.90	0.06
			nrl	0.04	0.05	0.03	0.02	0.00	0.02	-0.03	0.03	1.31	0.11	1.38	0.31
			nrm	0.01	0.01	0.01	0.01	-0.03	0.02	-0.01	0.04	1.02	0.16	0.98	0.02
		Summer	NRH	0.07	0.09	0.40	0.57	0.01	0.04	0.01	0.04	0.99	0.65	1.50	1.14
			NRL	0.03	0.01	0.56	1.23	0.07	0.08	0.02	0.03	0.75	0.14	1.76	1.93
			NRM	1.07	2.51	0.59	1.31	0.03	0.07	0.02	0.07	2.68	3.52	2.34	1.90

Table 5-8. Subsurface drain concentrations and field parameters summary.

Farm	Year	Season	PlotID	DO (mg/L)				pH				EC				Temp (deg-C)			
				In		Out		In		Out		In		Out		In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	Corn			0.31	0.16			6.57	0.10			435	47			18	2
			NRH	4.62	1.22	1.31	0.99	6.69	0.16	6.23	0.11	228	30	293	110	19	1	19	2
			NRL	3.79	0.49	2.69	1.56	6.55	0.21	6.46	0.15	273	115	291	163	19	2	19	2
			OR			0.87	1.23			6.44	0.24			476	152			19	2
		Winter	Corn			4.13	0.68			6.29	0.18			523	216			13	2
			NRH			2.60	3.73			6.11	0.35			526	245			12	2
			NRL	2.60	3.73	1.08	0.70	6.11	0.35	6.41	0.16	526	245	899	176	12	2	13	2
			OR			0.76	0.44			6.55	0.15			565	105			13	2
	2005	Summer	Corn			0.25	0.04			6.65	0.21			508	75			22	0
			NRH	6.08	3.81	1.51	1.80	6.48	0.21	6.28	0.16	169	19	190	18	21	1	20	1
			NRL	2.26	2.12	0.66	0.94	6.39	0.07	6.10	0.21	201	21	219	23	21	2	21	2
			OR			0.33	0.16			6.11	0.14			445	28			21	1
Wright	2004	Summer	Corn			0.74	0.55			6.98	0.79			667	184			19	5
Elmwood			NRH			1.29	2.11			6.95	0.14			994	81			21	2
Tract			NRL			2.88	2.38			5.56	0.22			1878	617			20	3
	2005	Winter	Corn			5.17	3.50			6.65	0.12			950	155			14	4
			NRH			2.36	1.36			6.59	0.23			1283	353			12	1
			NRL			2.35	1.41			6.02	0.21			1513	340			14	2
		Summer	Corn			0.27	0.18			6.82	0.13			610	35			23	4
			NRH			0.56	0.28			6.62	0.07			1065	97			316	731
			NRL			0.58	0.36			6.22	0.19			1555	66			19	2

Farm	Year	Season	PlotID	DOC (mg/L)				THMFP (ug/L)				TSS (mg/L)			
				In		Out		In		Out		In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	Corn			16.2	6.1							15.45	10.79
			NRH	13.1	6.5	28.7	24.7					10.55	21.06	4.08	2.86
			NRL	23.4	27.4	24.5	20.0					5.14	5.16	7.31	10.86
			OR			45.2	23.3							7.95	6.04
		Winter	Corn			7.6	1.2			567	104			4.06	1.40
			NRH			83.9	10.1			6212	363			19.60	17.39
			NRL	83.9	10.1	63.8	4.8	6212	363	4540	179	19.60	17.39	15.57	6.38
			OR			33.9	2.8			2539	272			14.19	6.02
	2005	Summer	Corn			16.8	3.5			1646	348			39.64	20.92
			NRH	9.4	2.0	18.4	3.3	851	172	1602	250	3.91	1.88	5.85	3.59
			NRL	14.2	4.2	20.1	3.7	1311	369	1807	361	5.20	4.47	7.00	4.89
			OR			45.8	3.4			3719	210			11.17	8.11
Wright	2004	Summer	Corn			16.1	11.5							13.93	12.94
Elmwood			NRH			21.8	3.7							20.61	14.65
Tract			NRL			64.7	23.7							17.43	10.01
	2005	Winter	Corn			19.4	2.7			1536	151			8.68	6.67
			NRH			20.4	4.0			1639	304			7.61	1.46
			NRL			30.7	4.3			2193	233			10.97	2.33
		Summer	Corn			15.8	13.0			1195	343			17.97	13.62
			NRH			22.6	1.6			1843	778			7.41	3.05
			NRL			63.6	8.9			5022	591			9.87	8.15

Farm	Year	Season	PlotID	NH4-N mg-N/L				NO3-N (mg-N/L)				TDN (mg-N/L)			
				In		Out		In		Out		In		Out	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bouldin	2004	Summer	Corn			0.28	0.38			0.05	0.13			1.34	0.59
			NRH	0.01	0.00	0.26	0.34	0.09	0.13	0.05	0.13	0.95	0.34	1.60	1.02
			NRL	0.25	0.35	0.52	0.71	0.06	0.13	0.07	0.15	1.35	1.14	1.74	1.31
			OR			1.95	0.85			0.07	0.14			4.61	2.30
		Winter	Corn			0.04	0.02			0.88	0.67			1.22	0.56
			NRH			0.84	0.37			0.19	0.21			4.50	0.35
			NRL	0.84	0.37	1.54	0.34	0.19	0.21	0.11	0.09	4.50	0.35	4.75	0.26
			OR			1.98	0.50			0.14	0.05			4.21	0.41
	2005	Summer	Corn			0.06	0.04			0.05	0.07			1.30	0.43
			NRH	0.10	0.20	0.13	0.04	0.00	0.02	<0.02	0.02	0.80	0.29	1.35	0.39
			NRL	0.06	0.02	0.14	0.07	<0.02	0.01	<0.01	0.02	1.25	0.54	1.67	0.51
			OR			1.05	0.89			0.05	0.07			4.86	0.25
Wright	2004	Summer	Corn			0.48	0.32			0.10	0.16			1.42	0.26
Elmwood			NRH			0.17	0.33			0.11	0.13			1.61	0.50
Tract			NRL			0.43	0.17			3.49	8.33			7.51	8.37
	2005	Winter	Corn			0.19	0.11			5.71	3.44			6.97	3.78
			NRH			0.28	0.23			2.63	1.74			3.90	1.83
			NRL			0.65	0.16			9.26	3.15			11.45	2.78
		Summer	Corn			0.75	0.49			0.04	0.06			1.63	0.25
			NRH			0.57	0.40			-0.01	0.01			2.63	1.29
			NRL			0.78	0.32			0.50	1.26			4.53	1.75

5.3.4.1 Calculations of Surface and Subsurface Loads

For the following loads discussion, subsurface loads were divided by groundwater contributing areas delineated by groundwater level data discussed and presented in section 5.3.6. Surface loads were divided by plot areas for Bouldin Island. To calculate per area surface-water outflow (SWO) loads for Muzio Farm at Wright-Elmwood Tract, we added all DOC loads and divided by the entire contributing area of 75.5 acres. This includes the 21.8 acres of our experimental rice site and 53.7 of upslope land planted to rice.

Tables 5-9 and 5-10 present the summary statistics for the instantaneous measurements of subsurface drainflows and surface water outflows. Table 5-9 presents surface water and subsurface loads and budget for Bouldin Island. Subsurface hydrologic and analyte loads at Bouldin Island were calculated by a mass budget using the measured inflows and outflows from the various weirs associated with each drain. Table 5-10 presents both surface and subsurface hydrologic and analyte loads at Wright-Elmwood Tract. Subsurface hydrologic loads at Wright-Elmwood Tract were measured directly with a weir and had no additional surface water inputs. These subsurface loads calculated for Wright-Elmwood Tract are considered more accurate estimates then those calculated at Bouldin Island based upon our discussion of sources of error at Bouldin Island. In the following sections, we statistically analyze the data but take into consideration these possible sources of error to interpret the results. Net loads were calculated as the difference between loads for surface water inflow and outflow. Gross loads were not adjusted for inputs.

Table 5-9. Summary statistics for constituent loads for surface water outflow and subsurface drainflows for Bouldin Island.

Year	Season	Treatment	Start Date	End Date	g/ac/d mean	g/ac/d sd	mg/ac/d mean	mg/ac/d sd	g-N/ac/d mean	g-N/ac/d sd	g-N/ac/d mean	g-N/ac/d sd	g-N/ac/d mean	g-N/ac/d sd
Gross Surface Water Loads					**Gross SW DOC**		**Gross SW THMFP**		**Gross SW NH4-N**		**Gross SW NO3-N**		**Gross SW TDN**	
2004	Summer	NRH	27-Jul-04	07-Sep-04	191	145			0.24	0.23	0.09	0.14	17.11	16.28
		NRL	27-Jul-04	07-Sep-04	223	102			0.56	0.51	0.16	0.31	25.34	15.14
		OR	27-Jul-04	07-Sep-04	470	104			0.07	0.12	0.17	0.30	44.00	12.37
2005	Summer	NRH	28-Jun-05	17-Aug-05	340	221	30,482	18,495	0.75	0.66	0.01	0.02	30.12	21.56
		NRL	28-Jun-05	29-Aug-05	584	624	55,642	58,679	0.81	1.34	0.00	0.01	66.67	83.10
		OR	07-Jul-05	29-Aug-05	347	181	36,088	19,690	7.08	14.95	0.00	0.00	32.99	24.15
Net Surface Water Loads					**Net SW DOC**		**Net SW THMFP**		**Net SW NH4-N**		**Net SW NO3-N**		**Net SW TDN**	
2004	Summer	NRH	27-Jul-04	07-Sep-04	111	189			-1.75	2.14	-9.96	14.49	-15.36	48.82
		NRL	27-Jul-04	07-Sep-04	15	67			-1.87	1.05	-27.89	11.24	-38.70	16.79
		OR	27-Jul-04	07-Sep-04	341	243			-0.37	0.65	0.79	1.37	27.89	26.27
2005	Summer	NRH	28-Jun-05	17-Aug-05	220	194	21,685	18,346	-6.05	5.25	-13.41	7.70	-15.65	17.75
		NRL	28-Jun-05	29-Aug-05	363	571	36,543	54,528	-4.68	5.26	-14.15	6.17	10.97	54.22
		OR	07-Jul-05	29-Aug-05	241	173	26,547	19,121	4.42	15.69	-12.88	3.60	-3.06	16.13
Calculated Subsurface Water Loads					**SSF DOC**		**SSF THMFP**		**SSF NH4-N**		**SSF NO3-N**		**SSF TDN**	
2004	Summer	Corn	27-Jul-04	21-Sep-04	59	122			0.56	0.77	0.10	0.17	3.90	7.13
		NRH	27-Jul-04	14-Sep-04	351	232			2.08	1.63	-0.83	5.21	17.04	13.23
		NRL	27-Jul-04	07-Sep-04	582	341			2.63	0.87	0.32	1.06	36.15	21.42
		OR	27-Jul-04	21-Sep-04	2256	2164			125.90	119.59	7.91	12.86	221.77	213.46
2005	Winter	Corn	09-Feb-05	09-Mar-05	299	132	22,438	9,504	2.11	2.21	39.23	22.99	54.15	32.23
		NRH	09-Feb-05	22-Mar-05	454	419	35,299	35,563	4.90	5.97	2.00	3.53	26.43	28.74
		NRL	09-Feb-05	22-Mar-05	673	675	47,388	49,275	20.33	22.50	1.04	1.61	55.64	56.46
		OR	09-Feb-05	22-Mar-05	642	270	48,783	22,347	39.88	12.76	2.49	2.49	77.21	21.09
	Summer	NRH	28-Jun-05	29-Aug-05	912	196	64,915	34,833	8.84	1.91	-0.36	0.53	61.33	5.53
		NRL	28-Jun-05	29-Aug-05	-101	485	9,191	10,830	1.10	5.57	0.19	0.26	-12.71	50.74
		OR	28-Jun-05	29-Aug-05	744	241	60,840	21,001	17.85	17.44	0.80	0.94	80.21	31.64

Table 5-10. Summary statistics for constituent loads for surface water outflow and subsurface drainflows for Wright-Elmwood Tract.

Year	Season	Treatment	Start Date	End Date	g/ac/d mean	g/ac/d sd	mg/ac/d mean	mg/ac/d sd	g-N/ac/d mean	g-N/ac/d sd
Gross Surface Water Loads					**Gross SW DOC**		**Gross SW THMFP**		**Gross SW NH4-N**	
2004	Summer	NRH	27-Jul-04	07-Sep-04	191	145			0.24	0.23
		NRL	27-Jul-04	07-Sep-04	223	102			0.56	0.51
		OR	27-Jul-04	07-Sep-04	470	104			0.07	0.12
2005	Summer	NRH	28-Jun-05	17-Aug-05	340	221	30,482	18,495	0.75	0.66
		NRL	28-Jun-05	29-Aug-05	584	624	55,642	58,679	0.81	1.34
		OR	07-Jul-05	29-Aug-05	347	181	36,088	19,690	7.08	14.95
Net Surface Water Loads					**Net SW DOC**		**Net SW THMFP**		**Net SW NH4-N**	
2004	Summer	NRH	27-Jul-04	07-Sep-04	111	189			-1.75	2.14
		NRL	27-Jul-04	07-Sep-04	15	67			-1.87	1.05
		OR	27-Jul-04	07-Sep-04	341	243			-0.37	0.65
2005	Summer	NRH	28-Jun-05	17-Aug-05	220	194	21,685	18,346	-6.05	5.25
		NRL	28-Jun-05	29-Aug-05	363	571	36,543	54,528	-4.68	5.26
		OR	07-Jul-05	29-Aug-05	241	173	26,547	19,121	4.42	15.69
Calculated Subsurface Water Loads					**SSF DOC**		**SSF THMFP**		**SSF NH4-N**	
2004	Summer	Corn	27-Jul-04	21-Sep-04	59	122			0.56	0.77
		NRH	27-Jul-04	14-Sep-04	351	232			2.08	1.63
		NRL	27-Jul-04	07-Sep-04	582	341			2.63	0.87
		OR	27-Jul-04	21-Sep-04	2256	2164			125.90	119.59
2005	Winter	Corn	09-Feb-05	09-Mar-05	299	132	22,438	9,504	2.11	2.21
		NRH	09-Feb-05	22-Mar-05	454	419	35,299	35,563	4.90	5.97
		NRL	09-Feb-05	22-Mar-05	673	675	47,388	49,275	20.33	22.50
		OR	09-Feb-05	22-Mar-05	642	270	48,783	22,347	39.88	12.76
	Summer	NRH	28-Jun-05	29-Aug-05	912	196	64,915	34,833	8.84	1.91
		NRL	28-Jun-05	29-Aug-05	-101	485	9,191	10,830	1.10	5.57
		OR	28-Jun-05	29-Aug-05	744	241	60,840	21,001	17.85	17.44

1) There were no measured loads for Wright-Elmwood during summer 2005 because there were no measurable flows.

5.3.4.2 Dissolved Organic Carbon (DOC)

5.3.4.2.1 Subsurface loads

Figure 5.9 shows box plots for DOC loads by treatment for subsurface drains. Median subsurface DOC loads varied substantially by treatment from 0 for Wright-Elmwood Tract NRH to 729 g/A-day for Bouldin Island NRH.

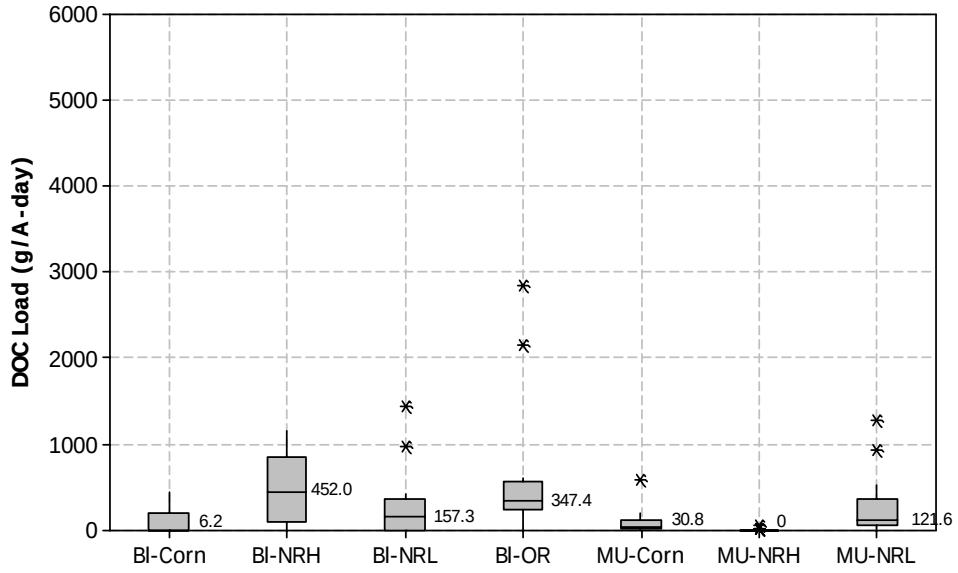


Figure 5-11. Box plots for subsurface drain DOC loads by treatment for 2004 and 2005.

The shaded box represents the 1st and 3rd quartile range values. Horizontal line in box and number to right of box represents the median. Vertical lines extending from the shaded box represent the range of the data and asterisks are outlying data points. "BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Calculated subsurface loads for the Bouldin Island treatments varied more than those subsurface loads for Wright-Elmwood treatments. The results of the Kruskall-Wallis and Mann-Whitney tests indicate for Bouldin Island, the subsurface loads for NRL and corn were not significantly different from one another. These statistical tests further indicated that subsurface loads for the NRH and OR treatments were not significantly different from one another but both were significantly larger than the corn subsurface loads.

Overall, subsurface DOC loads were significantly lower at Wright-Elmwood Tract relative to Bouldin Island. This may in part be due to our underestimation of contributing areas for the subsurface loads at Bouldin Island.

Comparison by treatment showed that all of the Bouldin Island subsurface NRH loads were significantly larger than the NRH subsurface loads at Wright-Elmwood Tract. The subsurface loads for corn at Wright-Elmwood Tract were significantly larger than the corn subsurface loads on Bouldin Island. NRL loads between the two islands were not significantly different. For the Wright-Elmwood Tract treatments, subsurface loads for all treatments were significantly different as follows: NRL > corn > NRH.

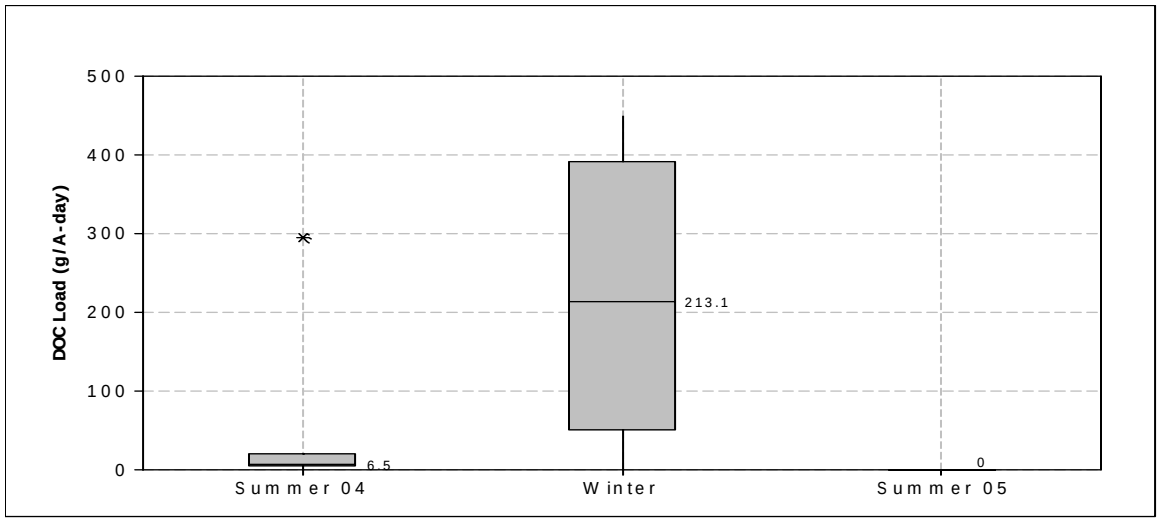


Figure 5-12. Box plots showing seasonal variation in Subsurface DOC load for corn on Bouldin Island.

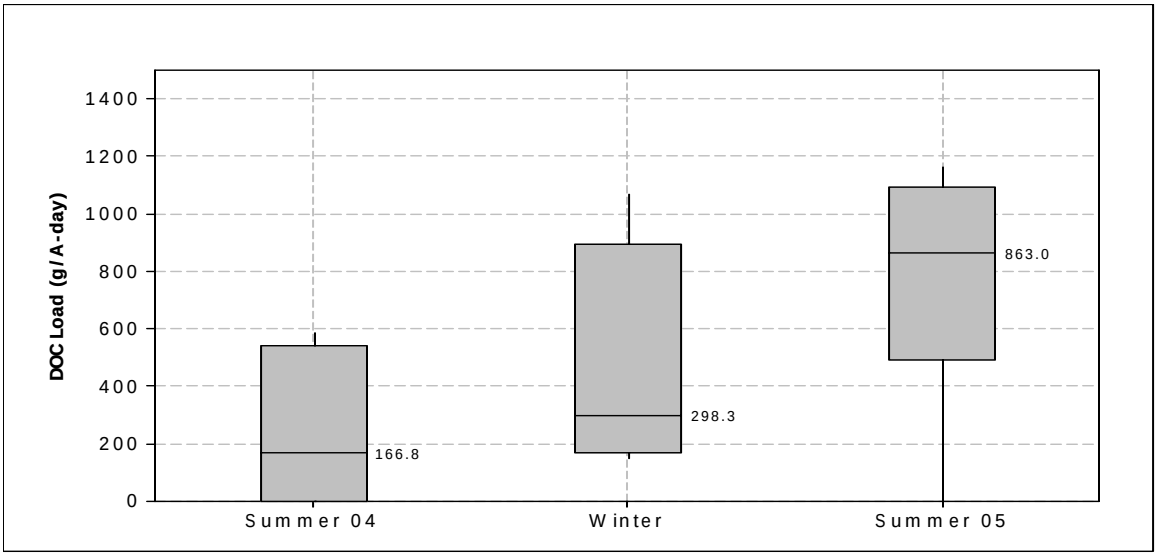


Figure 5-13. Box plots showing seasonal variation in DOC load for NRH on Bouldin Island.

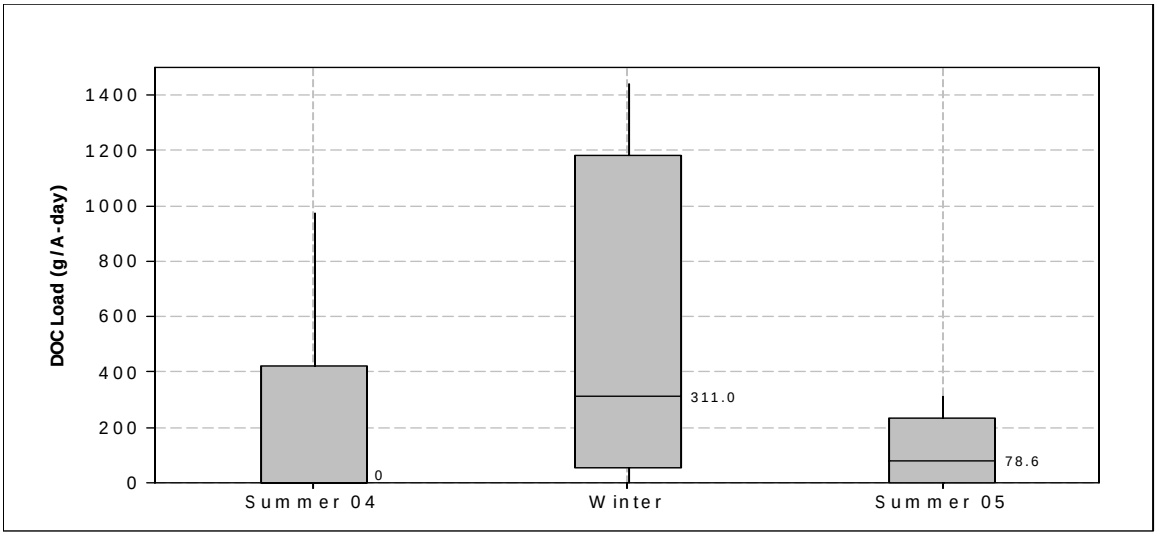


Figure 5-14. Box plots showing seasonal variation in Subsurface DOC load for NRL on Bouldin Island.

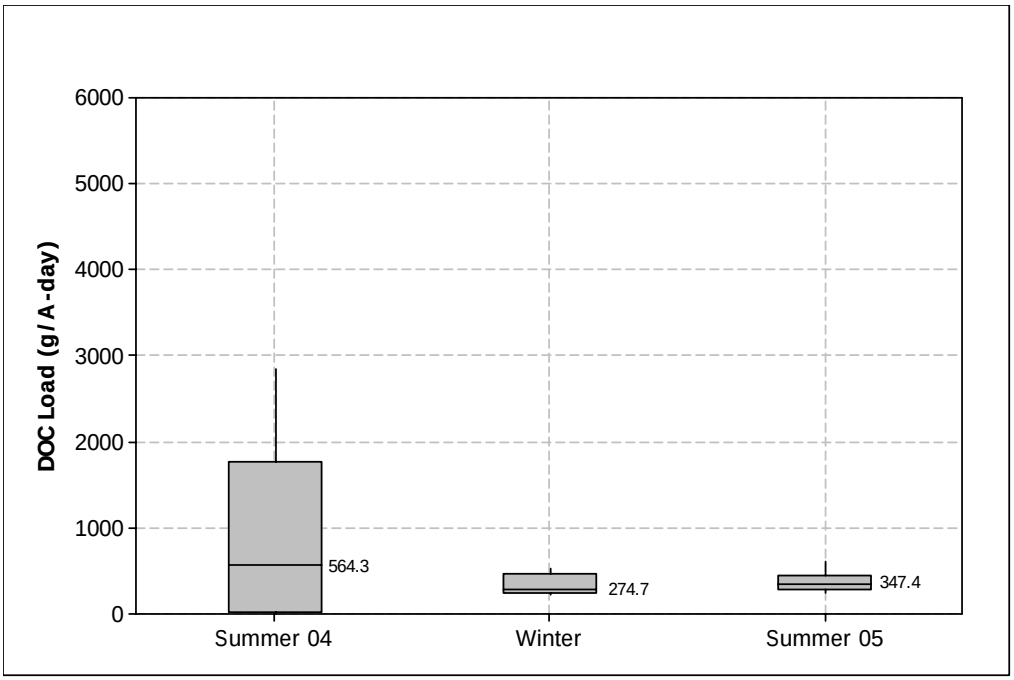


Figure 5-15. Box plots showing seasonal variation in Subsurface DOC loads for OR on Bouldin Island.

Figures 5-12 through 5-15 show seasonal differences for treatments on Bouldin Island. These differences likely result from the seasonal changes in water management. For corn, subsurface DOC loads were significantly lower during summer 2005 relative to summer 2004. Winter loads were not statistically different (at the 95% confidence level) from the summer loads. (For corn, the summer 2005 loads were lower from the winter loads at the 88% confidence level.).

The NRH subsurface loads were significantly lower during summer 2004 relative to summer 2005. However, neither summer 2004 nor summer 2005 loads were significantly different from the winter loads. Based upon our earlier hydrologic analyses and analyses of error, we believe the NRH subsurface loads are high based upon an overestimation of flow from that portion of the drain. This overestimation of NRH subsurface flow would correspond with an underestimation of NRL subsurface flow. This conclusion would is not inconsistent from the results shown in Figure 5-10. In Figure 5-10, the summer 2004 loads were not significantly different from the winter or summer 2005 loads or the winter loads.

For the OR treatment, there were no statistically significant seasonal differences. Overall, for all treatments combined, differences were not statistically significant.

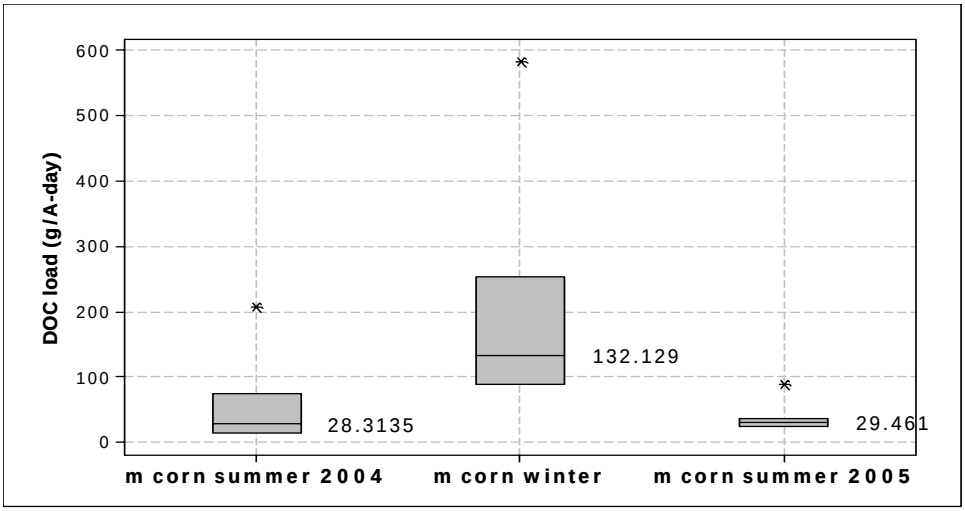


Figure 5-16. Box plots showing seasonal variation in subsurface DOC loads for corn at Wright-Elmwood Tract.

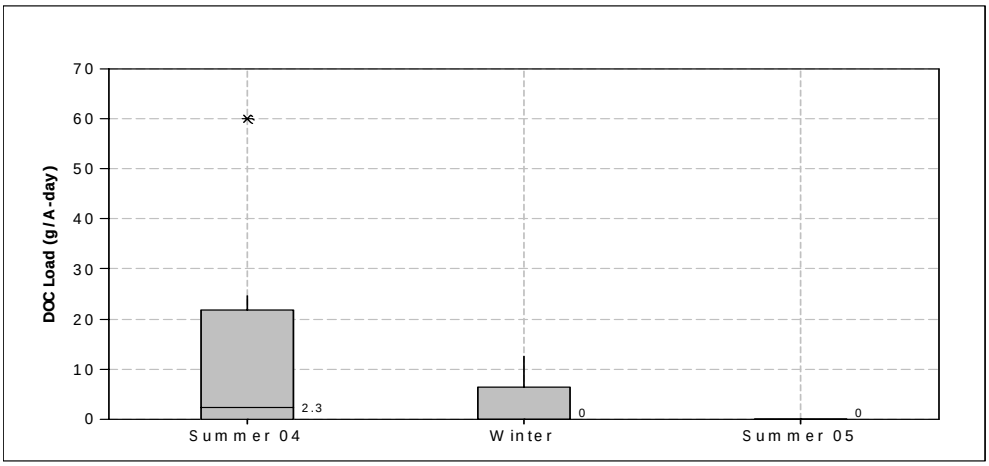


Figure 5-17. Box plots showing seasonal variation in subsurface DOC loads for NRH at Wright-Elmwood Tract.

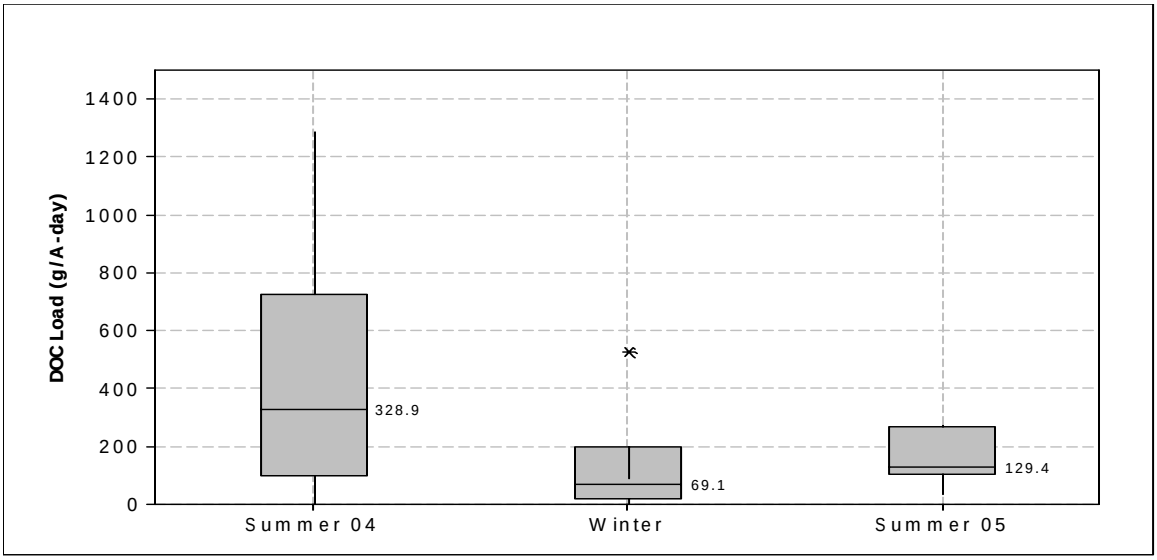


Figure 5-18. Box plots showing seasonal variation in subsurface DOC loads for NRL at Wright-Elmwood Tract.

Figures 5-16 through 5-18 show seasonal differences in subsurface DOC loads for treatments on Wright-Elmwood Tract. For corn, winter loads are significantly greater than summer 2005 loads at the 92.5 % confidence level. Summer 2004 loads were not statistically different from winter or summer 2005 loads. For the NRH treatment, statistical analysis did not indicate any significant differences. For the NRL treatment, statistical analysis did not indicate any significant seasonal differences at the 95 % confidence level. Overall for all treatments, there were no statistical seasonal differences.

Overall, dissolved organic carbon concentrations were not significantly different between the two islands. Figure 5-19 shows the box plots of DOC concentrations for all treatments. However, Figure 5-19 shows that except for Wright-Elmwood Tract NRL, DOC concentrations were generally lower than those determined in Bouldin Island drain samples. For the Bouldin Island treatments, there were not significant differences among NRL, NRH and OR but concentrations in samples from these treatments were all significantly greater than those collected at the corn drain. For the Wright-Elmwood Tract treatments, DOC concentrations were significantly different as follows, corn<NRH<NRL.

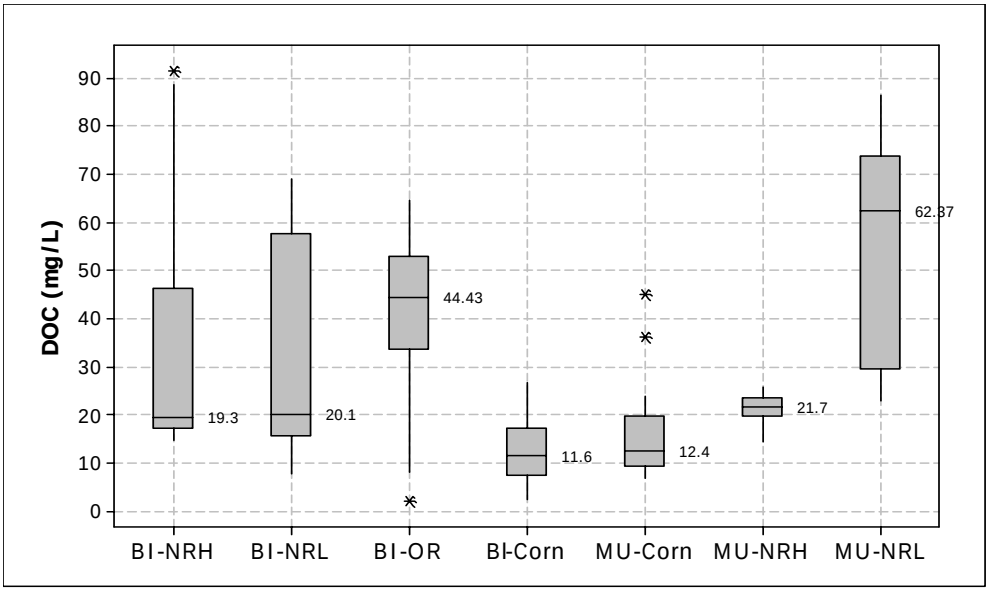


Figure 5-19. Box plots of subsurface drain DOC concentrations.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

5.3.4.2.2 Surface-water Outflow DOC loads

Figure 5-20 shows the box plots for DOC surface water outflow (SWO) loads for Bouldin Island and Wright-Elmwood Tract. Statistical analysis using the Kruskal-Wallis and Mann-Whitney tests indicate no significant differences in surface water loads between Bouldin Island and Wright-Elmwood Tract. Moreover, we did not identify statistically significant differences among treatments on Bouldin Island.

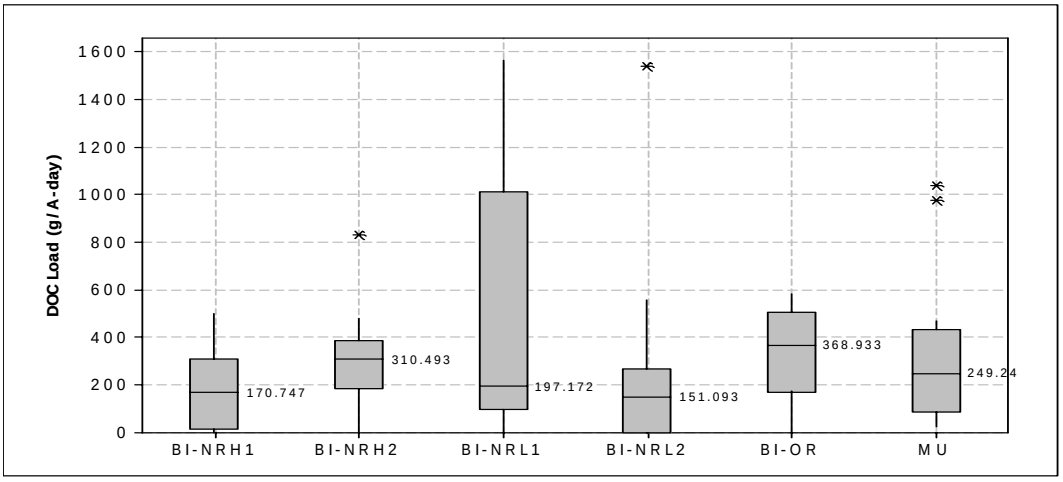


Figure 5-20. Surface water DOC loads for Bouldin Island and Wright-Elmwood Tract.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

There were temporal differences in SWO loads that appear to be due at least in part to changes in water management (Figure 5-21). At Wright-Elmwood Tract, the median for SWO loads was greater in 2004 relative to 2005. In contrast, on Bouldin Island, median loads were greater during 2005 relative to 2004. For the Wright-Elmwood Tract loads, the median load decreased by about 48 % from 302 g/A-day in 2004 to 157 g/A-day in 2005. The difference between the two years is significant at the 90 % confidence level. As discussed in section 5.4.2, in 2005, we installed additional controls in an attempt limit volumes of water flowing onto and off the fields at Wright-Elmwood Tract. These changes reduced flow to Wright-Elmwood Tract by about 56% (Table 5-11).

On Bouldin Island, SWO loads were significantly higher (by about 53 %) during 2005 relative to 2004 at the 95 % confidence level. At Bouldin Island in 2005, we attempted to implement management strategies and structures that would better regulate surface water inflows to rice fields. However, as discussed in more detail in section 5.4.2, water-management complexity

increased on Bouldin Island in 2005 which led to increased surface water outflow and loads. The increased complexity increased flows by about 68% (Table 5-11).

Table 5-11. Change in Median Irrigation Flows to Rice Fields

Location	2004 LPS	2005 LPS	Change between 2004 and 2005 %
Wright-Elmwood Tract	23.13	10.26	-56%
Bouldin Island	19.99	33.66	68%

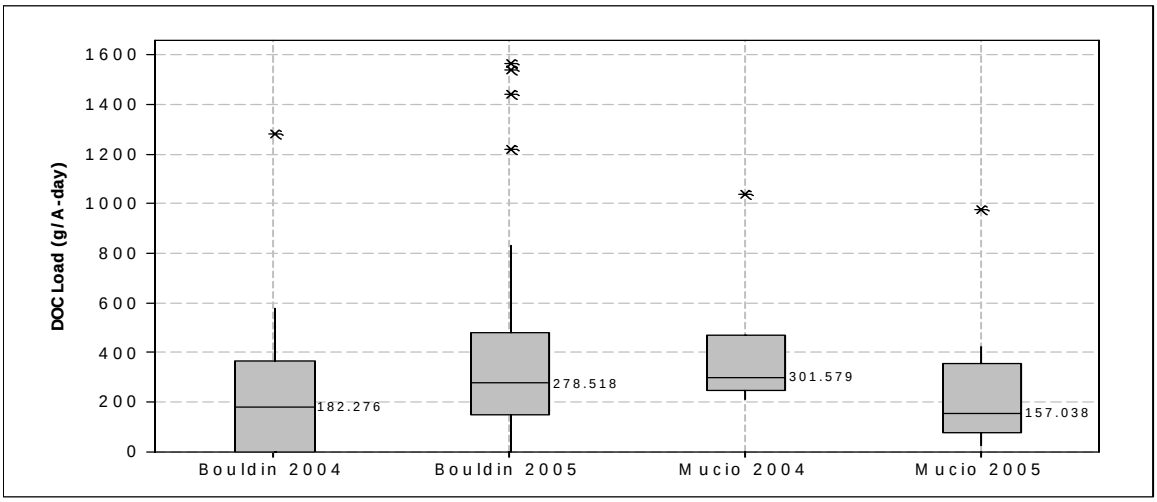


Figure 5-21. Box plots for SWO DOC loads on Bouldin Island and Wright-Elmwood Tract in 2004 and 2005.

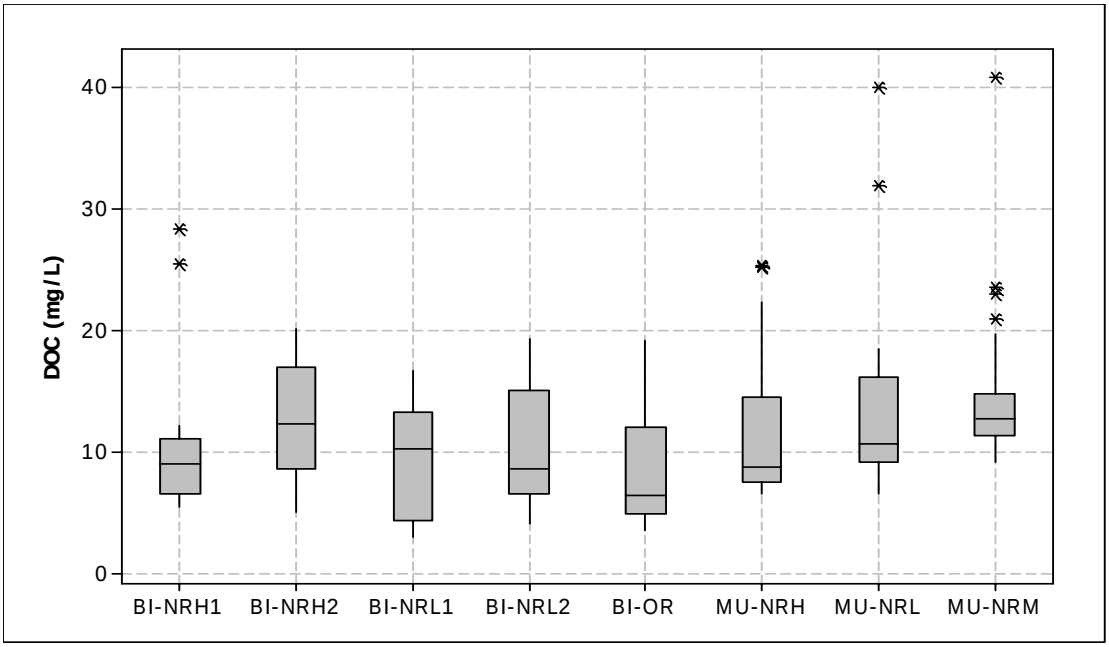


Figure 5-22. Box plots for SWO DOC concentrations on Bouldin Island and Wright-Elmwood Tract in 2004 and 2005.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-18 shows the SWO DOC concentrations on Bouldin Farms on Bouldin Island and at Muzio Farm on Wright-Elmwood Tract. Overall for all treatments, DOC concentrations were significantly higher ($p>0.05$) on Wright-Elmwood Tract (median = 11.74 mg/L) relative to Bouldin Island (median = 9.6 mg/L). On Bouldin Island, there were no significant differences among treatments. At Wright-Elmwood Tract, only NRM concentrations were greater than NRH.

Surface-water loads were larger than or equal to subsurface loads. On Bouldin Island, for all treatments, there was no significant difference between surface (median = 214 g/A-day) and subsurface loads (median = 232 g/A-day). At Wright-Elmwood Tract, subsurface loads were significantly smaller (median = 28.3 g/A-day) than the SWO loads (median = 249.2 g/A-day).

5.3.4.3 Trihalomethane Formation Potential (THMFP) Loads

THMFP Formation Potential is calculated through summing the concentrations of various species of THMs formed during the analytical analyses. Thus, this value represents the total mass of THMs formed.

5.3.4.3.1 Subsurface THMFP loads

Figure 5-23 shows the box plots for subsurface drainage THMFP loads for treatments on Bouldin Island and Wright-Elmwood Tract. Samples were analyzed for THMFP only during summer 2005. Figure 5-24 shows the relation of THMFP to DOC for Bouldin Island and

Wright-Elmwood Tract samples. For all subsurface drain samples, THMFP concentrations were significantly and highly correlated with DOC concentrations ($r^2 = 0.94$). R-squared values for Wright-Elmwood Tract and Bouldin Island are shown on Figure 5-24.

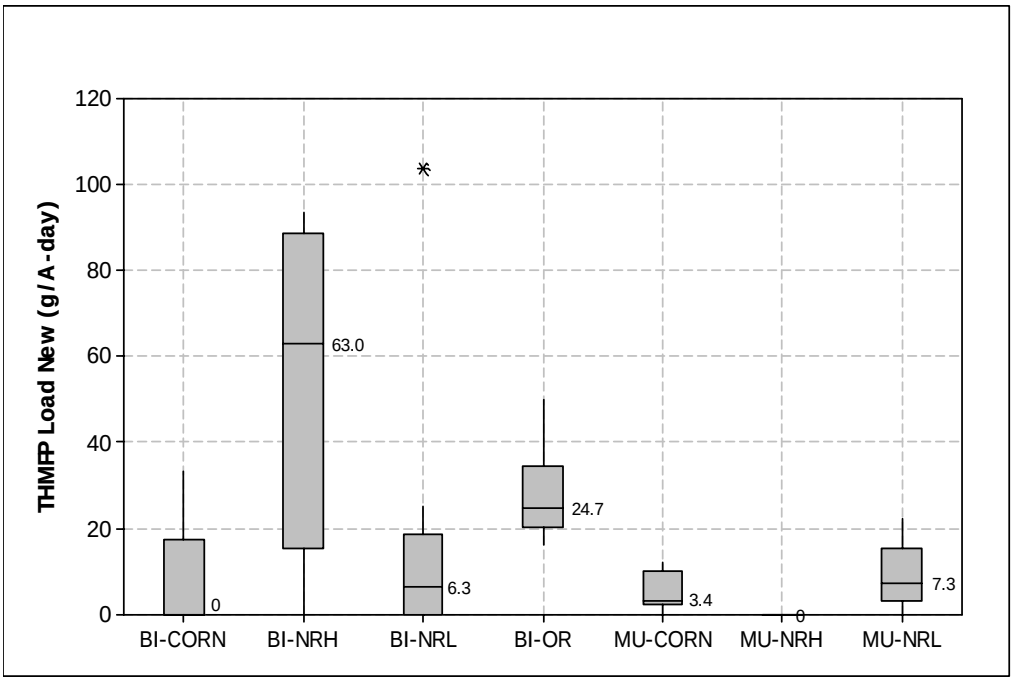


Figure 5-23. Box plots for subsurface drain THMFP loads by treatment for 2005.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

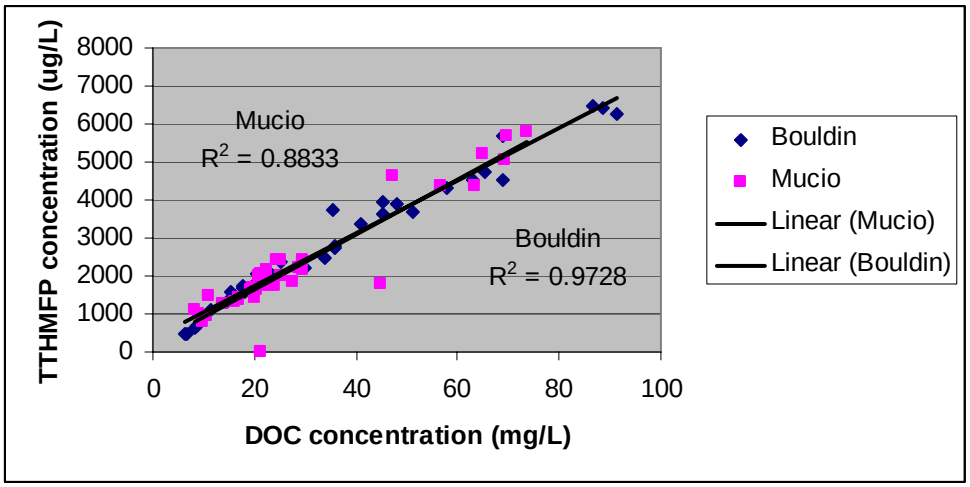


Figure 5-24. Relation of THMFP concentrations to DOC concentrations for DDO sites.

As with the DOC analyses, subsurface THMFP loads were significantly lower for Wright-Elmwood Tract (median = 2.8 g/A-d) relative to Bouldin Island (median = 25.3 g/A-d).

On Bouldin Island, subsurface THMFP loads vary as follows: NRH loads were not significantly different from OR loads and both of these are significantly larger than corn and NRL loads, NRL loads were not significantly different from corn loads. In summary, NRH=OR>corn = NRL. This result mirrored the results for DOC loads at Bouldin Island.

At Wright-Elmwood Tract, THMFP loads for NRL and corn were not significantly different but NRH loads were significantly lower than corn and NRL loads. This result was similar to the DOC result where subsurface loads were significantly different between treatments and NRL had the highest load and NRH had the lowest load.

Because subsurface THMFP loads mirror DOC loads for this project, several other conclusions can be made. First, THMFP loading has similar seasonal variation as DOC loads. Figure 5-24 shows the close association between DOC and THMFP and our above analyses confirms that statistical relationships for THMFP are consistent with those for DOC. Second, the errors associated with calculating subsurface flows at Bouldin Island will also affect our analyses here. Mainly, that error analyses suggests that the THMFP loading from NRH drains is overestimated in 2005 and the associated NRL drain load is underestimated because of errors in calculating high flows through the v-notch weir separating the high drain portion from the low drain portion.

Drain concentrations of THMFP were not significantly different between Bouldin Island and Wright-Elmwood Tract (Figure 5-25). Similarly, STHMFP values are not significantly different between the two islands (Figure 5-26). However, on Bouldin Island, THMFP concentrations are significantly lower for corn (median = 883 μg/L) than NRL (median = 1,881 μg/L), OR (median 3,516 μg/L) and NRL (median = 2,204 μg/L). The NRL, NRH and OR concentrations are not significantly different. For STTMFP, there were no significant differences among treatments on Bouldin Island.

For the Wright-Elmwood Tract treatments, THMFP concentrations were significantly lower for corn (median = 1,379 μg/L) than NRH (median = 2.002 μg/L) and NRL (median = 4,368 μg/L). The NRL THMFP concentrations were significantly greater than the NRH concentrations. For STHMFP on the Wright-Elmwood Tract treatments, corn values are significantly greater than NRL but not significantly different from NRH. NRH and NRL were also not significantly different. Figures 5-25 and 5-26 show the box plots for THMFP concentrations and STHMFP values for all treatments on both islands.

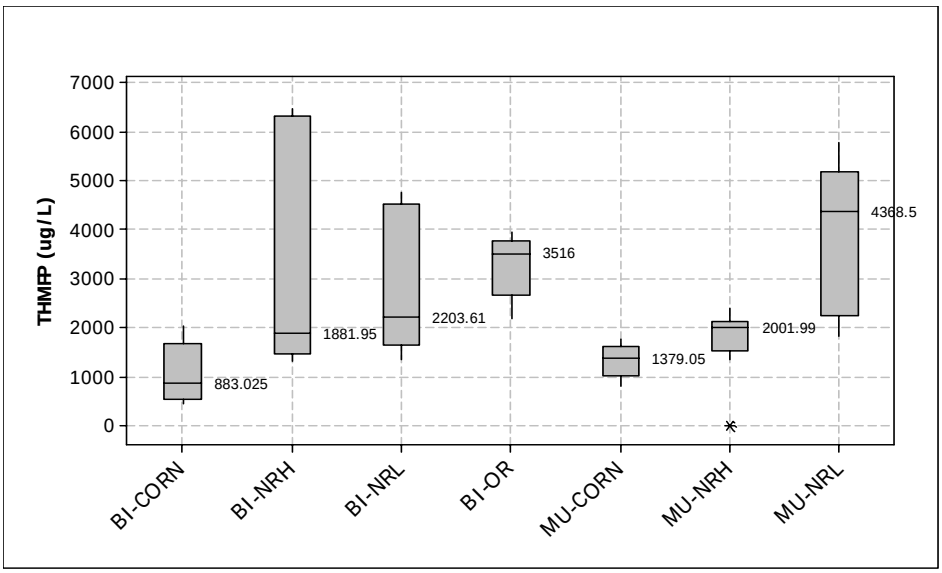


Figure 5-25. Box plots of drain flow THMFP concentrations.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

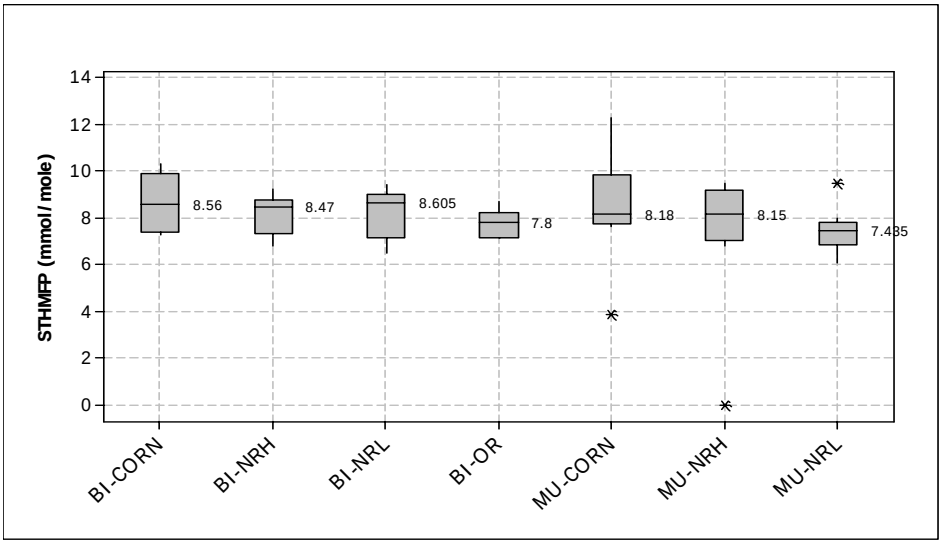


Figure 5-26. Box plots of drain flow STHMFP values.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

5.3.4.3.2 Surface THMFP loads

Figure 5-27 shows box plots for surface drainage THMFP loads for treatments on Bouldin Island and at Wright-Elmwood Tract. For Wright-Elmwood Tract, we added loads for the three SWO sites and divided by the total contributing area of 75.5 acres. This includes the experimental plots (21.8 acres) and the upslope land planted to rice. Samples were analyzed for THMFP only during summer 2005. Figure 5-28 shows the relation of THMFP to DOC for Bouldin Island and Wright-Elmwood Tract samples. For all SWO samples, THMFP concentrations were significantly and highly correlated with DOC concentrations ($r^2 = 0.92$). R-squared values for Wright-Elmwood Tract and Bouldin Island are shown on Figure 5-28.

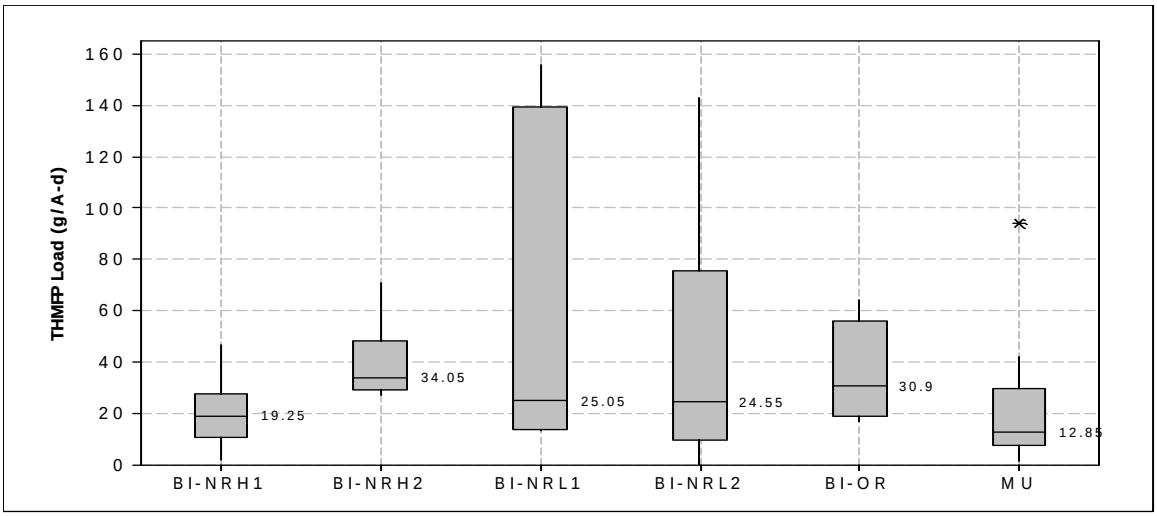


Figure 5-27. Box plots for THMFP for SWO sites on Bouldin Island and Wright-Elmwood Tract.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

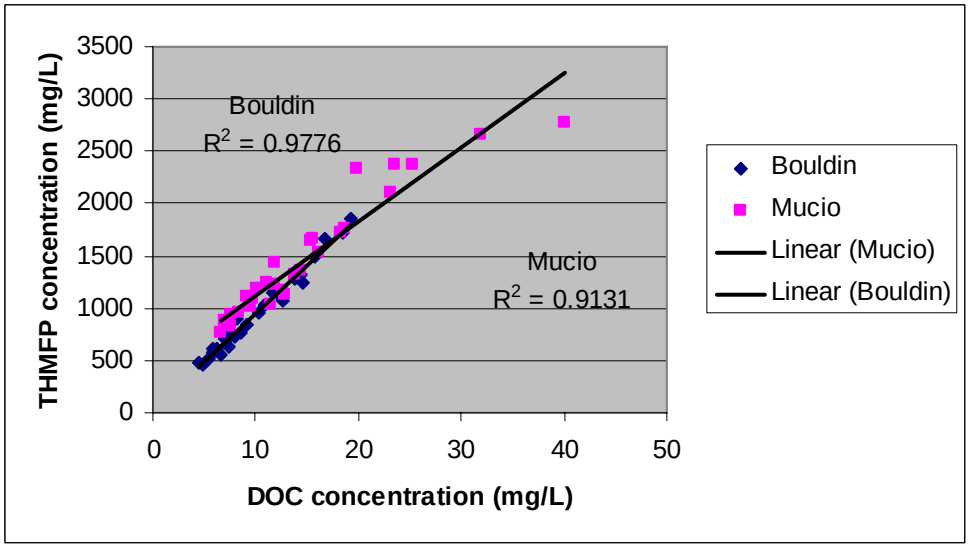


Figure 5-28. THMFP Concentrations from the Rice Fields linearly related to DOC concentrations for SWO sites.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Using the Mann-Whitney and Kruskal-Wallis tests, we determined that THMFP loads on Bouldin Island (median load = 28 g/A-day) were significantly greater (at the 92.5 % confidence level) than at Wright-Elmwood Tract (median load = 13 g/A-day). Moreover, there were not significant differences among treatments on Bouldin Island. In contrast, SWO THMFP concentrations on Wright-Elmwood Tract were significantly higher relative to Bouldin Island. There were not significant differences among treatments for THMFP concentrations on Bouldin Island or at Wright-Elmwood Tract. Figure 5-29 shows the box plots for concentrations for all treatments on both islands.

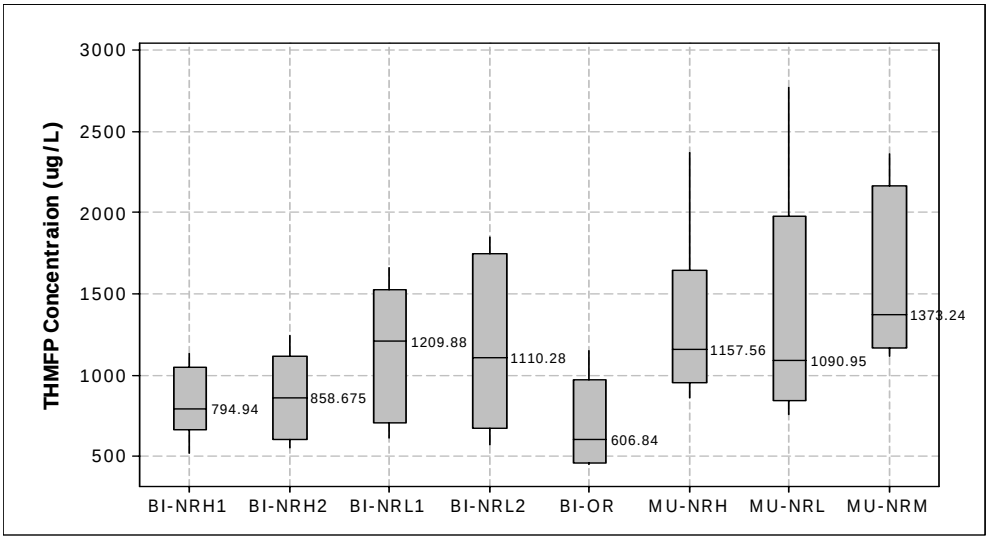


Figure 5-29. Box plots for THMFP concentrations.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

5.3.4.4 Nitrogen loads

5.3.4.4.1 Subsurface loads

Figures 5-30 through 5-32 show box plots for loads for nitrogen species; ammonia (NH_4), nitrate (NO_3) and dissolved organic nitrogen (DON) by treatment for subsurface drains. Subsurface loads were calculated in the same manner as DOC loads discussed in Section 5.3.3.1. Variations in loads among treatments were different for the different N species. Ammonia and DON were similar across treatments with the old rice field of Bouldin Island (B OR) exporting the greatest loads for both species. Nitrate loads were very different than NH_4 and DON for both farms' corn fields; Wright-Elmwood Tract NRL drain treatment exported large amounts of NO_3.

The large exports of NO_3 from the corn fields occurred exclusively in the winter season whereas the NRL field at Wright-Elmwood Tract exhibited large exports during initial flooding of the field during the first year of the study and during the winter season flooding. The Wright-Elmwood Tract NRL field had elevated exports at initial flood of the second growing year of the study but the levels were lower than the first. No other rice field exhibited any seasonal changes; although DON exports from Bouldin Island the NRH treatment appeared to increase throughout the study period and seemed to approach exports of the OR field.

Proportions of the N species in the export loads differed between treatments. The corn field exports were primarily as NO_3 and DON with small amounts of NH_4. The rice fields primarily exported DON with the old rice field containing a higher proportion of NH_4 than the new rice fields. Only the low drain treatment at Wright-Elmwood Tract contained significant NO_3 loads as discussed above.

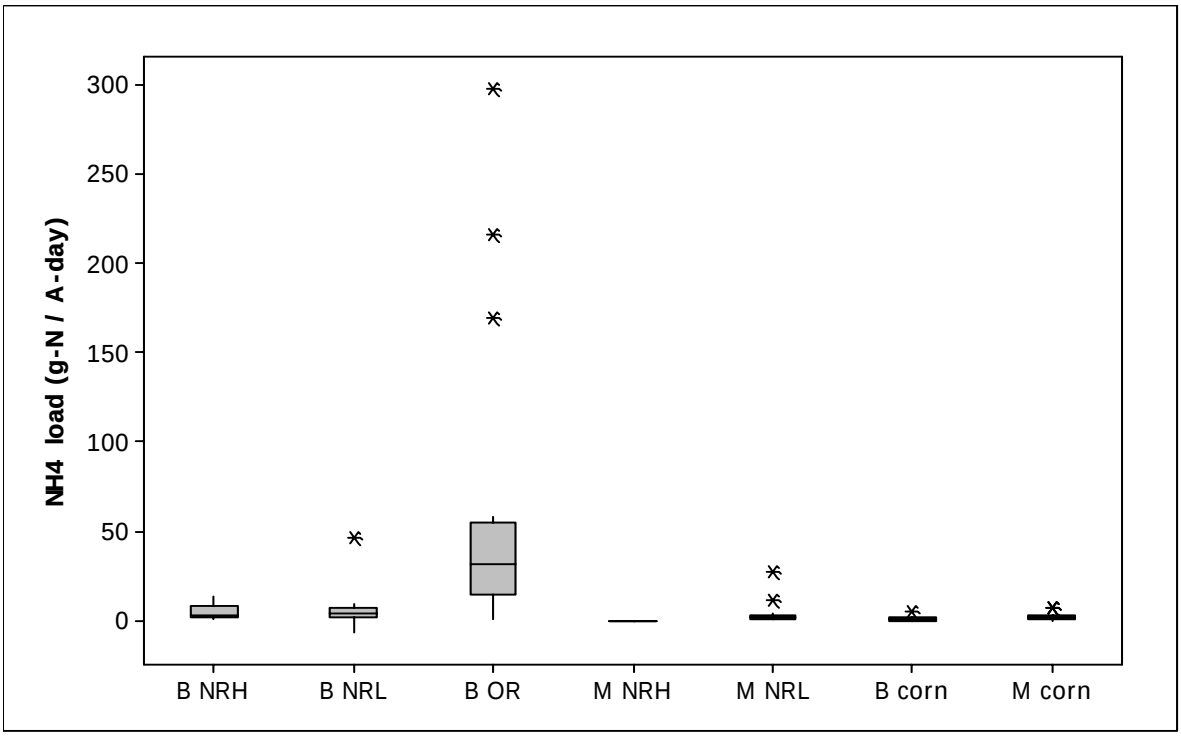
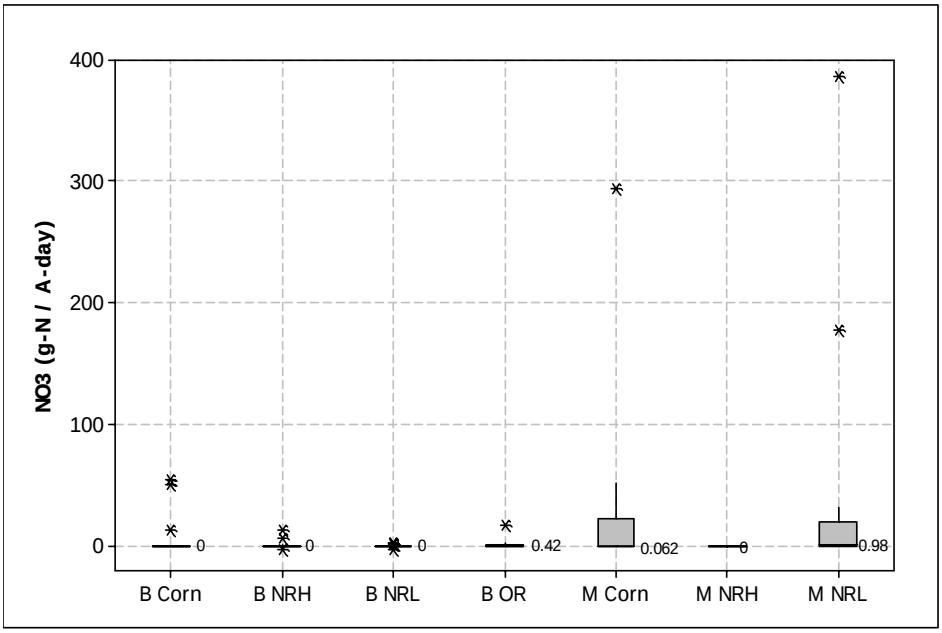


Figure 5-30. NH_4 (or Ammonia) loads for subsurface drains.

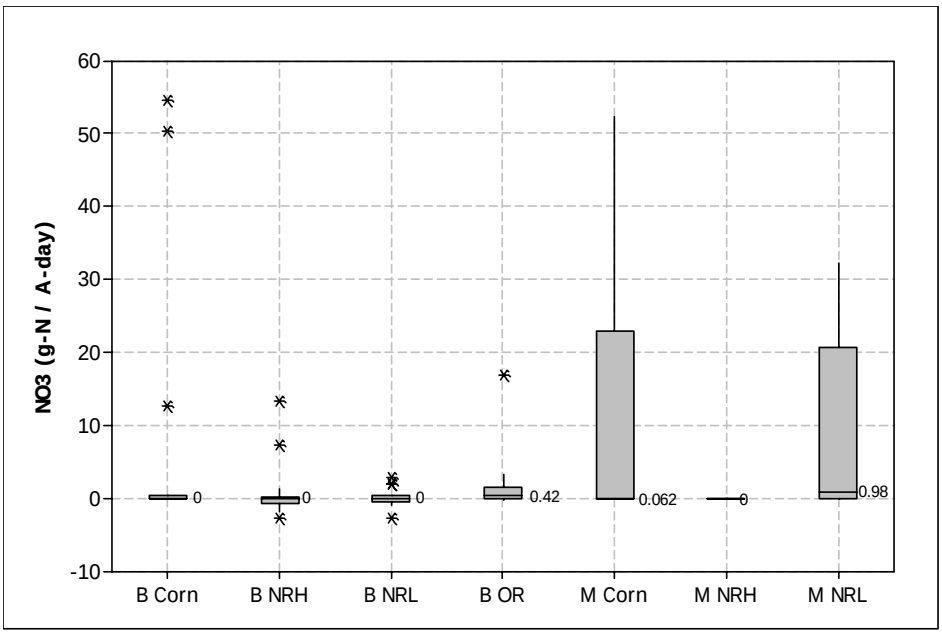
"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-31. Subsurface Nitrogen Loads

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.



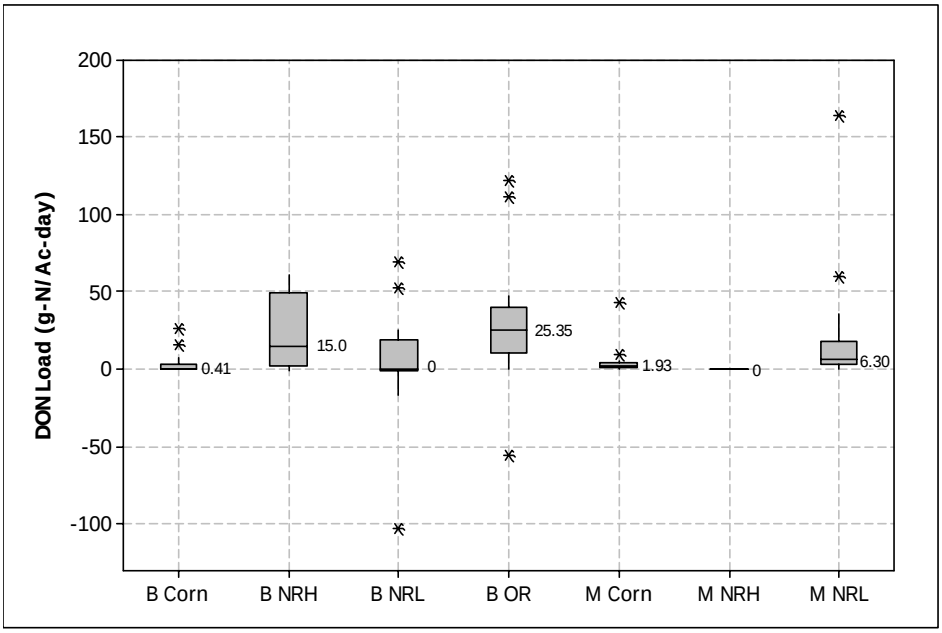
A. Nitrate loads for subsurface drains.



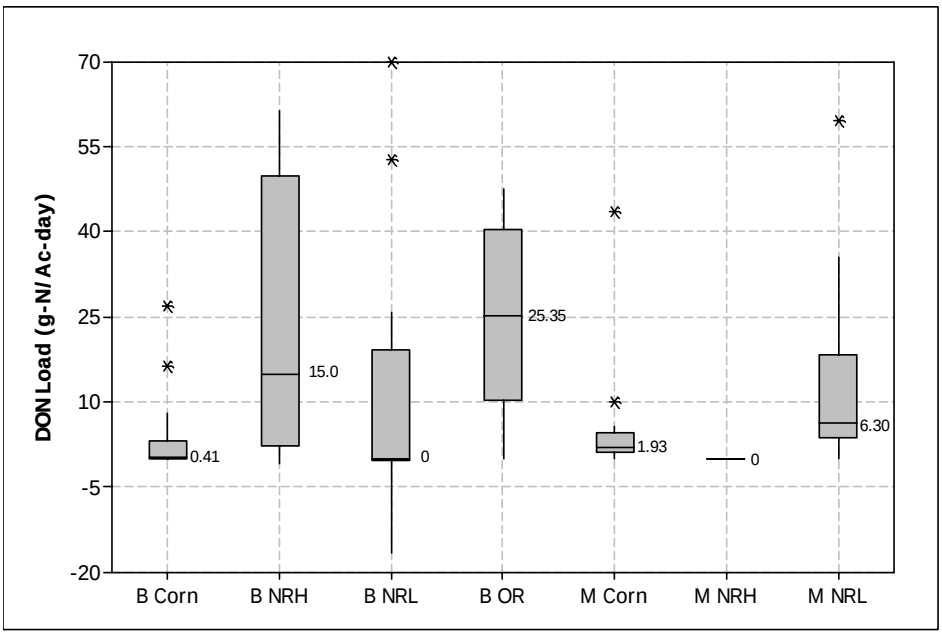
B. Nitrate loads for subsurface drains without outliers.

Figure 5-32. Dissolved Organic Nitrogen Loads for Subsurface Drains

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.



A. With outliers.



B. Without Outliers

5.3.4.4.2 Surface Water Outflow loads

Nitrogen loads from rice field surface water outflow are similar for all treatments (Figure 5-33 through Figure 5-35). Overall, the only significant difference is that Wright-Elmwood Tract had greater NH_4 exports than Bouldin Island. Surface water N loads are dominated by DON with only small amounts of NH_4 and NO_3, which is typical in a wetland setting.

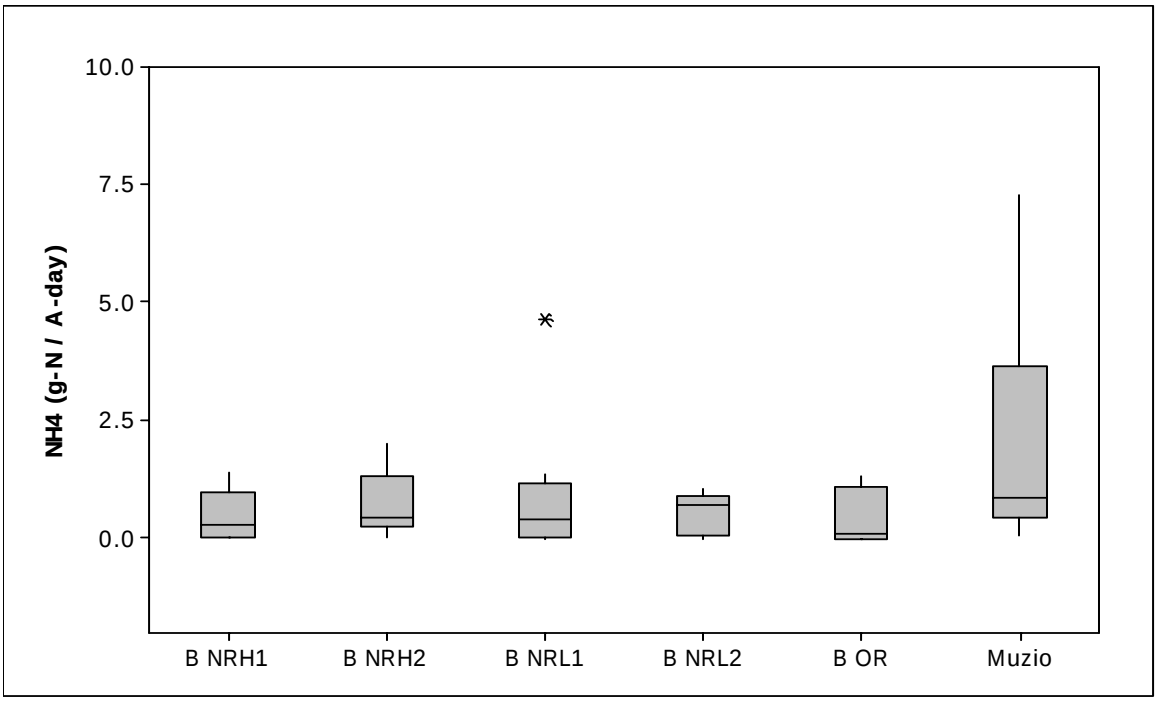


Figure 5-33. NH_4 loads for surface water outflow.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

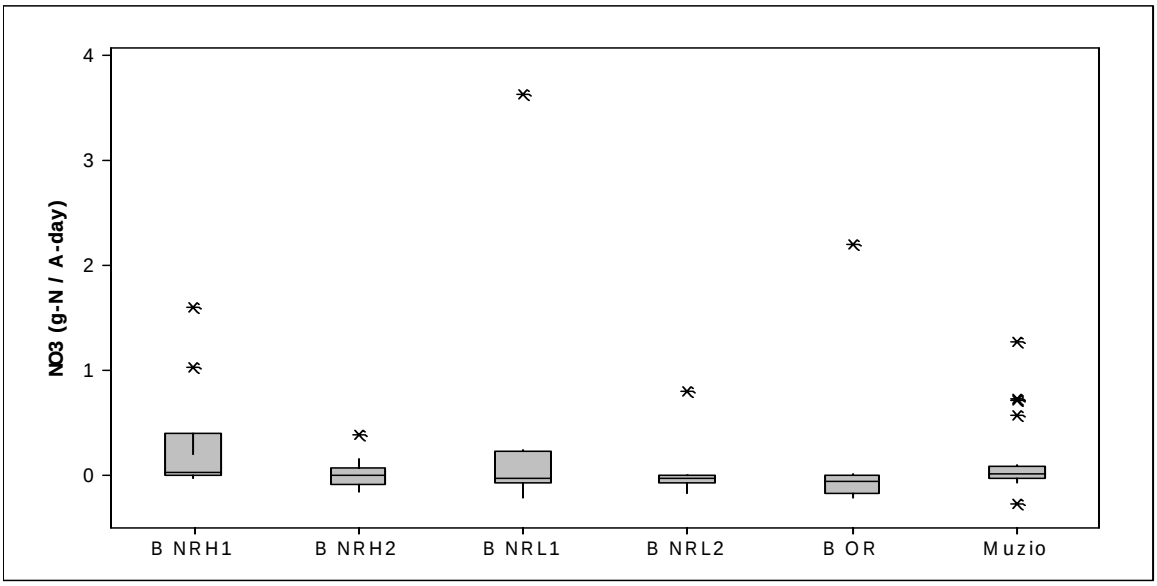


Figure 5-34. Nitrate loads for surface water outflow

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

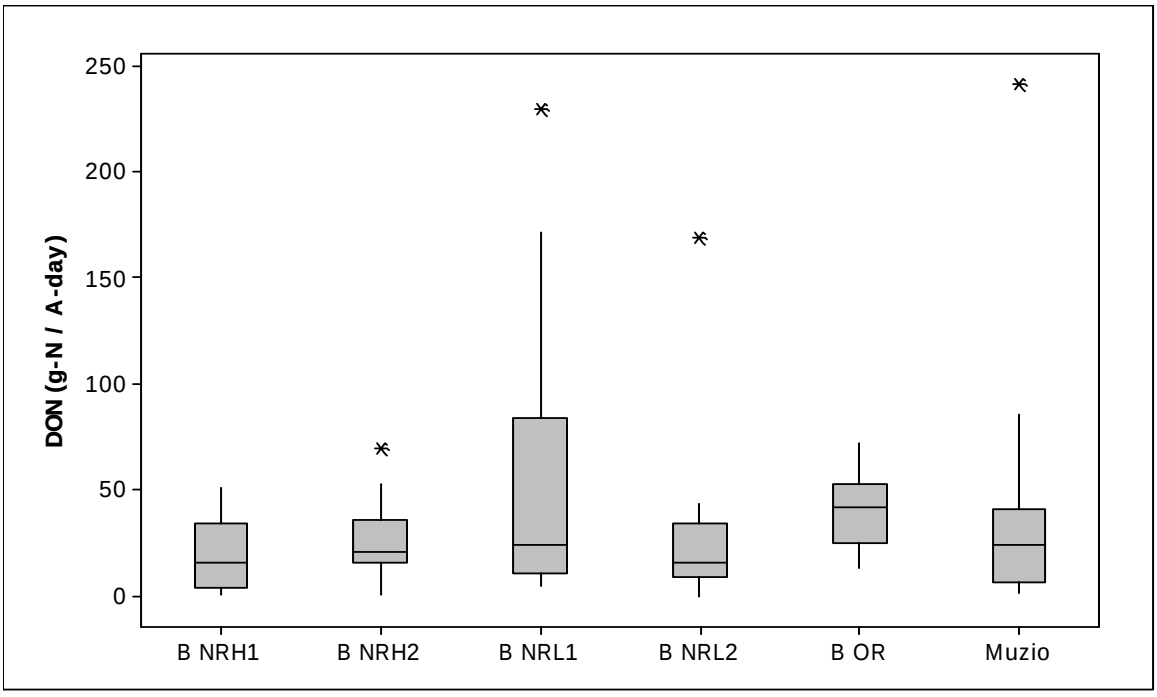


Figure 5-35. Dissolved organic nitrogen loads for surface water outflow

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

5.3.4.5 Comparison with Subsurface and Surface-water Outflow Loads for Other Delta Islands.

Table 5-9 shows that subsurface DOC loads for corn measured during this study were within the range of values measured on other Delta islands. For rice, Bouldin Island and Wright-Elmwood Tract winter DOC loads were generally consistent with other winter loads for other Delta islands. Summer rice loads are consistently higher than other summer DOC loads reported in Table 5-9 except for Jersey Island loads reported by Deverel and Rojstaczer (1996). Average wetland subsurface DOC loads on Twitchell Island (Fleck et al, in review) ranged from 816 to 1,340 g/A-day generally consistent with subsurface DOC loads for Bouldin Island rice but higher than DOC loads for Wright-Elmwood rice.

Surface-water DOC outflow loads for Twitchell wetlands ranged from 170 to 364 g/A-day. Rice surface-water outflow loads for Bouldin Island and Wright-Elmwood Tract are generally consistent with these values. Average values for NRL Wright-Elmwood Tract ranged from 180 to 428 g/A-day and average values for Bouldin Island ranged from 191 to 584 g/A-day.

Table 5-12. Comparison of subsurface loads with other Delta Islands.

Island	Summer loads (g carbon/A-d)	Winter loads (g C/A-d)	Source
Jersey Island (fallow)	Average = 1,208 Range = 720 – 1,640		Deverel and Rojstaczer (1996)
Orwood Tract (asparagus)	Average = 8 Range = 0.52 – 9.6	Average = 46 Range = 38 - 53	Deverel and Rojstaczer (1996)
Sherman Island (winter grains and fallow)	Average = 7.2 Range = 0.08 – 21		Deverel and Rojstaczer (1996)
Twitchell Island 1995 - 1996 (Predominantly corn with other field and row crops)	Average = 72 Range = 18 - 159	Average = 570 Range = 77 – 1,238	Templin and Cherry (1997) and Department of Water Resources Municipal Water Quality Investigations Program
Twitchell 2000 – 2003 corn	Average = 37 Range = 8 - 79	Average = 143 Range = 55 - 250	Range of averages for entire island and two study areas.
Bouldin Rice	101 – 2,256	299 - 673	(this study)
Bouldin Corn	59 +/- 122	299 +/- 132	(this study)
Wight-Elmwood Corn	38 - 53	221 +/- 222	(this study)
Wright-Elmwood Rice	25 - 501	12 - 218	(this study)

5.3.4.6 Loads Summary

A summary of major conclusions from our analysis of measured loads follows.

5.3.4.6.1 DOC Loads

- Subsurface Loads
  - Overall, subsurface DOC loads on Bouldin Island were larger than those at Wright-Elmwood Tract. These subsurface loads at Bouldin Island are likely overestimated by 20 to 50 % because of an underestimation of contributing areas. Even after adjusting the loads, Bouldin Island subsurface loads are higher then those at Wright-Elmwood Tract.
  - On Bouldin Island, subsurface DOC loads for OR and NRH were larger than those for the NRL and corn treatments. A closer look at errors associated with estimating subsurface loads suggests that DOC loads are not statistically different between the different rice treatments (i.e. established v new rice, low drain v high drain).
  - On Wright-Elmwood Tract, subsurface NRL loads were greater than corn loads which were greater than NRH loads. Differences in head between field surface water elevation and drain ditch water elevation explains about half the variance associated with subsurface flows at Wright-Elmwood Tract.
  - There were seasonal differences in subsurface loads for specific treatments on both islands. These seasonal differences likely are a reflection of the seasonal differences in water management on the islands. Overall for all treatments, there were not significant seasonal differences.
  - Overall, dissolved organic carbon concentrations in subsurface drains were not significantly different among the two islands. However, except for the Wright-Elmwood Tract NRL treatment, drain DOC concentrations at Wright-Elmwood Tract were generally lower than those determined in Bouldin Island drain samples.

- Surface Loads
  - There were no statistically significant differences in surface-water outflow (SWO) loads between islands or among treatments.
  - On Bouldin Island, SWO DOC loads were about 53 % higher in summer 2005 relative to summer 2004. At Wright-Elmwood Tract, DOC loads were about 48 % lower in summer 2005 relative to summer 2004. These increases and decreases in surface water loading mirror changes in irrigation practices and the corresponding water volumes applied during those two years at each site. Surface flows increased by 68% in Bouldin Island between summer 2004 and summer 2005 and surface flows decreased by 56% at Wright-Elmwood Tract during the same period.
  - Overall, SWO DOC concentrations at Wright-Elmwood Tract (median = 11.74 mg/L) were significantly larger than Bouldin Island (median = 9.6 mg/L).

- Surface v Subsurface Comparison
  - On Bouldin Island, overall subsurface DOC loads (median = 232 g/A-day) were approximately equal to surface loads (median = 214 g/A-day). Errors in

estimating contributing error suggests that surface DOC loads were approximately 20 to 50 % higher then subsurface loads (Section 5.3.2.2). At Wright-Elmwood Tract, subsurface loads (median = 28.3 g/A-day) were significantly less than surface loads (median = 249.2 g/A-day).

5.3.4.6.2 THMFP Loads

- For Bouldin Island and Wright-Elmwood Tract and overall, DOC and THMFP concentrations were significantly and highly correlated for subsurface and SWO samples.
- Overall, subsurface THMFP loads at Bouldin Island (median = 25.3 g/A-day) were larger than those at Wright-Elmwood Tract (median = 2.8 g/A-day). At Wright-Elmwood Tract, the NRH significantly limited loads relative to the other treatments.
- Drain water THMFP concentrations were not significantly different between the two islands.
- Overall, surface THMFP loads on Bouldin Island (median = 28 g/A-day) were greater than at Wright-Elmwood Tract (median = 13 g/A-day) at the 92.5 % confidence level.
- Surface-water outflow THMFP concentrations were significantly higher at Wright-Elmwood Tract relative to Bouldin Island but there were not significant differences among treatments on Bouldin Island or at Wright-Elmwood Tract.

5.3.4.6.3 Nitrogen Loads

- Surface water loads
  - Nitrogen loads for rice field surface water outflows are similar for all treatments. Overall, the only significant difference is that Wright-Elmwood Tract had greater NH_4 exports than Bouldin Island. Seasonally, Wright-Elmwood Tract had higher exports of DON and NO_3 from the surface waters in 2005 than in 2004 growing seasons. Surface water N loads are dominated by DON with only small amounts of NH_4 and NO_3, which is typical in a wetland setting.
  - Nitrogen loads for rice field surface water outflows are similar for all treatments although Wright-Elmwood Tract had greater NH_4 exports than Bouldin Island.
  - Surface water N loads were dominated by DON with only small amounts of NH_4 and NO_3.

- Subsurface water loads
  - Subsurface NH_4 and DON loads were similar across treatments with the old rice field of Bouldin Island (B OR) exporting the greatest loads for both species.
  - Subsurface nitrate loads for corn and Wright-Elmwood Tract NRL were significantly higher than the other treatments.
  - The large subsurface NO_3 exports from the corn fields occurred exclusively in the winter season.
  - The NRL field at Wright-Elmwood Tract exhibited large exports during initial flooding of the field during the first year of the study and during the winter season flooding.
  - The corn field subsurface N loads were primarily as NO_3 whereas the rice field subsurface loads were primarily as DON.

5.3.5 Soils Data

The average thickness of organic soil varied between the two locations (Table 5-13). On Bouldin Island, organic soil depths ranged from 98.0-124.0 cm with the minimum and maximum thickness at the NRH1 and NRL1 fields, respectively. The depth of organic soils on the four treatment areas at Wright-Elmwood Tract ranged from 62.3-96.0 cm. Peat thickness generally thinned to the west, with the minimum and maximum thickness in the NRH and NRL plots, respectively. A sand layer was generally under the peat soils at Bouldin Island. At Wright-Elmwood Tract, a sandy clay loam or clay underlay the peat soils.

Table 5-13. Average organic soil thickness (cm) on Bouldin Island and Wright-Elmwood Tract.

Bouldin Island					
Site	**NRH1**	**NRH2**	**NRL1**	**NRL2**	**OR**
Average depth of peat (cm)	98.2	112.0	124.5	108.2	113.2
Wright-Elmwood Tract					
Site	**Corn**	**NRH**	**NRM**	**NRL**	
Average depth of peat (cm)	75.5	96.0	75.6	62.4	

5.3.5.1 Soil Carbon

Figure 5-36 shows the box plots for percent soil carbon for the 0 to 45 cm depth interval. Median values ranged from 12.15 % for Bouldin Island NRH1 to 23.8 % for Bouldin Island NRL1. Using the Mann-Whitney test, we determined that for the 78 samples collected on Bouldin Island and 59 samples collected on Wright-Elmwood Tract in the 0 – 45 cm depth interval, there was no significant difference. Within treatments on Bouldin Island, there were no significant differences between OR, NRL1, NRL2 and NRH2 but all of these were greater than NRH1. On Wright-Elmwood Tract, significant differences were as follows: NRH>corn. There were no significant differences between corn, NRM and NRL.

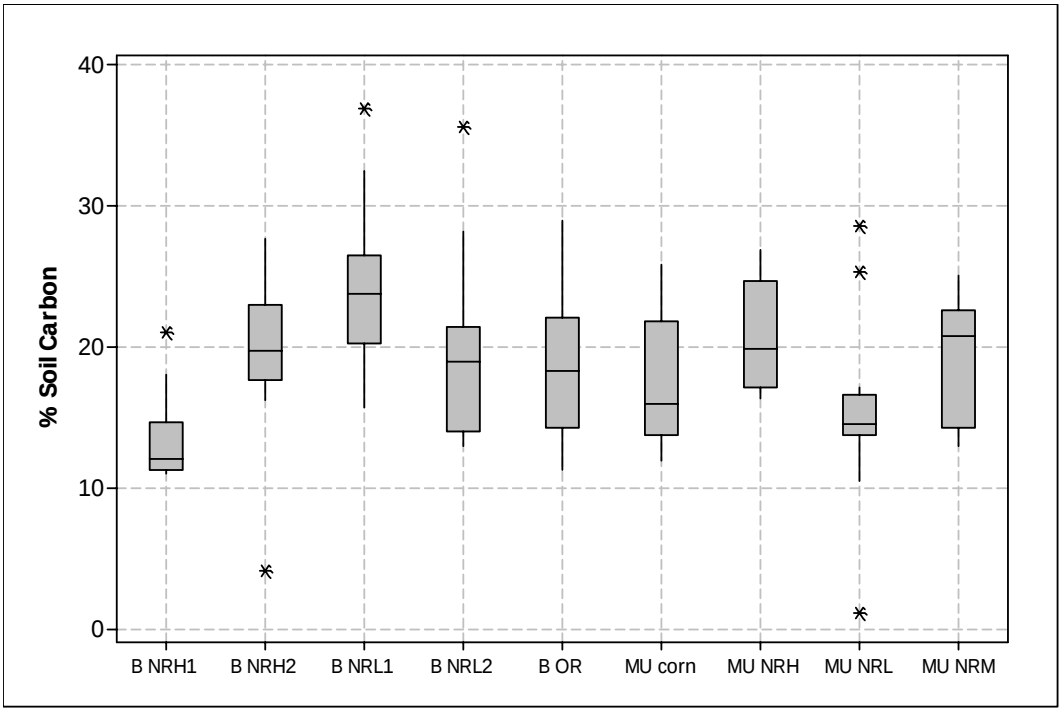


Figure 5-36. Box plots for percent soil organic carbon for the 0 to 45 cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

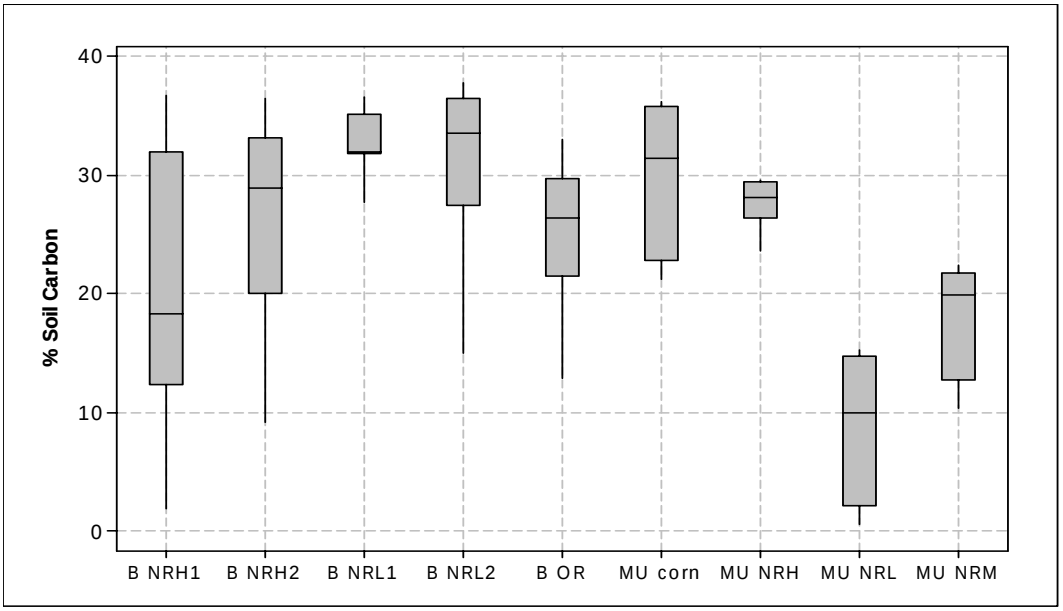


Figure 5-37. Box plots for percent soil organic carbon for the 46 to 89 cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-37 shows the box plots for percent soil carbon for the 46 – 89 cm depth interval. Median values ranged from 10 % for Wright-Elmwood Tract NRL to 33.6 % for Bouldin NRL2. Using the Mann-Whitney test, we determined that for the 37 samples collected in the 46 - 89 cm depth interval on Bouldin Island and 22 samples collected on Wright-Elmwood Tract, percent soil carbon was higher at the 92.5 % confidence level on Bouldin Island (median = 29.3 %) relative to Wright-Elmwood Tract (median = 23.4 %). Within treatments on Bouldin Island, there were significant differences as follows: NRL1 and NRL2 were greater than OR. There were no significant differences between NRL1, NRL2, NRH1 and NRH2. On Wright-Elmwood Tract, significant differences were as follows: NRH > NRL and NRM and Corn>NRL.

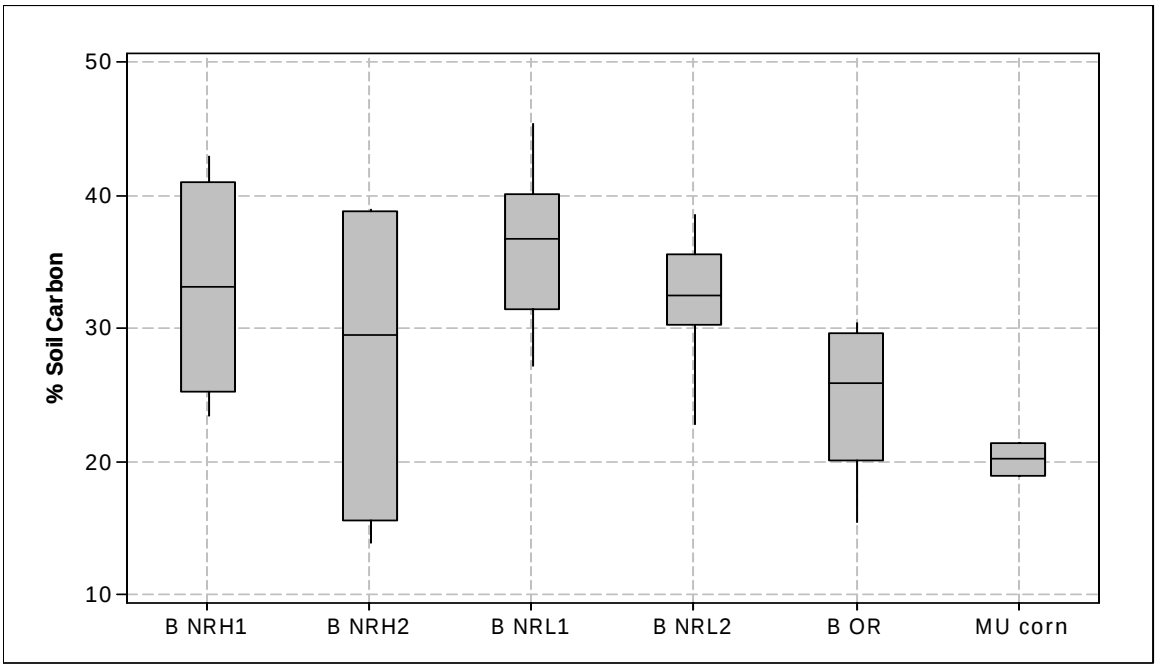


Figure 5-38. Box plots for percent soil organic carbon for the 90+ cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-38 shows the box plots for percent soil carbon for the 90+ cm depth interval. Median values ranged from 20.14 % for Wright-Elmwood Tract corm (2 samples) to 36.6 % for Bouldin Island NRL1. Because the peat is generally shallower than 90 cm at Wright-Elmwood Tract, there were only two samples collected in the corn field. Within treatments on Bouldin Island, there were significant differences as follows: NRL1>OR and NRL2>OR.

5.3.5.2 Soil Nitrogen

Figure 5-39 shows the box plots for percent soil nitrogen for the 0 to 45 cm depth interval. Median values ranged from 0.98 % for Wright-Elmwood Tract NRL to 1.6 % for Bouldin Island NRL1. Using the Mann-Whitney test, we determined that for the 82 samples collected on Bouldin Island and 59 samples collected at Wright-Elmwood Tract in the 0 – 45 cm depth interval, soil nitrogen was higher on Bouldin Island (overall median = 1.35 %) relative to Wright-Elmwood Tract overall median = 1.18 %.) . Within treatments on Bouldin Island, there were significant differences as follows: NRL1>NRH2=OR=NRL2>NRH1. There were no significant differences between NRH2, NRL2 and OR. On Wright-Elmwood Tract, significant differences were as follows: NRH=corn=NRM>NRL.

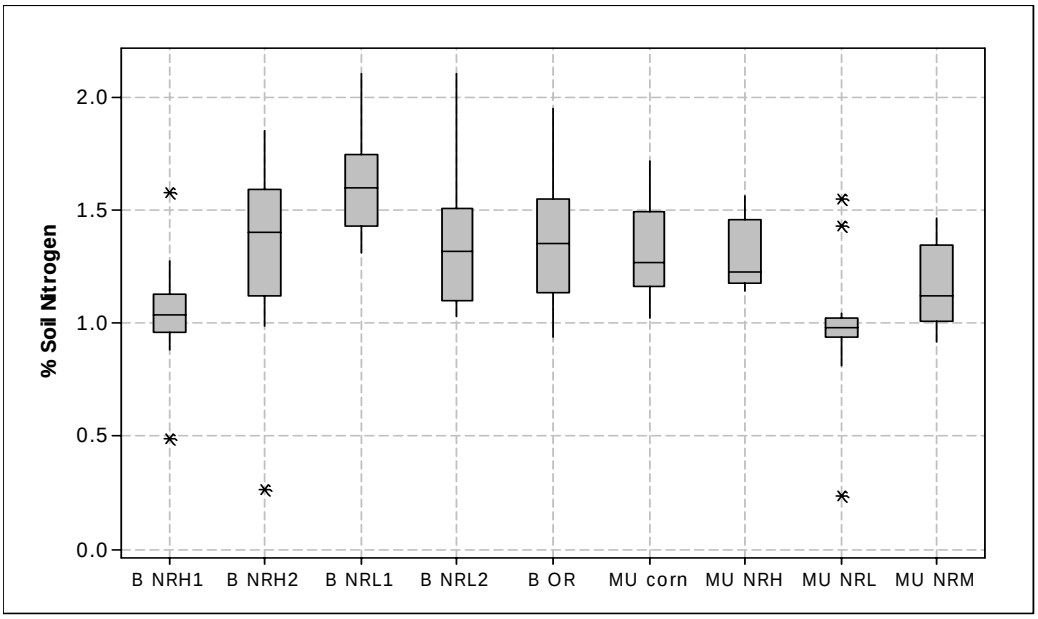


Figure 5-39. Box plots for percent soil nitrogen for the 0 to 45 cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-40 shows the box plots for percent soil nitrogen for the 46 – 89 cm depth interval. Median values ranged from 0.6 % for Wright-Elmwood Tract NRL to 1.83 % for Bouldin Island NRL2. Using the Mann-Whitney test, we determined that for the 33 samples collected in the 46 - 89 cm depth interval on Bouldin Island and 23 samples collected on Wright-Elmwood Tract, percent soil nitrogen was higher at the 95 % confidence level on Bouldin Island (median = 1.7 %) relative to Wright-Elmwood Tract (median = 1.4 %). Within treatments on Bouldin Island, there were no significant differences as follows except NRL1 was greater than OR. On Wright-

Elmwood Tract, all treatments were significantly different as follows: Corn>NRH.> NRM. > NRL

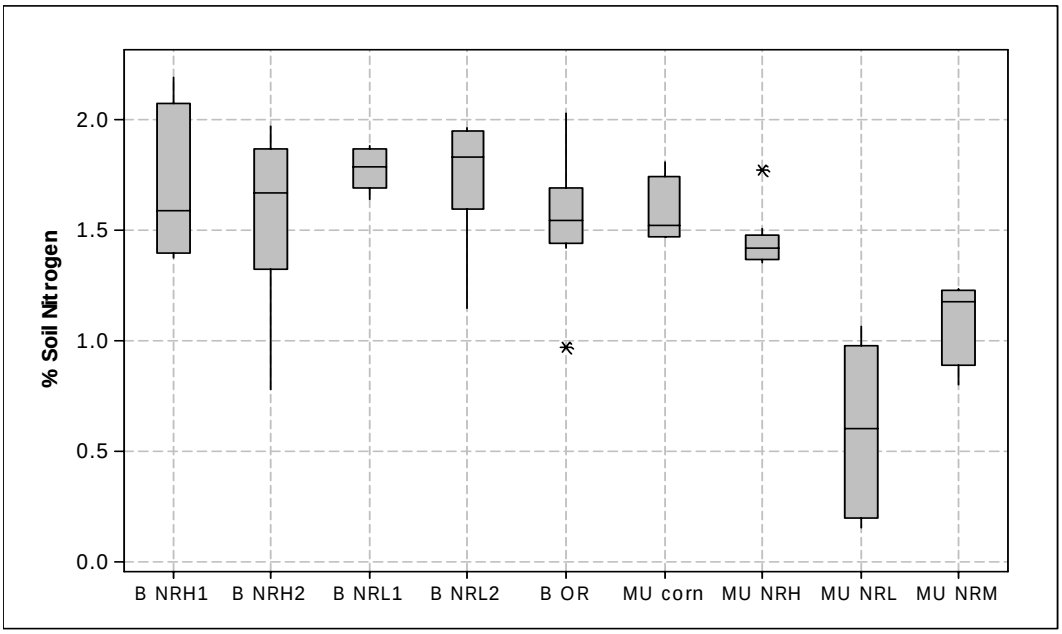


Figure 5-40. Box plots for percent soil nitrogen for the 46 to 89 cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Figure 5-41 shows the box plots for percent soil carbon for the 90+ cm depth interval. Median values ranged from 1.71 % for NRH1 to 1.4 % for Bouldin Island OR. Because the peat is generally shallower than 90 cm at Wright-Elmwood Tract, there were only 2 samples collected in the corn field. Within treatments on Bouldin Island, there were no significant differences among treatments except NRL1 was significantly greater than OR.

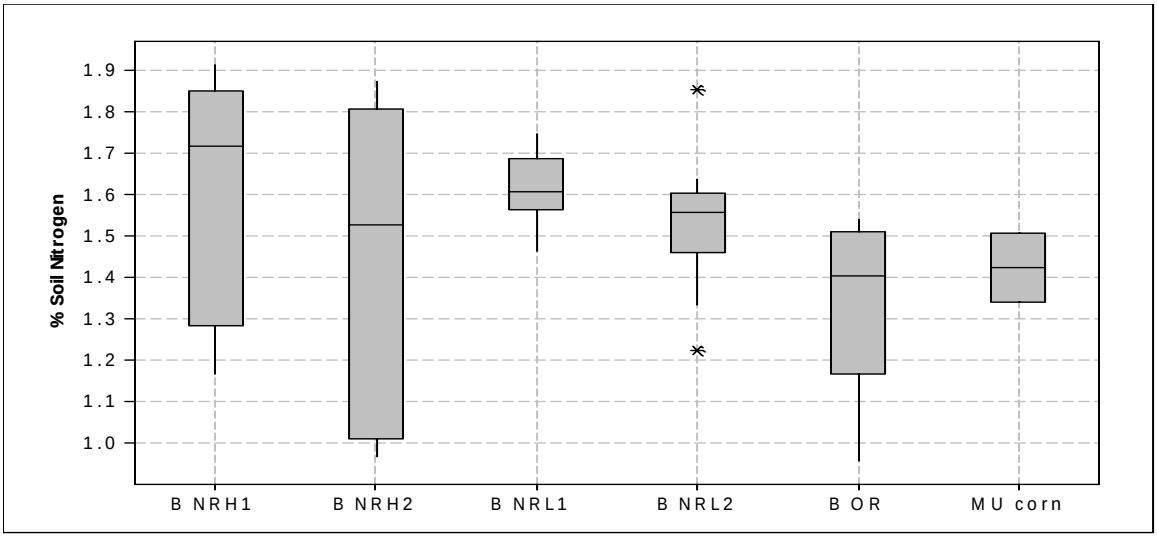


Figure 5-41. Box plots for percent soil organic carbon for the 90+ cm depth interval by treatment.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

5.3.5.3 Soil Summary

- The peat layer was thicker at Bouldin Island and generally underlain by sand. The narrower peat layer at Wright-Elmwood Tract was underlain by sandy clay loam and clay.
- The median percent carbon in the soils at Bouldin Island about 12 % in the upper 45 cm and about 35 % in the deeper layers. Median percent nitrogen was more uniform throughout the soils layer at Bouldin Island at about 1.5 %. Median percent carbon concentrations in the soils at Wright-Elmwood Tract are more similar in the upper 90 cm, with a median value of around 10 to 12 %. Percent nitrogen values at Wright-Elmwood Tract were fairly uniform throughout the upper 90 cm, with medians between 0.6 and 1 %. These data suggests some factor is causing a decrease in percent carbon in the upper layer at Bouldin Island but not at Wright-Elmwood Tract.

5.3.6 Groundwater

We measured deep and shallow groundwater levels in monitoring wells installed on Bouldin Island and Wright-Elmwood Tract in June 2004. We used water measurements on September 3, 2004 to delineate groundwater contributing areas to drainage ditches. We installed pressure transducers in selected wells to continuously monitor groundwater levels.

5.3.6.1 Shallow Groundwater Levels and Drainage Contributing Areas

5.3.6.1.1 Spatial Variability and Contours

Figure 5-42 shows the shallow groundwater contours and contributing areas to drainage ditches at Wright-Elmwood Tract. Shallow groundwater was groundwater measured in the upper one meter of soil. Shallow groundwater flowed from the southwest and northeast to the NRH and NRL drainage ditches. The contours indicate a steep hydraulic gradient towards the NRL drainage ditch and shallow gradient towards the NRH drainage ditch. In the central part of the experimental plots, groundwater data indicates flow towards the island main drainage ditch which flows from northeast to southwest. Approximate delineation of the areas of groundwater flow to drainage ditches resulted in contributing areas of 8.1 and 8.3 acres for the NRL and NRH areas respectively.

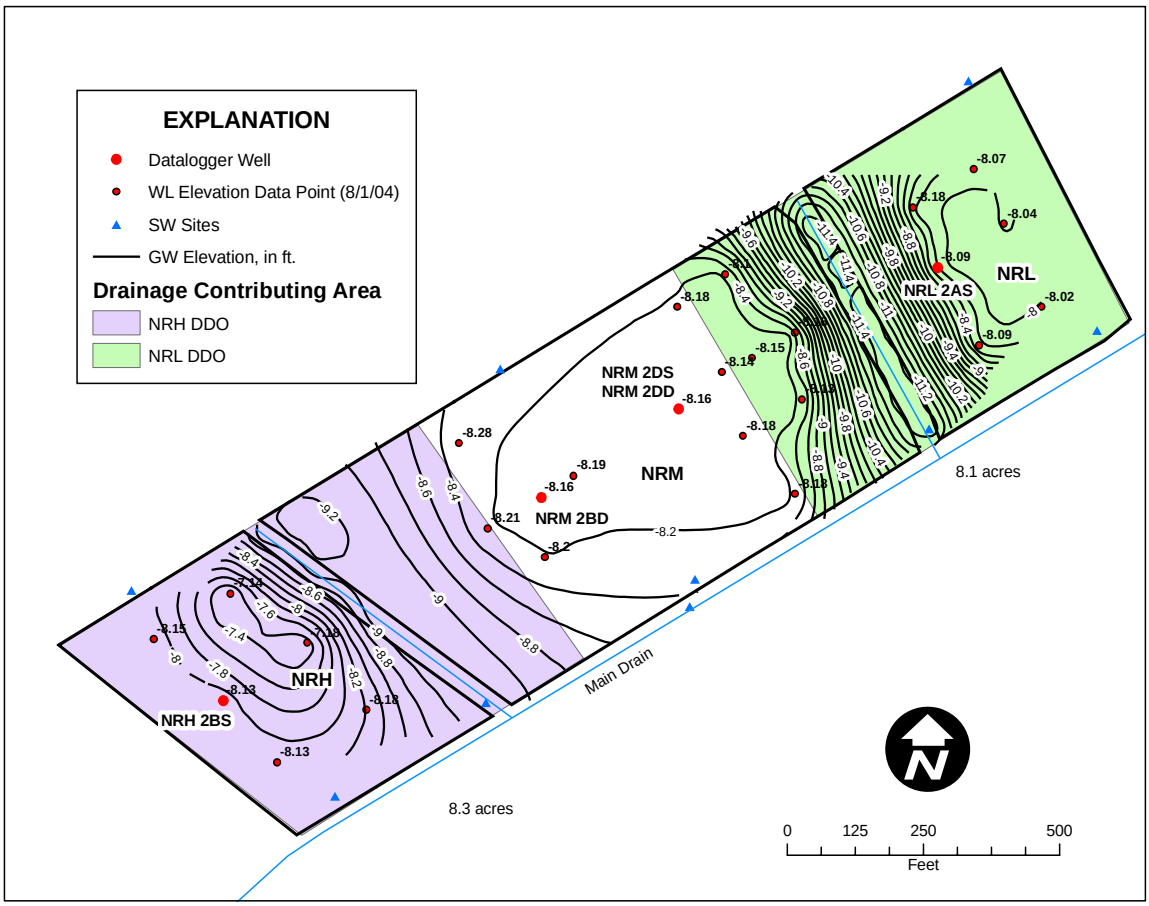


Figure 5-42. Shallow groundwater level contours (for September 3, 2004), contributing areas for drainage ditches and locations of experimental fields, monitoring wells, surface water outlets and drainage ditches at Muzio Farms on Wright-Elmwood Tract.

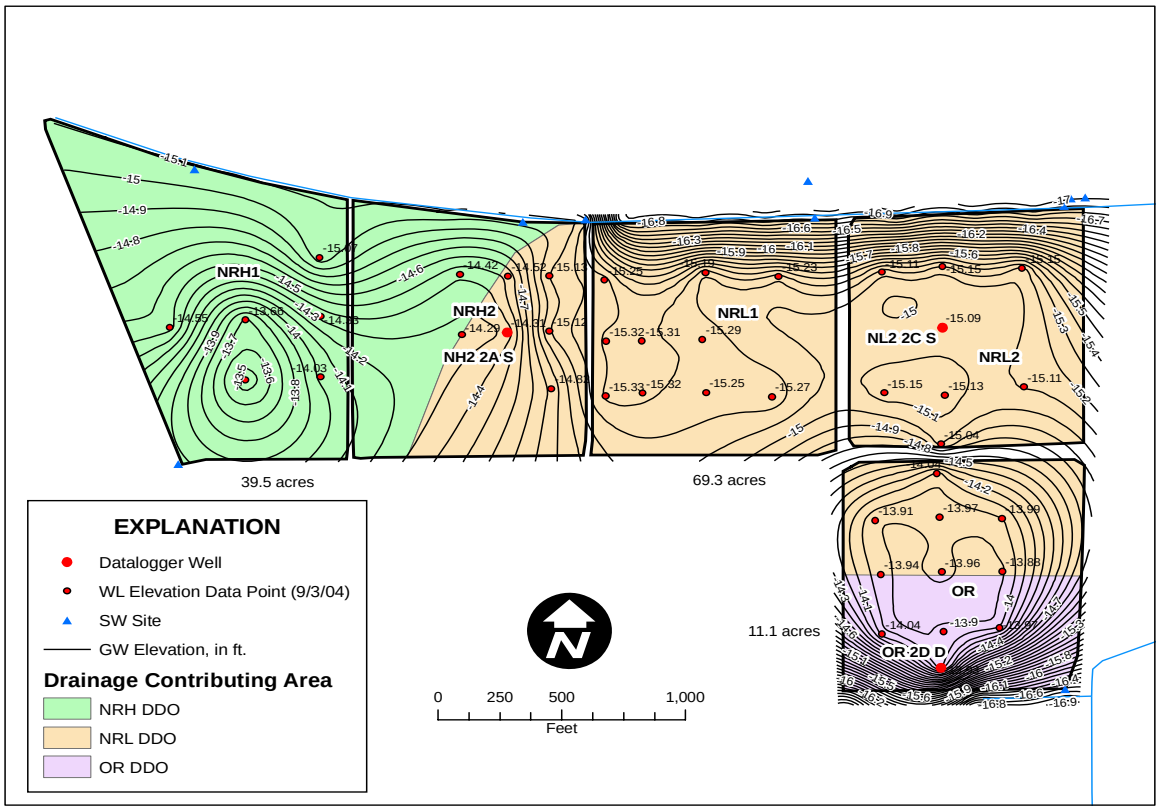


Figure 5-43. Shallow groundwater level contours (for September 2, 2004), contributing areas for drainage ditches and locations of experimental fields, monitoring wells, surface water outlets and drainage ditches on Bouldin Island.

Figure 5-43 shows the shallow groundwater contours and contributing areas to drainage ditches on Bouldin Island. Groundwater flowed from south to north to the NRH and NRL drainage ditches and from north to south towards the OR ditch. The contours indicate steep hydraulic gradients towards the NRL and OR drainage ditches and a shallower gradient towards the NRH drainage ditch in which a shallower water level was maintained. This noticeable affect of drain water level on shallow groundwater gradient is the same as was found for Wright-Elmwood Tract. This characteristic is important in considering the effects of drain management on groundwater contributions. Raising drain levels decreased the shallow groundwater gradient, and based upon Darcy's law, this reduced groundwater gradient reduced the shallow subsurface flows to the drains.

Approximate delineation of the areas of shallow groundwater flow to drainage ditches resulted in contributing areas of 39.5, 69.3 and 11.1 acres for the NRL, NRH and OR areas respectively. However, contributing areas are probably larger than depicted in Figure 5-43. Specifically, contributing areas probably extended south into fields in which we did not collect data. Therefore we were not able to estimate the entire contributing area. We believe the contributing areas are underestimated on the order of 20 to 50 %. This estimate is from extrapolating to the

west the groundwater divide shown in the OR field. We do not have sufficient data to more closely approximate this error. However, we are certain that the contributing area for the Bouldin OR field was larger than the 11.1 acres shown in Figure 5-43. We assumed for calculation of loads that the contributing area for the Old Rice drain was doubled to 22 acres by extending into the field immediately south.

Regardless of the possible underestimation, an important result is seen when looking at contributing areas. By raising the drain level, the contributing area of shallow groundwater was decreased. Thus, raising the drains reduced subsurface flows of shallow groundwater to the drains by both reducing the hydraulic gradient and by reducing the contributing area for the shallow subsurface water. This effect occurred at both sites.

5.3.6.1.2 Temporal Variability

Water level data from transducers installed in selected wells indicate stable conditions such that estimated contributing areas were probably stable for the 2004 and 2005 growing seasons. Specifically, hydrographs for summer 2004 and 2005 (Figures 5-44 to Figures 5-47) indicate relatively stable groundwater conditions for most of the growing season. In 2004, Figure 5-44 which is a hydrograph for a shallow observation well (within 4 feet of land surface) on the NRL2 field at Bouldin Island shows stable water levels between early July and mid September when the field was drained for harvest. We expect that between July and field draining in mid-September, contributing areas were stable as water levels during this period were stable. Similarly at Wright-Elmwood Tract, Figure 5-45 shows stable water levels between early August and mid September when the field was drained for harvest. Figures 5-46 and 5-47 show 2005 hydrographs which indicate similar groundwater level conditions as 2004.

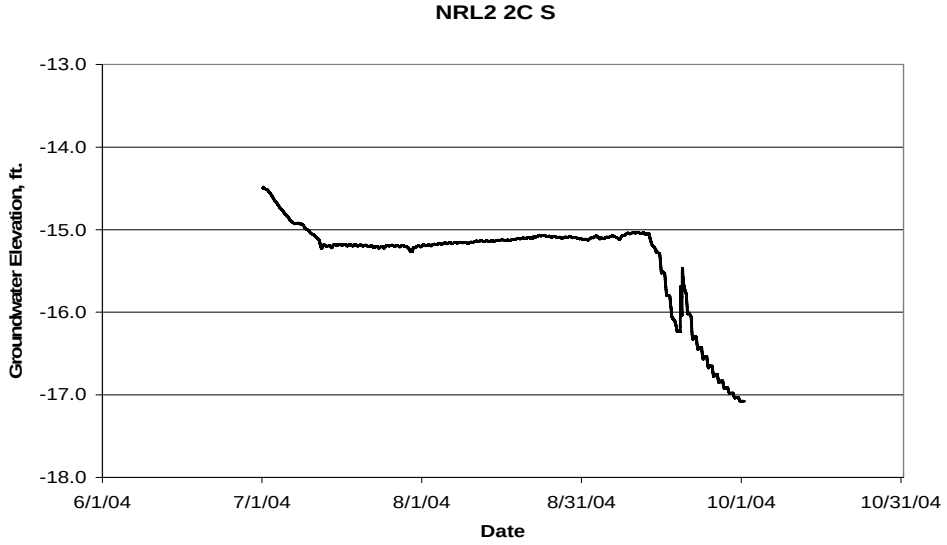


Figure 5-44. Shallow groundwater elevations for well NRL2 2C S in field NRL2 on Bouldin Island.

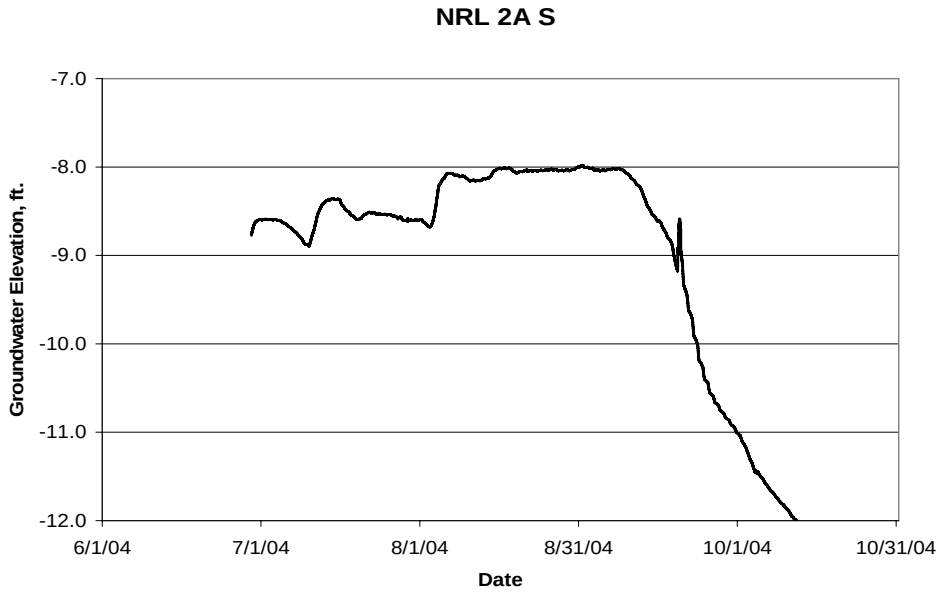


Figure 5-45. Shallow groundwater elevations for well NRL 2A S in field NRL on Wright-Elmwood Tract.

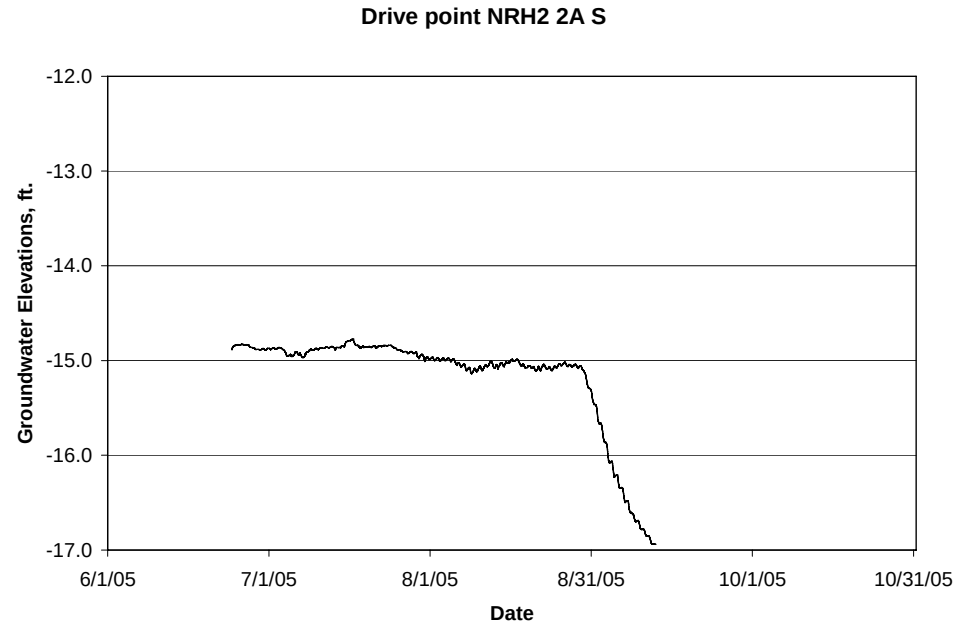


Figure 5-46. 2005 Shallow groundwater elevations for drive point NRH2 2A S in field NRH2 on Bouldin Island.

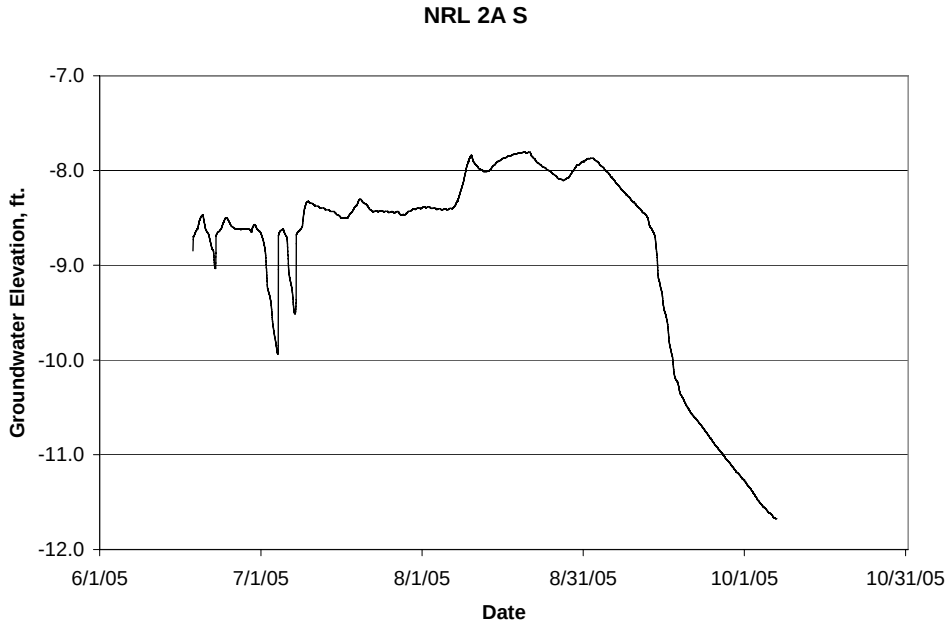


Figure 5-47. 2005 Shallow groundwater elevations for well NRL 2A S in field NRL at Wright-Elmwood Tract.

5.3.6.2 Groundwater Chemistry

We collected groundwater samples from selected wells in early September 2004. Samples were analyzed for DOC and nitrate (NO_3) and ammonia (NH_4) (among other constituents). Twelve wells were sampled on Bouldin Island and 10 wells were sampled at Wright-Elmwood Tract. Deep (about 6 feet) and shallow (about 4 feet) wells were sampled.

Figure 5-48 and Table 5-14 show differences in DOC concentrations among shallow and deep well samples on the two islands. The medians for DOC for shallow-well samples (6 wells on Bouldin Island and 5 wells at Wright-Elmwood Tract) were 178 and 141 mg/L for the Bouldin Island and Wright-Elmwood Tract, respectively. The medians for DOC for deep-well samples (6 wells on Bouldin Island and 5 wells on Wright-Elmwood Tract) were 34 and 23 mg/L for the Bouldin Island and Wright-Elmwood Tract, respectively. For all samples and for shallow and deep wells from the two islands, Mann-Whitney comparisons indicated no significant differences.

Figure 5-48 Box plots for groundwater DOC concentrations.

"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

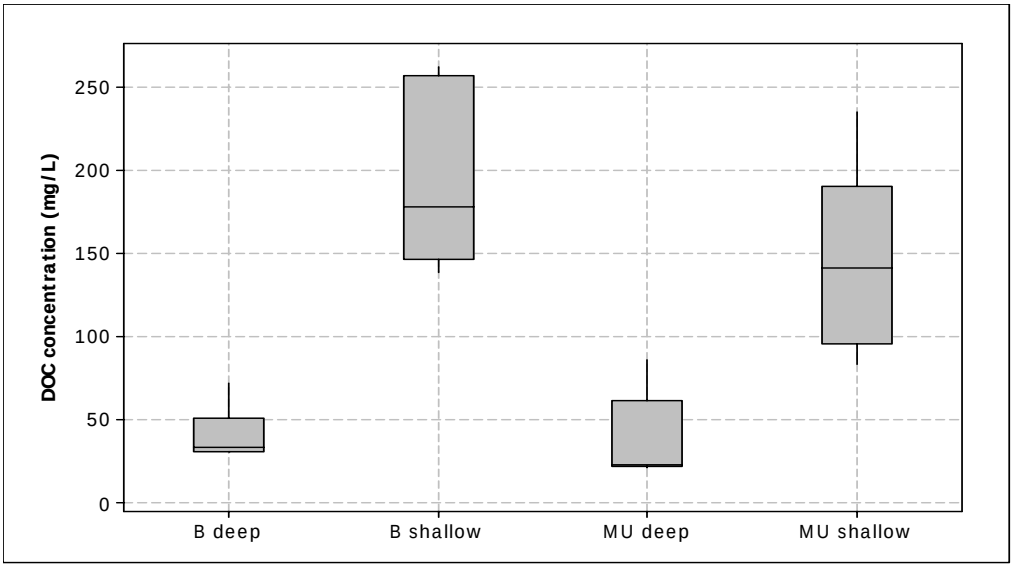


Table 5-14. Descriptive statistics for groundwater DOC concentrations in mg/L.

Location	Median	Minimum	Q1	Q3	Maximum
Bouldin Island deep wells (6)	34.06	31.09	31.29	51.57	72.66
Bouldin Island shallow wells (6)	178.3	139.0	146.6	257.6	262.0
Wright-Elmwood Tract deep wells (5)	23.1	21.5	22	61.9	86.5
Wright-Elmwood Tract shallow wells (5)	141.1	83.9	96.0	190.3	235.2

There were no detectable nitrate concentrations in the groundwater samples. This is probably due to denitrification due to chemically reducing conditions. Figure 5-48 and Table 5-15 show differences in NH_4 concentrations among shallow and deep well samples on the two islands. The medians for NH_4 for shallow-well samples (6 wells on Bouldin Farms on Bouldin Island and 5 wells at Muzio Farm on Wright-Elmwood Tract) were 0.15 and 0.06 mg/L for the Bouldin Island and Wright-Elmwood Tract, respectively. The medians for NH_4 for deep-well samples (6 wells on Bouldin Island and 5 wells on Muzio Farm on Wright-Elmwood Tract) were 1.07 and 0.34 mg/L for the Bouldin Island and Wright-Elmwood Tract, respectively. For all samples and for deep wells from the two islands, Mann-Whitney comparisons indicated higher concentrations on Bouldin Island at the 95% confidence level. For the shallow wells, NH_4 concentrations in the Bouldin Island wells were higher at the 90% confidence level.

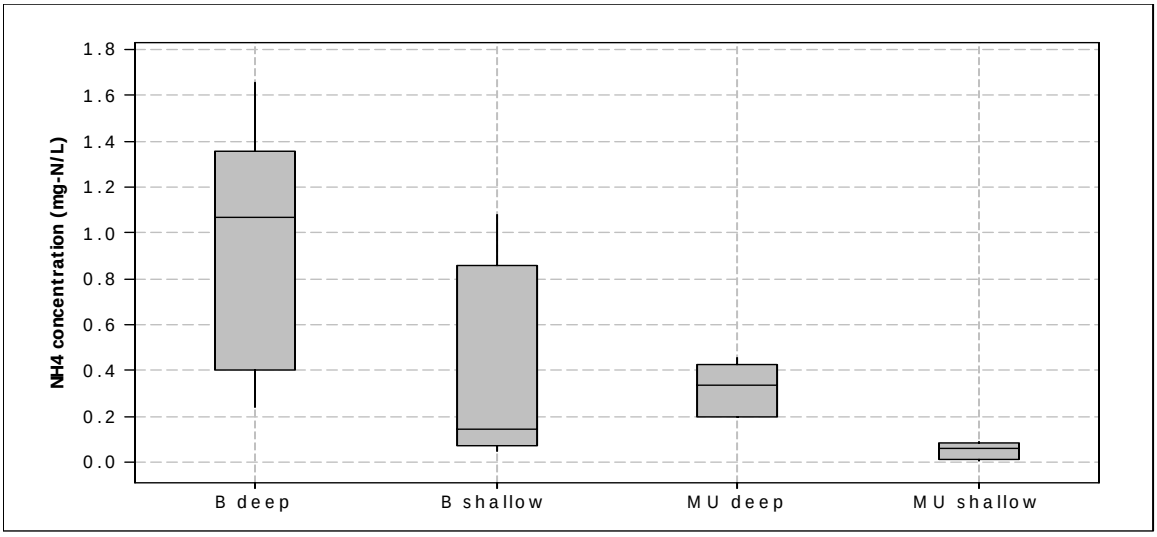


Figure 5-49.**Box plots for groundwater** NH_4 **concentrations.**
"BI" in location codes represents Bouldin Island. "MU" in location codes stands from Muzio Farm and is for results from Wright-Elmwood Tract.

Table 5-15. **Descriptive statistics for groundwater** NH_4 **concentrations in mg-N/L.**

Location	Median	Minimum	Q1	Q3	Maximum
Bouldin Island deep wells (6)	1.07	0.24	0.405	1.36	1.66
Bouldin Island shallow wells (6)	0.145	0.05	.073	0.86	1.08
Wright-Elmwood Tract deep wells (5)	0.34	0.20	0.20	0.425	0.46
Wright-Elmwood Tract shallow wells (5)	0.06	0.01	0.015	0.085	0.09

5.4 Discussion

5.4.1 Factors and Processes Affecting Loads

5.4.1.1 Dissolved organic carbon

Subsurface and surface (SWO) dissolved organic carbon loads varied among treatments and locations and seasonally.

5.4.1.1.1 Effects of Water Management and Flow on Subsurface DOC Loads

The primary factor affecting subsurface loads is drain flow variations. Figure 5-50 shows the relation of the log of DOC load (g/A-d) to flow (L/s-A) for all drains. Figure 5-50 shows that 1) drain flows were generally lower at Wright-Elmwood Tract relative to Bouldin Island and 2) logs of flow explain over 65 % of the variance in loads at Wright-Elmwood Tract. For all the data, the log of flow explains 75% of the variance. Consistently, statistical analysis of DOC loads showed that overall, subsurface DOC loads on Bouldin Island were larger than those at Wright-Elmwood Tract.

The effect of flow was also demonstrated at Wright-Elmwood Tract through the establishment of the NRH drain treatment which significantly reduced DOC loads relative to NRL and corn. The difference between surface water elevations and drain water elevations at Wright-Elmwood Tract accounted for over 50 % of the variance associated with drain flows (Figure 5-9). This effect was also shown in shallower hydraulic groundwater gradients along the high ditch treatment as opposed to the low ditch treatment (Figure 5-42) and the statistically different and lower DOC and THMFP loading from the NRH drain as compared to the NRL drain at Wright-Elmwood Tract (Figures 5-11 and 5-23). Thus, drain flow is largely affected by hydraulic gradients from rice fields to drainage ditches. Raising the level of the drain water though the use of weirs limits flow and loads.

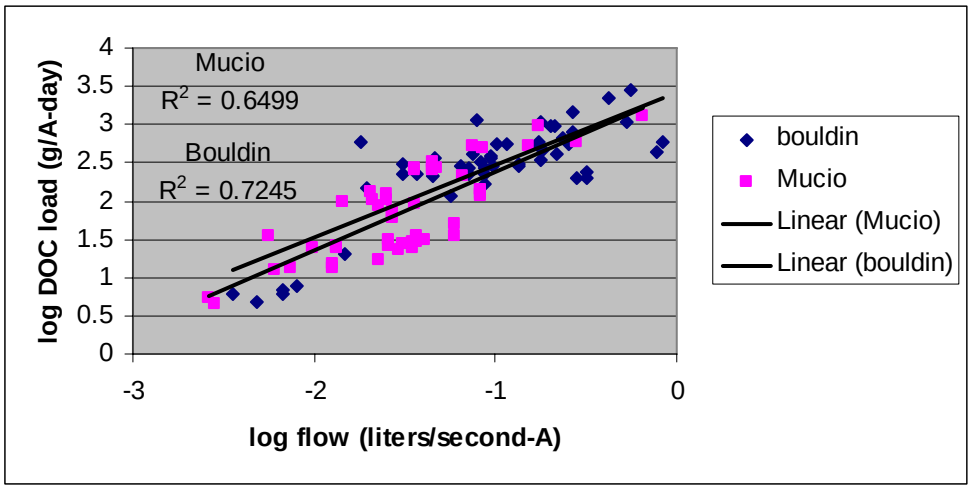


Figure 5-50. Relation of log of DOC loads to log of drain flows.

At Bouldin Island, several factors compromised our ability to demonstrate the effects of drain water management on subsurface flows. Because subsurface flows at Bouldin Island could only be calculated through a hydrologic budget for the different sections of the drains, integrating multiple SWO and DDO flow measurements, error propagation was a much greater issue. Also, with the higher flows seen during the summer of 2005 across the v-notch weir at drain location NRH, flow rates were likely overestimated. Measured heights over the weirs were well outside the range of our calibration curve; published constants suggest we overestimated flow across the v-notch weir by about 20 % (Table 5-5). Thus, when analyzing the data, the first impression is the NRH drain exported greater amounts of DOC and THMFP then the NRL drain. However, when considering the errors in the measurements and not considering data outside the calibration range (i.e., NRH during summer 2005), the subsurface flows are not statistically different between sites (Figure 5-10). This conclusion that high subsurface flow estimates at NRH (and the corresponding low subsurface flow estimates at NRL) is largely an artifact of errors in our method is supported by the shallow groundwater contour map for Bouldin Island (Figure 5-43). That figure shows that the raising drain water elevations reduced the hydrologic gradient between the shallow water and the drain water elevation. According to Darcy's law, this gradient would reduce subsurface flows as well. This data supports our conclusion raising the drains did lower shallow subsurface flows, even at Bouldin Island.

Under initial examination, DOC and THMFP subsurface loads from the NRH water management factors on Bouldin Island limited the effectiveness of the NRH treatment for limiting DOC loads. However, when excluding the 2005 data for NRL and NRH, the subsurface DOC and THMFP loads from the NRH drains are lower then those at the NRL drains or the OR drains (Table 5-9).

5.4.1.1.2 Effects of Water Management and Flow on Subsurface DOC Concentrations

Water-management treatment (NRL, NRH or corn) had a statistically significant effect on drain-water concentrations. Where drain-water levels remain low (as was the case for the NRL treatment at Wright-Elmwood Tract), more high DOC groundwater flowed to drainage ditches

relative to corn. This causes higher drain-water DOC concentrations relative to the corn drainage ditch. Drain water-management for corn results in the movement of deeper, lower DOC groundwater to drainage ditches. Similarly at Bouldin Island, drain-water DOC concentrations were significantly lower for corn relative to the rice treatments because deeper, lower DOC groundwater moved towards the drainage ditch.

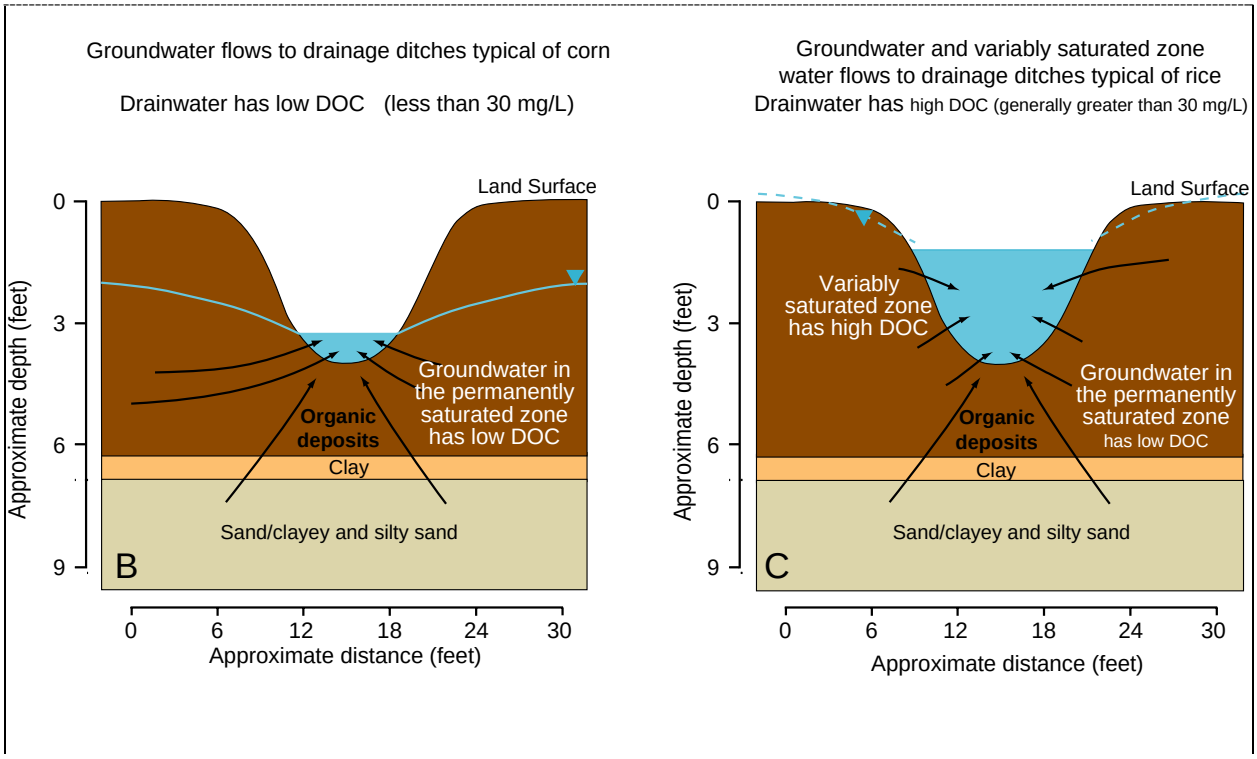


Figure 5-51. Conceptual model for groundwater flow to agricultural drainage ditches in delta organic soils.

Figure 5-51 illustrates groundwater flow to drains in peat soils. Groundwater in the permanently saturated zone generally has low DOC concentrations; the median DOC concentrations were 23 and 34 mg/L at Wright Elmwood Tract and Bouldin Island, respectively (Table 5-14). In contrast, DOC concentrations in the shallow variably saturated zone were 141 and 178 mg/L for Wright-Elmwood Tract and Bouldin Island, respectively. For corn and other crops that require and aerated root zones, groundwater from the permanently saturated zone flows to the drainage ditch and the drainwater DOC concentrations reflect the lower groundwater DOC concentrations. Under flooded conditions, a mixture of groundwater and water in the variably saturated zone flows to the drainage ditch resulting in a higher drainwater DOC concentration.

5.4.1.1.3 Effects of Drain Water DOC Concentrations on Subsurface DOC Loads

Variations in drain-water DOC concentrations have substantially less of an effect on DOC drain loads than drain flow and factors affecting drain flow. While our analysis did not indicate significant differences in drain-water DOC concentrations between islands, Figure 5-19 shows that DOC concentrations were generally lower at Wright-Elmwood Tract relative to Bouldin Island except for the NRL treatment at Wright-Elmwood Tract. Moreover, drain-water DOC concentrations were generally lower than shallow groundwater DOC concentrations (Table 5-14, Figures 5-19 and 5-48) and probably reflect some mixing of shallow and deep groundwater.

5.4.1.1.4 Effects of Groundwater DOC Concentrations on Drain DOC Concentrations

Groundwater DOC concentrations were not significantly different between the two islands or among treatments.

5.4.1.1.5 Effects of Soil Carbon on Drain DOC Concentrations

Also, differences in soil carbon do not fully explain differences in drain-water DOC concentrations among treatments or between islands. Soil carbon percentages were significantly different between the two islands for the 46 to 89 cm interval but differences in drain-water DOC concentrations among treatments do not correspond to observed differences in percent soil carbon on either island. Moreover, differences in organic-soil thickness do not fully explain differences in drain-water or groundwater DOC concentrations. Specifically, Table 5-13 shows that on Bouldin Island, the organic soil is 98 to 124 cm thick whereas at Wright-Elmwood Tract, it is 62 to 96 cm thick. However, groundwater DOC concentrations in the deep wells between the two islands were not significantly different. Variations in drain-water DOC are most affected by the spatial variability of groundwater DOC concentrations and varying proportions of shallow and deep groundwater flowing to drainage ditches.

5.4.1.1.6 Effects of Flow on Surface Water DOC Loads

Surface water outflow (SWO) DOC loads were also primarily influenced by flow. Figure 5-52 shows the relation of the logs of load in mg/s to logs of flow in L/s for Bouldin Island and Wright-Elmwood Tract. For all data for both islands, the log load-flow relation explains 79 % of the variance in loads. However, the 4 lowest data points (three at Bouldin Island and one at Wright-Elmwood Tract) have an undue influence on the regression relation. Removal of these points results in the log of flow explaining 70 % of the variance. R-squared values for Bouldin Island and Wright-Elmwood Tract shown on Figure 5.44 and indicate that the log of flow explains 76 and 87 % of the variance in loads for Bouldin Island and Wright-Elmwood Tract, respectively. However, removing the 4 smallest flows and loads results in r^2 values of 0.55 and 0.83 for Bouldin Island and Wright-Elmwood Tract, respectively.

Dissolved organic carbon loads are relatively independent of DOC concentrations and loads were not significantly correlated with concentrations. Moreover, SWO DOC loads were not significantly different between the two islands or among treatments yet DOC concentrations in

surface runoff were higher on Wright-Elmwood Tract relative to Bouldin Island. The primary process probably affecting DOC concentrations in surface water is diffusion of DOC from shallow soils into overlying water. For percent carbon, there were no significant differences for shallow soil (0 to 45 cm) samples between Bouldin Island and Wright-Elmwood Tract. There were differences among treatments on both Bouldin Island and Wright-Elmwood Tract but there were significant differences among treatments for DOC loads for Bouldin Island.

Temporal differences in surface-water loads further point to water-management and flow effects on DOC loads. On Bouldin Island, surface water DOC loads were about 53 % higher in summer 2005 relative to summer 2004. At Wright-Elmwood Tract, DOC loads were about 48 % lower in summer 2005 relative to summer 2004. These seasonal differences were the result of changing water-management. Surface water flows at Wright-Elmwood Tract were reduced by about 56 % between 2004 and 2004 because of improved water management through the use of adjustable weir inserts (Table 5-11). At Bouldin Island, surface water flows increased by about 68% between Summer 2004 and Summer 2005 because of more complex supply ditch network. These water management differences between 2004 and 2005 are reflected in the DOC loading from surface water. Figure 5-52 shows that data points representing summer 2004 flows (yellow triangles) predominantly plot above and to the right (higher loads and flows) of the points representing summer 2005 (red triangles).

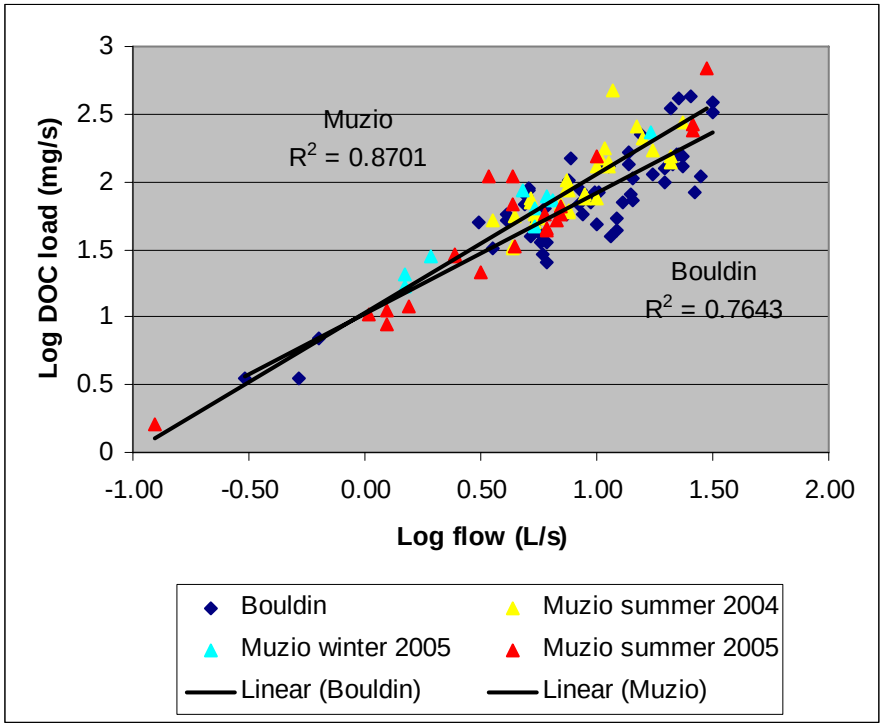


Figure 5-52. Relation of log of DOC loads to log of flows for surface water outflow.

5.4.1.2 Total Trihalomethane Formation Potential (THMFP)

Similar to DOC loads, flow is the primary explanatory variable for surface and subsurface THMFP loads. Figure 5-49 shows the load-flow relation for the subsurface drains. Overall, the logs of flow explain 63 % of the variance in loads. R-squared values for the log flow-load relations were significant for both Bouldin Island ($r^2 = 0.31$) and Wright-Elmwood Tract ($r^2 = 0.51$). Subsurface THMFP loads at Bouldin Island (median = 25.3 g/A-day) were larger than those at Wright-Elmwood Tract (median = 2.8 g/A-day). Flow is the primary determinant for differences in loads between the islands. Figure 5-53 shows that flows and loads at Wright-Elmwood Tract were almost universally smaller than those at Bouldin Island. Drain water THMFP concentrations were not significantly different between the two islands and there was not a statistically significant relation between loads and concentrations.

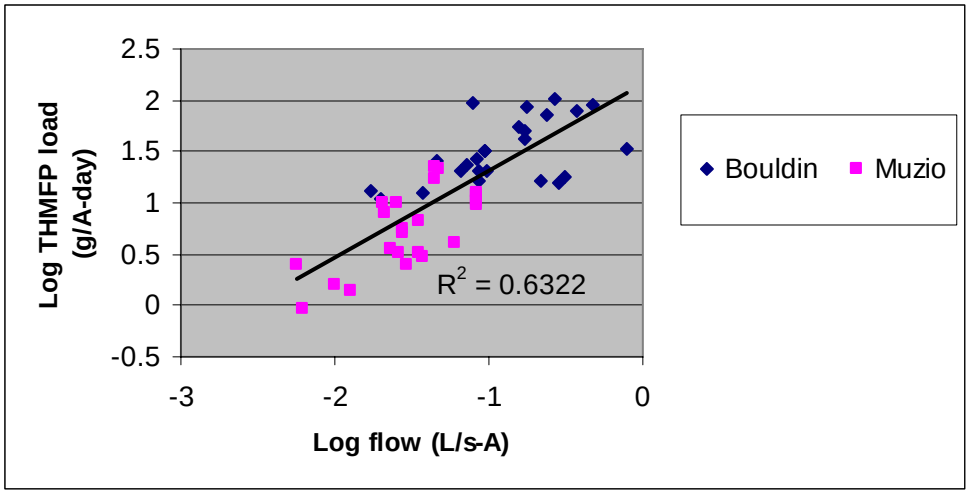


Figure 5-53. Relation of log THMFP loads to log flow for subsurface drains.

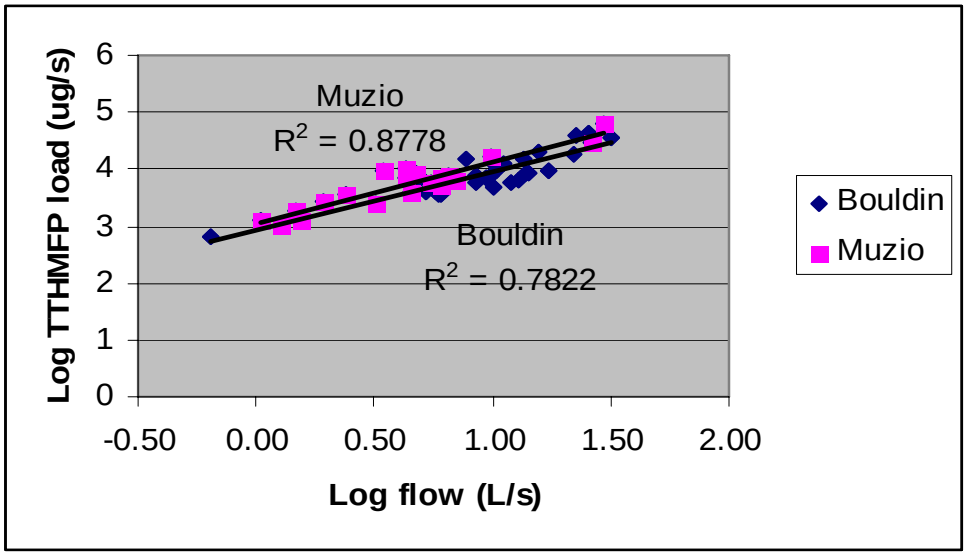


Figure 5-54. Relation of log THMFP loads to log flow for surface-water outflow.

Figure 5-54 shows the load-flow relation for surface-water outflow. Overall, surface THMFP loads on Bouldin Island (median = 28 g/A-day) were greater than at Wright-Elmwood Tract (median = 13 g/A-day) at the 92.5 % confidence level. Figure 5-50 shows that flow is the primary variable influencing the differences in loads between the islands. There was not a statistically significant relation between loads and concentrations. Moreover, surface water THMFP concentrations were significantly higher at Wright-Elmwood Tract relative to Bouldin Island. Overall for both islands, the logarithmic load-flow relation explains 80 % of the variance. R-squared values on Figure 5-50 show that 78 and 87 % of variance in the logs of loads was explained by variations in logs of flows.

5.4.1.3 Nitrogen

Similar to DOC and THMFP, subsurface drain flow is the primary determinant of total dissolved nitrogen (TDN) loads. Figure 5-55 shows the relation of the logs of subsurface TDN loads to logs of flow. For all the data, variations in flow explain 62 % of the variance in loads. Flow explains 78 % and 50 % of the variance in loads at Wright-Elmwood Tract and Bouldin Island, respectively.

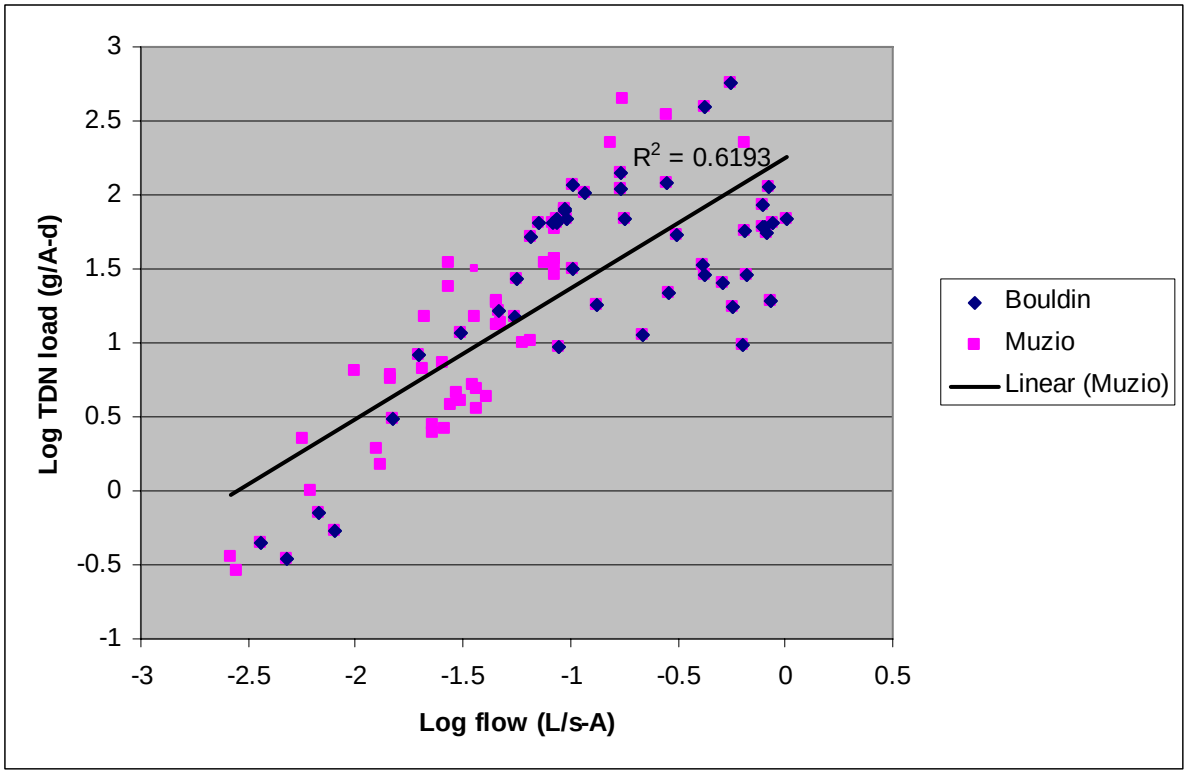


Figure 5-55. Relation of log of subsurface load to log of flow for total dissolved nitrogen.

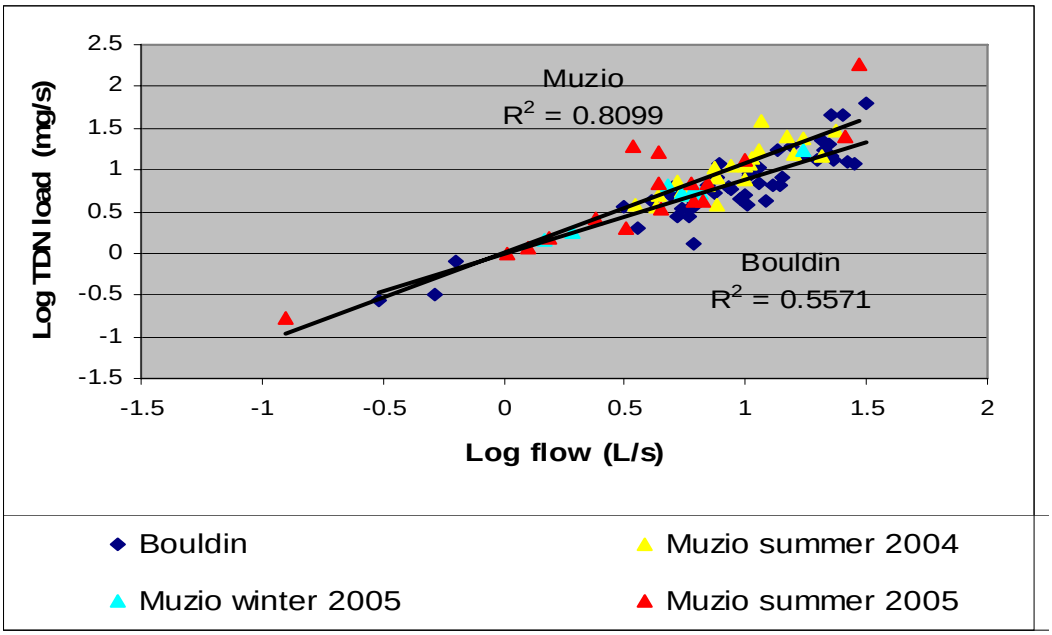


Figure 5-56. Relation of log of surface-water load to log of flow for total dissolved nitrogen.

Figure 5-56 shows the relation of the logs of surface-water outflow TDN loads to logs of flow. For all the data, variations in flow explain 88 % of the variance in loads. Flow explains 81 % and 56 % of the variance in loads at Wright-Elmwood Tract and Bouldin Island, respectively.

Temporal differences in surface-water loads further point to water-management and flow effects on TDN loads. Seasonal differences in TDN loads shown in figure 5-56 were the result of changing water-management. At Bouldin Island, we modified water inlet structures for improved control of flow onto the fields. However, increased demand on water-supply ditches for other fields resulted in less control and increased surface-water outflow and loads from rice fields. In contrast, at Wright-Elmwood Tract, water-control structures reduced flow and thereby reduced SWO loads. Figure 5-56 shows that data points representing summer 2004 flows (yellow triangles) predominantly plot above and to the right (higher loads and flows) of the points representing summer 2005 (red triangles).

5.4.2 Development of Management Practices for Minimizing Loads

For subsurface and surface-water outflow loads, flow is the primary determinant. Therefore, management practices that limit flow will reduce loads. For subsurface loads, we were able to clearly reduce loads by maintaining a high water levels in the NRH drainage ditch at Wright-Elmwood Tract. This practice resulted in lower subsurface DOC and THMFP loads than corn. For surface-water outflow, reduced flows also reduced loads. At Wright-Elmwood Tract, installation of control structures that reduced inflow and outflow reduced DOC loads by 48% during summer 2005 relative to summer 2004. When considering the measurement errors at Bouldin Island and the groundwater map data showing that high drain levels reduced the groundwater hydrologic gradient, the data from Bouldin also suggests that the high drain reduced subsurface loading of DOC and THMFP. This conclusion as it relates to Bouldin Island though is less clear because the data collection and methods needed to calculate flow were much more complex and more affected by errors.

Under this project, we also designed and developed inexpensive adjustable weir inserts that would make water level adjustments in rice fields more precise and easier. These inserts helped reduce surface flows at Wright-Elmwood Tract by about 50% and that reduction in flow led to a reduction in surface water THMFP and DOC loads. At Bouldin Island, we installed weirs at the inflows during the second year to facilitate water management. But an increasingly complex water delivery network hindered that effort and surface water flows to the rice paddies increased by over 50%, resulting in increased surface water DOC and THMFP loads from Bouldin Island during 2005 as compared to 2004.

Thus, the effectiveness of practices to reduce loads at Wright-Elmwood Tract relative to Bouldin Island points to the importance of farm land- and water-management practices for limiting loads. Strategic placement of weirs, utilizing adjustable weir inserts to improve water level and flow control, and having rice fields in a serial configuration rather then a parallel configuration are all methods that help improve surface water management. But a complex irrigation network can offset all these efforts.

Aside from flow structures and irrigation networks, field implementation and maintenance appear to be also key factors in using surface water efficiently. At Bouldin Island, areas with checks are generally larger than and not as level as at Wright-Elmwood Tract Farms. During both seasons, there was non-uniform water distribution on Bouldin Island but not at Wright-Elmwood Tract. This non-uniform water distribution was in large part to mitigate the effects of field unevenness. More inflow locations were needed on some fields to allow broader distribution of water spatially around the field. Water distribution was uniform at Wright-Elmwood Tract.

The primary factor preventing more effective field water delivery control at Wright-Elmwood Tract was the tidal effect on water inflows. Because water is siphoned from the adjacent channel, tidal variations of several feet affect flow to rice fields. This caused flows to fluctuate

daily and prevented additional limiting of surface-water outflow. Reducing or eliminating tidal effects will reduce surface outflows substantially.

It is possible to grow rice with minimal and no or minimal surface water outflow by providing only enough water for seepage and evapotranspiration. Seepage can be reduced by maintaining high water levels in the drainage ditches. Effects on tidal variations on flow can be eliminated by using a standpipe on the land side of the levee. A standpipe with small holes at some elevation below low tide will generally maintain a constant water level in the standpipe. (A similar structure is used on Twitchell Island for water delivery to a demonstration wetland). An outflow valve on the downstream side of the standpipe will allow precise control of water to rice fields which can be adjusted to match demand. Additional controls on flashboard risers in fields will provide further control.

There is evidence the continued flooding of organic soils will reduce soil and groundwater DOC concentrations. Data for soil cores (USGS written communication, 2003) indicate that continued water movement though shallow, previously oxidized organic soils under permanently flooded conditions will lead to decreased drain-water DOC and THMFP concentrations over time. Maintenance of flooded conditions during the summer will also reduce oxidation of the organic soils and the production of DOC. Continued rice cultivation will probably reduce DOC concentrations in shallow groundwater over the long term.

In summary, subsurface carbon and nitrogen loads can be reduced by land- and water-management practices that reduce inflows and outflows to rice fields. Based on our data and observations, the following practices will limit loads.

- Establish precision leveled areas between checks.
- Develop effective control of water between fields and basins and to islands.
- Use evapotranspiration and seepage estimates to allocate flow to fields.
- Install subsurface drain and surface-water outflow structures to minimize subsurface surface-water outflow.
- Utilize adjustable inserts or equivalent methods to better manage surface water elevations and flows.
- Raise drain water elevations to minimize subsurface contributions from fields.
- Minimize tidal effects on island water deliveries.

5.5 Summary and Conclusions

During 2004 and 2055, groundwater, soils, and surface and subsurface drainage data on Bouldin Island and Wright-Elmwood Tract (Muzio Farms) related to rice and corn cultivation were collected. We evaluated different management practices and treatments relative to loads. Major conclusions follow.

5.5.1 DOC and THMFP

- Management Practices and Flow Effects
  - For dissolved organic carbon (DOC) and total dissolved nitrogen, our results indicate that management practices that limit subsurface and surface-water outflow will reduce loads for these constituents.
  - For Bouldin Island and Wright-Elmwood Tract and overall, DOC and Trihalomethane Formation Potential (THMFP) concentrations were significantly and highly correlated for subsurface and SWO samples

- Subsurface Flows, Concentrations and Loads
  - Overall, subsurface DOC loads on Bouldin Island were larger than those at Wright-Elmwood Tract.
  - On Bouldin Island, subsurface drainage DOC loads for rice fields generally were larger than those for corn. On Wright-Elmwood Tract, subsurface rice loads were greater than corn loads except where water levels were maintained near land surface as was the case for the new rice high treatment (NRH). NRH DOC loads were less than corn loads
  - Overall, subsurface THMFP loads at Bouldin (median = 25.3 g/A-day) were larger than those at Wright-Elmwood Tract (median = 2.8 g/A-day). At Wright-Elmwood Tract, the NRH significantly limited loads relative to the other treatments. A consideration of the errors suggests that the result was also true at Bouldin Island.
  - Groundwater carbon was not significantly different between the two islands. Dissolved organic carbon concentrations decrease with depth.

- Surface Flows, Concentrations and Loads
  - Overall, there were no statistically significant differences in surface-water outflow (SWO) DOC loads between islands or among treatments.
  - On Bouldin Island, SWO DOC loads were about 53 % higher in summer 2005 relative to summer 2004. At Wright-Elmwood Tract, DOC loads were about 48 % lower in summer 2005 relative to summer 2004. The reduction of SWO loads at Wright-Elmwood Tract was due to installation of water control structures and implementation of practices to minimize inflows and outflows. Changes in flows during the two years as a result of the practices account for most the difference in surface water DOC loading.

- Relative Contributions of Surface and Subsurface Loads at the different Sites
  - On Bouldin Island, overall subsurface DOC loads (median = 232 g/A-day) were estimated approximately equal to surface loads (median = 214 g/A-day). A likely underestimation of contributing area suggests that subsurface DOC loads are in fact about 20 to 50% lower and thus somewhat less then surface DOC loads. At Wright-Elmwood Tract, subsurface loads (median = 28.3 g/A-day) were significantly less and an order of magnitude less than surface loads (median = 249.2 g/A-day).

- Subsurface drain water THMFP concentrations were not significantly different between the two islands.
- Surface-water outflow THMFP concentrations were significantly higher at Wright-Elmwood Tract relative to Bouldin Island.

5.5.2 Nitrogen

- Subsurface concentrations and loads
  - Subsurface ammonia and dissolved organic nitrogen loads were similar across treatments with the previously farmed rice field on Bouldin Island (B OR) exporting the greatest loads for both species.
  - Subsurface nitrate loads for corn and Wright-Elmwood Tract rice where drain water levels were maintained low were significantly higher than the other treatments.
  - The large subsurface nitrate exports from the corn fields occurred exclusively during the winter.
  - The corn field subsurface nitrogen loads were primarily as nitrate whereas the rice field subsurface loads were primarily as DON.
  - Groundwater carbon and nitrogen chemistry was not significantly different between the two islands. No nitrate was identified in the groundwater samples. Dissolved organic carbon concentrations decrease with depth. Ammonia concentrations increase with depth.
- Surface concentrations and loads
  - Nitrogen loads for rice surface-water outflows were similar for all treatments although Wright-Elmwood Tract had greater ammonia exports than Bouldin Island.
  - Surface water nitrogen loads were dominated by dissolved organic nitrogen with only small amounts of ammonia and nitrate.

5.5.3 Soils

- Soil carbon percentages were not different for shallow (0 – 45 cm) soils among the islands but carbon percentages were larger on Bouldin Island for deeper soil samples (46 – 85 cm). Differences in soil carbon may have explained some difference in subsurface DOC loading though that effect appears secondary to flows.
- Soil nitrogen percentages were consistently higher on Bouldin Island. However, these differences did not explain the generally higher nitrogen loads observed at Wright-Elmwood Tract.

Our conclusions point to the need for development of strategies and structures for growing rice that allow for more precise control of irrigation water and surface-water outflow. This was shown most clearly in the Wright-Elmwood data where there was significant reduction in loads associated with structures that minimized inflows and surface-water outflows in 2005 relative to 2004 and loads for high drain management in rice. The data for Bouldin Island point to the same

conclusion. Less effective water control and infrastructure resulted in more difficult drain flow measurement and lack of statistically significant differences between loads between the high and low drain treatments. Personal observations clearly point to the need for improved water management on Bouldin Island to decrease loads. Many delta islands such as Bouldin Island lack the infrastructure for rice production that will optimize irrigation application and minimize drain loads. Wright-Elmwood is an exception is this regard.

Relative to these conclusions, it is important to emphasize the following. First, this is the first water-quality study of rice in the Delta and as such provides critical information about magnitudes of and processes affecting constituent loads. Since there was no previous experience or data for measuring flow under these circumstances, our study serves as demonstration project that illustrates methodology for rice water-quality assessment on delta islands. Second, surface and subsurface drain flows are difficult to measure on Delta islands because velocities are very low, channel bottoms and sides are unstable and channel vegetation changes throughout the season. This and other factors discussed previously resulted in errors in discharge measurements and load estimates that in the case of Bouldin Island resulted in high uncertainty in loads. Lastly, our stated initial goal for this project was to explore the possibility of growing rice for limiting DOC export from delta agriculture in light of its economic and subsidence-mitigation benefits. The results of our project have clearly met this goal and provided important data for managing rice for minimizing DOC loads.

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6 Comparing wildlife usage of rice fields with corn

6.1 Introduction

The Sacramento-San Joaquin Delta is located in the mid-portion of the Central Valley between Sacramento and the San Joaquin Rivers. The Delta is characterized by numerous sloughs and channels due to convergence of the Sacramento, San Joaquin, Mokelumne, and Calaveras Rivers, as well as numerous smaller rivers and creeks. The Delta is an important bird habitat, especially for water birds during the spring and fall migratory seasons (Elphick and Oring, 1998; Elphick, 2000). With the goal of improving water bird habitat, Ducks Unlimited has over the last ten years promoted rice fields in the Delta, providing growers with assistance and expert guidance in converting to rice. This chapter provides the results of our monitoring effort in the Delta. The purpose of this monitoring effort was to document bird abundance on agriculture fields recently converted to rice, on corn fields, and on managed wetlands and compare bird usage amongst the different habitats.

6.2 Methods

Avian monitoring activities were conducted on rice and corn fields on Wright-Elmwood and Rindge Tracts and Bouldin Island. Managed wetlands at Consumnes River Preserve were also surveyed to compare bird use on wetlands to the agricultural fields. The units surveyed within the Consumnes River Preserve included the Barn Ponds and Lost Slough Ponds located along Desmond Road (Figure 6-1). All areas surveyed are within the geographic area of the Delta, and the study area for the Delta Rice Project.

Surveys occurred twice yearly during summer and winter. Surveys were conducted in 2004 and 2005 at both Wright-Elmwood Tract and Bouldin Island on one rice field and an adjacent corn field. In 2005, surveys were repeated at these locations and a rice field and corn field were added at Rindge Tract. Additionally, two managed wetlands in the Consumnes River Preserve were surveyed in 2004 and 2005.

Using 75X power spotting scopes and 8X42 power binoculars, one rice field, one adjacent corn field, and one managed wetland were surveyed on each monitoring day. Monitors selected survey points that permitted the observer to survey the entire field or wetland. Fields were monitored for an interval of 30 minutes per survey point and recorded all bird species diversity and abundance observed. Bird species were recorded using a U.S. Fish and Wildlife Service four-letter alpha code system (Attachment A—Four Letter Alpha Codes, Pyle and DeSante). Land use or habitat types were defined as agricultural or managed wetland. Agricultural habitat types were either harvested rice or corn fields while managed habitats were wetlands that were seasonally flooded during fall and winter months. Managed wetlands typically were characterized by emergent (e.g., cattails and tules) and annual (e.g., watergrass, swamp timothy, and smartweed) vegetation.

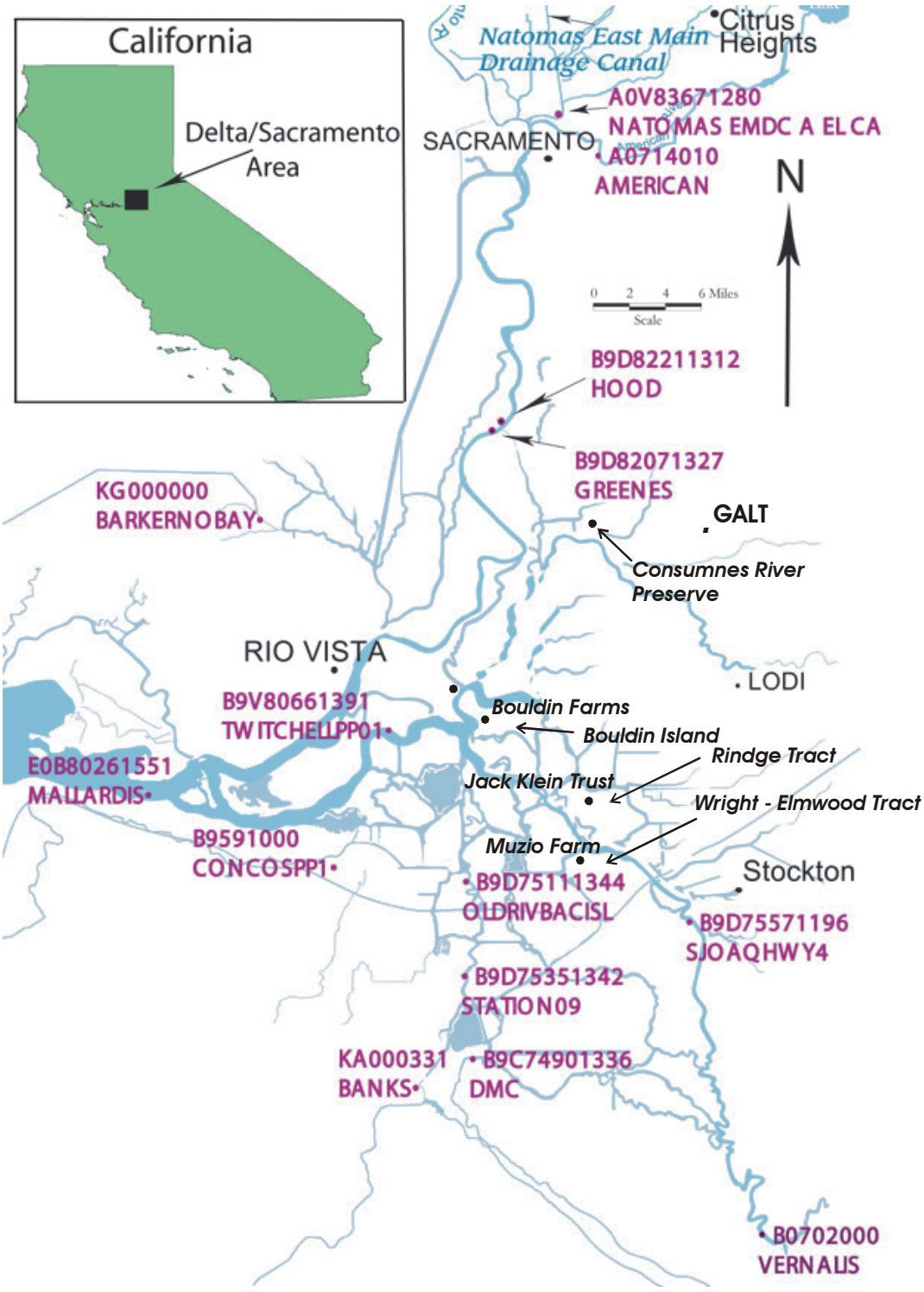

Figure 6-1. Wildlife Monitoring Locations for the Rice Project.

Avian monitoring was conducted at Bouldin Farms on Bouldin Island, Muzio Farm on Wright-Elmwood Tract, Jack Klein Trust on Rindge Tract, and Barn Ponds and Lost Slough Ponds at the Consumnes River Preserve.

During summer monitoring, bird species were classified into three categories: land birds, waterfowl (ducks, geese, and swans), and other water birds. Land birds were either raptors or passerines. Other water birds included all water birds (e.g., coots, herons, and grebes) excluding waterfowl. Waterfowl included ducks, geese, and swan species.

For winter monitoring, birds were grouped into eight distinct categories: land birds, mallard, northern pintail, geese (e.g., Canada, white-fronted), swans, total waterfowl (all waterfowl species), sandhill crane, and other water birds (all water birds excluding waterfowl and cranes). Categories were expanded for winter monitoring due to the greater diversity of water birds present, and to showcase differential use of habitats by individual species.

6.3 Results and Discussion

California rice fields have been shown to be important habitat for migratory birds (Elphick and Oring, 1998; Elphick, 2000). These results document the usage and compare usage amongst the different habitats.

In considering the wildlife data, the key issue of spatial and temporal variability needs consideration. Time of day can greatly affect the count as during certain periods of the day, birds stay low in the vegetation and are not seen, while during other times, birds are more active. Moreover, during the survey time, birds may be in one field but not in an adjacent field with the same habitat. Essentially, these fields are a relatively small area in the larger Delta, and expecting to document average bird use with limited surveys is not realistic.

Nonetheless, the fields and farms taken as a whole provide a data set that would be expected to provide a typical range of usage.

6.3.1 Land birds

One sampling event was conducted during each of the seasons for each of the participating farms as well as at the Consumnes River Preserve (Table 6-1).

Land bird use between the agricultural types and managed wetland habitat was generally similar during the two summer observations (Table 6-2). In rice and corn fields on Wright-Elmwood Tract and on Rindge Tract, and in the managed wetlands, between 25 and 70 land birds were counted over the two years. Counts in corn and rice very similar at the different locations (Wright-Elmwood and Rindge Tract). The exception was Bouldin Island where summer land bird counts in the rice were an order of magnitude greater then in the corn or those counts at the other locations. High abundance during summer observations for Bouldin Island was primarily a factor of the large recorded use by swallow and blackbird flocks, especially in 2005.

There was not an apparent pattern of use between habitat types during winter observations though the most land birds were counted in corn planted at Wright-Elmwood Tract and rice

planted at Bouldin Island. The combination of corn and rice fields together as adjacent habitats appeared to attract more land birds then the seasonal wetland habitat. During the winter months, limited food resources and reduced land bird habitat availability from flooded regimes decrease land bird use.

6.3.2 Water birds and waterfowl

Waterfowl and other water birds almost exclusively used rice and managed wetlands in summer (Table 6-3). Similar waterfowl and other water bird use of rice fields and managed wetlands during summer observation can be attributed to these habitat types having similar water depths (12-30 in) favorable by water birds, providing important components to satisfy life-history events (e.g., vegetative cover for nesting sites and refuge during molt) for these species, and providing critical food base (e.g., invertebrates) to complete reproductive and molt requirements. The Consumnes River Preserve seemed to provide better habitat to water birds in the summer. One hundred and fifty six water birds were counted for 2004 and 2005 combined for the managed wetlands as compared to between 42 and 60 water birds counted in the rice for the same time periods. Corn fields were not flooded during summer observations, and did not provide water bird habitat needs. Consequently, occurrence of water birds during summer observations was none.

During winter, all habitat types experienced high use by waterfowl and water birds. All habitat types were flooded (0-36 inches); however, some corn fields on both Wright-Elmwood Tract and Bouldin Island were not. During the winter, corn fields had greater abundance observations. Water bird use for the 2004-2005 survey was greater in rice then in corn. For the 2005-06 survey, the reverse was true, with water bird use two to three times higher in the corn then in rice. Additionally, winter water bird use recorded for the 2005-06 survey was an order of magnitude greater then recorded for the 2004-05 survey. Water bird use in the managed wetlands was less variable between the years. In the second winter, water bird use for the managed wetlands and rice were similar, and both were less then for corn.

The winter results demonstrate the high variability that can be found between years. These surveys only illustrate two days of water bird use. Use of all habitat types by water birds is highly variable depending various conditions including depth, duration and timing of flooding; weather; hunting pressure; and quality of food resources. The level of variability can change from day to day. Overall, the least variability was found in the managed wetland site, with winter wetland surveys showing water bird usage on the same order of magnitude for both years.

As expected and observed, corn fields not flooded attracted a high abundance of geese and limited numbers of ducks. Typically, geese are upland feeders that prefer foraging in dry agriculture fields. Managed wetlands and flooded agricultural fields are more attractive to ducks and other water bird species.

Table 6-1. Wildlife Survey Dates.

Same colors represent same date, same site and same habitat.

Season	Date	Site	Habitat
Summer	8/8/2004	MUZIO	RICE
	8/8/2004	MUZIO	CORN
	8/8/2004	COSUMNESLOSTSLOUGH	SEASWET
	8/10/2004	BOULDIN	RICE
	8/10/2004	BOULDIN	CORN
	8/10/2004	COSUMNESDESMOND	SEASWET
Winter	2/7/2005	MUZIO	RICE
	2/7/2005	MUZIO	CORN
	2/7/2005	COSUMNESLOSTSLOUGH	SEASWET
	2/10/2005	BOULDIN	RICE
	2/10/2005	BOULDIN	CORN
	2/10/2005	COSUMNESDESMOND	SEASWET
Summer	7/13/2005	MUZIO	RICE
	7/13/2005	MUZIO	CORN
	7/13/2005	KLEIN	RICE
	7/13/2005	KLEIN	SEASONAL
	7/13/2005	KLEIN	CORN
	7/13/2005	COSUMNESLOSTSLOUGH	SEASONAL
	7/14/2005	BOULDIN	RICE
	7/14/2005	BOULDIN	CORN
	7/14/2005	COSUMNESBARN	SEASONAL
Winter	12/8/2005	KLEIN	RICE
	12/8/2005	KLEIN	CORN
	12/9/2005	COSUMNESBARN	SEASONAL
	12/9/2005	MUZIO	CORN
	12/9/2005	MUZIO	RICE
	12/9/2005	BOULDIN	RICE
	12/9/2005	BOULDIN	CORN
	1/14/2006	COSUMNESLOSTSLOUGH	SEASONAL

Table 6-2. Land bird Survey.

Sampling was conducted on one day during each season at each participating farm and at the Consumnes River Preserve.

Season	Year		Agricultural							Managed
			Muzio Farm, Wright-Elmwood		Jack Klein Trust, Rindge Tract[2]		Bouldin Farms, Bouldin Island			Consumnes River Preserve
			Rice	Corn	Rice	Corn	Rice	Corn		Seasonal
Summer	2004		10	9	—	—	70	21		25
Sampling	2005		39	59	26	25	279	20		29
Event		**Total**	**49**	**68**	**26**	**25**	**349**	**41**		**54**
Winter	2004-2005		5	36	—	—	38	2		4
Sampling	2005-2006		0	0	1	0	0	0		1
Event		**Total**	**5**	**36**	**1**	**0**	**38**	**2**		**5**

[1] Landbirds include such birds as raptors and passerines.

[2] Rindge Tract was added in 2005.

Table 6-3. Water bird Survey

Season	Year	Taxonomical Category	Agricultural							Managed
			Wright-Elmwood Tract		Rindge Tract[1]		Bouldin Island			Cosumnes River Preserve
			Rice	Corn	Rice	Corn	Rice	Corn		Seasonal
Summer	2004	Waterfowl	1	0	—	—	0	0		0
		Other Waterbirds[2]	2		—	—	0	0		20
		Total 2004	**3**	**0**	**—**	**—**	**0**	**0**		**20**
	2005	Waterfowl	36	0	41	0	29	0		103
		Other Waterbirds	8	0	19	0	13	1		33
		Total 2005	**44**	**0**	**60**	**0**	**42**	**1**		**136**
Winter	2004-2005	Mallard	7	0	—	—	0	23		21
		Northern Pintail	1	0	—	—	0	0		308
		Geese	0	0	—	—	0	0		31
		Swans	90	0	—	—	0	0		46
		Total Waterfowl	**98**	**0**	—	—	**0**	**32**		**1558**
		Sandhill Crane	0	0	—	—	0	8		53
		Other Waterbirds	101	0	—	—	314	0		663
		Total 2004-2005	**199**	**0**	—	—	**314**	**40**		**2274**
	2005-2006	Mallard	0	0	0	0	0	0		182
		Northern Pintail	0	0	230	1000	0	1000		2223
		Geese	0	0	1000	19712	3500	0		2750
		Swans	0	0	8489	1500	595	32		0
		Total Waterfowl	**0**	**0**	**9823**	**22212**	**4095**	**11822**		5924
		Sandhill Crane	0	0	0	325	0	0		0
		Other Waterbirds	0	0	250	0	0	225		329
		Total 2005-2006	**0**	**0**	**10073**	**22537**	**4095**	**12047**		**6253**

[1] Rindge Tract was added in 2005.

[2] Other waterbirds include species such as herons and coots.

6.4 Conclusion

Table 6-4 provides a summary of the average count by plot and year. Recorded land bird use was higher during the summer sampling events as compared to the winter sampling event. The opposite was true with the water birds.

On average rice provided better land bird habitat in the summer then the other two habitats (e.g. corn, managed wetlands). This was do to high use at Bouldin Island, as there was overlap in the range of land bird use across the different land uses. Rice and corn together seemed to provide better land bird use then managed wetlands alone.

Water bird use in the summer was highest in the managed wetlands, being about two and a half times greater then for rice. Nearly no water birds used corn in the summer. In the winter, water bird use was lowest in the rice and highest in the corn. However, the range of water bird use by the different land uses was high with overlap between the different land uses.

The mix of usage by land birds and water birds between the habitats during the different seasons suggest that continued integration of managed wetlands along with rice and corn fields will provide habitat for a variety of breeding and migratory waterfowl and water birds.

Table 6-4. Summary average land bird and water bird count by land use and year.

Averages are by land use and year. Thus, the averages for rice and corn are for a total of 5 plots (2 plots in 2004 and 3 plots in 2005). For managed wetlands a total of two plots were used with Consumnes treated as a single managed wetland in 2004 and in 2005.

Land Use	Landbird				Waterbird			
	Summer		Winter		Summer		Winter	
	Average	Range	Average	Range	Average	Range	Average	Range
rice	85	10 - 279	9	0 - 38	30	0 - 60	2,936	0 - 4,095
corn	27	9 - 59	8	0 - 36	0	0 - 1	6,925	0 - 22,537
managed wetlands	27	25 - 29	3	1 - 4	78	20 - 136	4,264	2,274 - 6,253

6.5 Chapter References

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7 Assessing the feasibility of rice production along an east-west gradient in the Delta

7.1 Introduction

Agricultural production that requires the drainage of peat soils in the Delta has the potential to releases DOC into the irrigation return waters as a result of crop residues and soil organic matter decomposition. The DOC released from agricultural activities potentially poses serious health concerns when Delta waters are disinfected for use as drinking water. One possible option in the Delta to minimize DOC export is through conversion from agricultural practices that require repeated surface irrigations to crops having different irrigation requirements such as rice production. Rice, unlike other crops, can be grown under continuous flood resulting in lower decomposition of peat soils. This has the potential to minimize export of high DOC drainage water as is discussed in Chapter 5. Rice potentially offers other benefits as well such as mitigating or reversing oxidative subsidence through the rebuilding of organic soils, providing ecosystem restoration benefits to waterfowl, and enabling growers a more profitable crop option to other grain crops. More studies are needed to determine the effects rice has on mitigating or reversing oxidative subsidence, and to compare rice to other crops with regard to subsidence mitigation.

7.1.1 Background on growing rice in California

The Sacramento Valley of Northern California is an ideal region in the for the production rice. Historically, rice has been planted in the Sacramento Valley since the 1900s. Most rice production occurs on land with fine-textured clay soil that drains slowly. The area where rice is grown over the past twenty-five years has fluctuated between 300,000 acres and 600,000 acres and today averages about 500,000 acres. Colusa, Butte, Sutter, and Glenn counties account for approximately half the rice production in California. Other areas of rice production include Placer, Sacramento, Yolo and Yuba with acreages covering from 80,000 to 93,000 acres in any given year. The San Joaquin Valley region, including San Joaquin, Stanislaus, Merced and Fresno counties, account for about 15,000 acres of rice production. The primary Delta zone of Yolo, Sacramento, and San Joaquin counties account for approximately 5000 acres of production in the last ten years. The unique water seeding method and abundant sunshine combine to produce rice yields unrivaled anywhere in the world.

7.1.2 Moves to and Motivations for Growing Rice in the San Joaquin Delta

The most important historic constraint to growing rice in the Delta has been the climate and its effect on varieties and weed control from high organic matter soils. The cool night temperatures often fall below the critical temperature range for successful pollination. These conditions can cause “blanking” an abortion of the rice seed filling process. Some newly developed rice seed varieties are more suited to Delta environmental conditions. An excellent rice variety and well

suited to the Delta environment produced by the California Rice Experiment Station at Biggs is M104. M-104 is an early variety, with equal vigor to M202, which is the most commonly planted rice in the Sacramento Valley. M104 resists blanking and produces above average head and milled rice yields. It resists lodging, an important characteristic for windy Delta conditions and nitrogen rich soils that encourage vegetative growth. M104 yields about 7% more than M-202 under San Joaquin County planting conditions.

New varieties of rice have introduced an opportunity to Delta growers for an alternative other row crops. The potential economic advantages of rice over corn have led local farmers to begin converting cornfields and other row crops to rice production. These efforts have been supported by both the San Joaquin County Cooperative Extension office and Ducks Unlimited.

The San Joaquin Cooperative Extension has an ongoing program of testing for different varieties of rice appropriate to Delta environmental conditions, and has been working with growers who are interested in rice as either a permanent crop or as part of their crop rotation. The Cooperative Extension has offered workshops to growers to provide an overview of the agronomics associated with growing rice, with the most recent workshop in being held in February 2005. They also have been assisting individual farmers in their conversion to rice production. The Cooperative Extension is supportive in promoting rice as part of a crop rotation regime to control weeds, nematodes and diseases associated with other vegetable crops that grow in drained soils. The Cooperative Extension hypothesizes that the very different hydrologic regimes, dry seeded practices for stand establishment and new post emergence chemistry to control weeds will aid in reducing nematodes and other disease pests and has begun testing that hypothesis.

Ducks Unlimited has been actively promoting rice over the past ten years as a means to improve waterfowl habitat in the Delta, especially during the migratory season. Flooded rice fields have a documented history as excellent habitat for waterfowl and other water-dependent species. Ducks Unlimited has found funding sources to aid growers in their conversion to rice production, and has provided one-on-one expertise in rice agronomic practices to growers throughout their conversion process.

7.1.3 Chapter Goal

This chapter seeks to quantify some of the constraints to rice production, summarizing the economics for rice grown for each of the participating farms; discussing the different soils and climate at the study locations; and providing guidance information for converting to rice production in the Delta.

7.2 Methods

Three field sites located in San Joaquin County were used for investigating the feasibility of growing rice throughout the Delta (Figure 7-1). These sites were located along a northwest-southeast gradient. The sites were Bouldin Farms on Bouldin Island (Fig.7-2), Muzio Farm on Wright-Elmwood Tracts (Fig. 7-3), and Jack Klein Trust on Rindge Tract (Figure 7-4)..

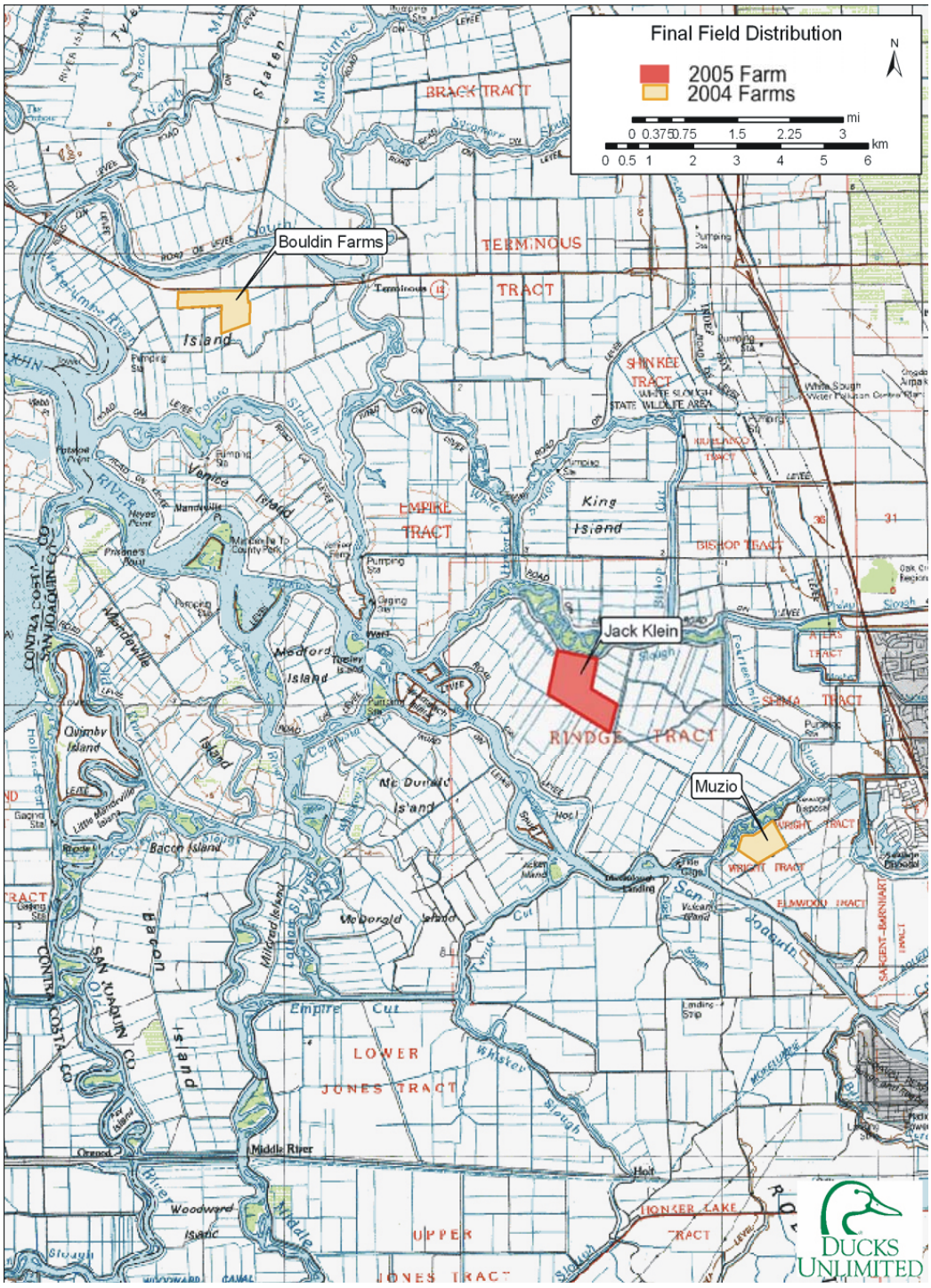


Figure 7-1 – Delta Map including locations of the selected farms.

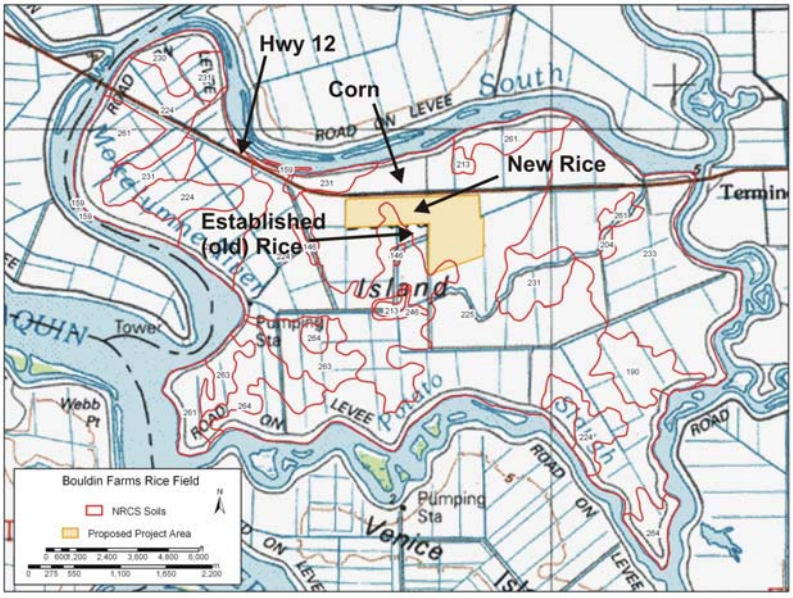


Figure 7-2. Bouldin Island is located within the channels of the Mokelumne and San Joaquin rivers.

Location of the treatment plots is indicated in the color tan and is managed by Bouldin Farms.

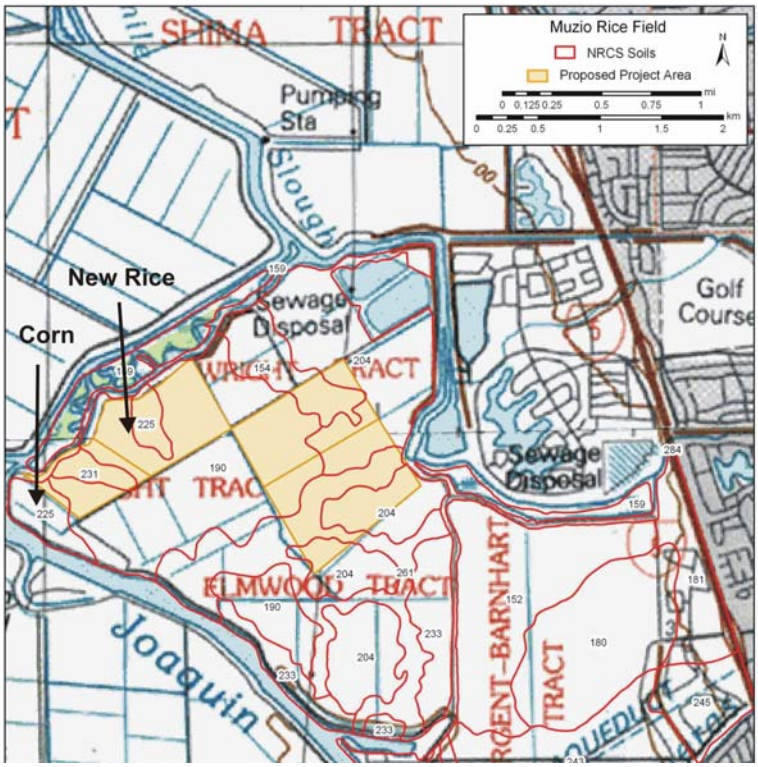


Figure 7-3. The Wright-Elmwood Tract is located west of Stockton.

Studies were conducted on rice and corn plots indicated. Plots were farmed by Muzio Farm.

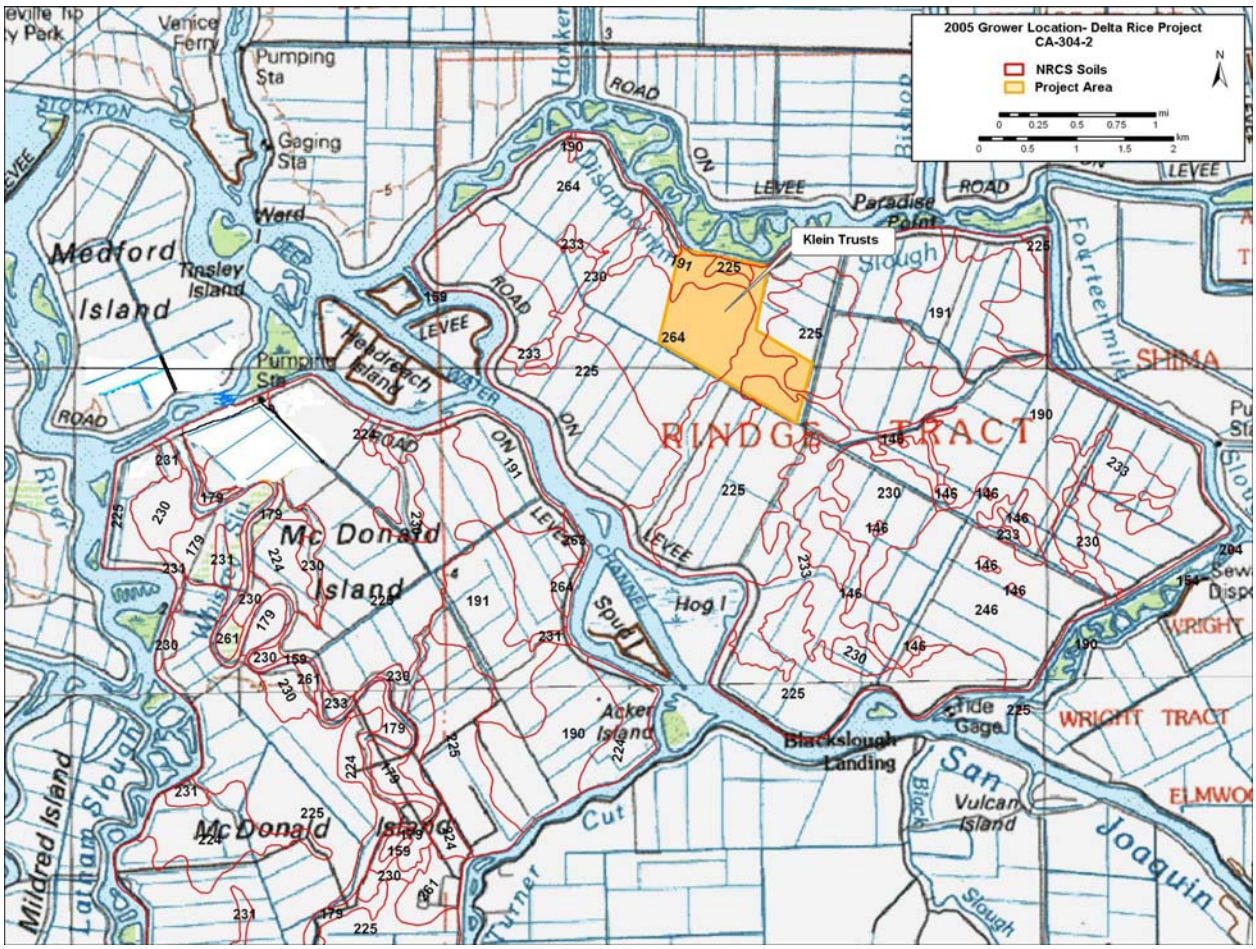


Figure 7-4. Rindge Tract is northwest of Wright Elmwood Tract.

Studies at Jack Klein Trust were conducted on 100-ac plot of the total fields converted to rice in 2005.

7.2.1 Economics and Yield Measurements

For Bouldin Island and Wright-Elmwood Tract, rice production costs and profits were developed for both 2004 and 2005. These data were to provide information on the change in economics for rice during the two years of this project and how the economics for rice compared to corn for that period. Production costs were also developed for 2005 data for Bouldin Island, Wright-Elmwood Tract and Rindge Tract. These economics are to provide information on the spatial differences in economics throughout the Delta.

For both analyses, standard categories relative to rice production were used. Variation exists within the expense categorization and tracking of each of the project participants. For example, Rindge Tract represented the costs of harvesting as contracted services and compiled them into its Overhead Costs. While Bouldin Island placed harvesting contractor expenses into the Harvest Category. Though variation exists, the project team was able to develop standard expense

categories to describe rice production costs: Field Preparation, Planting, Growing, Harvest, and Overhead Costs. Income categories include an average yield per acre value (in hundredweight or cwt), and an estimated income per acre based on a rice commodity value of $11 per hundredweight. Hundredweight is a standard grain yield measurement representing the average amount of rice in 100-pound increments harvested per acre and is often referred to in the industry as "sacks per acre". The estimated yield was provided by the individual growers.

Rice commodity prices, as well as the reporting project participants, have represented the price per hundredweight near $11. This price represents a typical price expected to be received this year. Categories could be further divided to analyze specific elements such as land leveling, disking, planting, or drying. However for the purposes of this report, the categories have been consolidated for ease of interpretation. Finally, the expense total is subtracted from the estimated income amount to calculate profit or loss per acre.

The cost and revenue rates for the project participants are compared to typical cost and revenue information for rice production in the Sacramento River Valley. This comparison is made because upon average as much 500,000 acres of rice is grown in the Sacramento River Valley. This amount represents a substantial proportion (>95%) of California's rice production. Though general comparisons are made for the various categories, the actual means of preparing, planting and cultivating rice between the two California regions are quite different.

The expense and yield values for the three Delta Rice participants were provided by the project participants themselves. The expense and yield values for rice production in the Sacramento Valley are estimated and were provided by the Ducks Unlimited Rice Consultant. These estimated values are based on the consultant's extensive experience and familiarity with the topic. The price per hundredweight was estimated based on current commodity pricing and information provided by the project participants.

Additionally, yield estimates were developed by UC Davis. These estimates are based upon pounds per acre and were developed to test the effects of the different treatments. For these estimates, rice plant samples were collected from 5 randomly located microplots within the high and low water treatments. The rice was cut just above the soil surface from 0.25-m^2 quadrats taking care to remove the entire plant from the plot. Rice residue and grain dry matter were determined after drying the samples until constant weight at 60° C and separating into grain and straw residue. Dried residue sub-samples were ground using a Wiley mill fit with a 2-mm screen; and then grain and residue sub-samples were ball milled to pass a 250-µm sieve. Total C and N content were determined by dry combustion. All plant determinations are expressed on a 16% moisture basis.

7.2.2 Climate Data

The climate data was collected from CIMIS stations at Twitchell Island and Lodi that bracketed the northwest transect on which our growers were located for this study. Monthly averaged data was used to characterize the summer and winter seasons during which this project was conducted.

7.2.3 Soil measurements

Soil samples from all treatment plots were taken to the depth of mineral soil. Sampled soil depths included 0 to 15 centimeters for the first three horizons up to 45 cm deep and then were followed by 30 cm increments until the mineral horizon was reached. A minimum of 5 sample locations per field were sampled.

At each sample location, composited and discrete soil samples were collected. The composited samples consisted of 5 separate soil sample collected radially around the sampling location to a depth of 45 cm. These samples were composited by horizon. On these composited samples (location X horizon), percent carbon and percent nitrogen were determined by drying the samples at 60° C and analyzed for total C and N by dry combustion. On the corresponding discrete samples, bulk density was also measured in addition to percent carbon and percent nitrogen. These samples were taken to the full depth at which the mineral horizon was reached, if possible, and on these samples soil lithology was described.

7.2.4 Specifications and Cultural Practices

Information on specifications for checks and water control structures and on the cultural practices was learned through interviewing the growers at Bouldin Island and Wright Elmwood Tract during the fall of 2004, and our discussions with our rice expert and the San Joaquin County Agricultural Extension. These practices are described and discussed in "Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots", November 2005.

7.3 Results

7.3.1 Yield and Economics

Though variation existed in the reporting of expense values and their categories (as discussed in the Methods for this chapter), the project team was able to determine the overall expenses that these growers incurred. Based on their yield information and on a comfortably estimated price per hundredweight, a profit or loss value was determined.

Tables 7-1 and 7-2 respectively show the costs and profits for growing rice and corn at Bouldin Island and Wright-Elmwood Tract during 2004 and 2005.

7.3.1.1 Bouldin Island

At Bouldin Island, rice expenses did not vary much between the years except for the use of herbicides. In 2005, there was much greater weed pressure at Bouldin Island because of the wet spring. This weed pressure also resulted in a drop in production at Bouldin Island the second year, with rice production decreasing by over 15% from 75 sacks to 63 sacks per acre.

During 2004, profits on rice at Bouldin Island were $213 per acre as compared to $161 per acre for corn. In 2005, profits on rice dropped to $152 per acre and dropped to $141 per acre for corn. During both years, rice was more profitable then corn. Rice earned about $50 per acre more in 2004 and about $10 per acre more in 2005.

7.3.1.2 Wright-Elmwood Tract

At Wright-Elmwood Tract, rice expenses were uniform between the two years. Rice production increased in 2005 from 75 to 85 sacks per acre, increasing estimated profits from about $316 to $363 per acre. For both years, rice was much more profitable then corn. Corn earned only about $35 per acre during both 2004 and 2005. This earnings was lower then the earnings at Bouldin Island because or greater costs associated with growing the crop at Wright-Elmwood Tract. At Wright-Elmwood Tract, more was spent on fertilizers, herbicides and irrigation. The increased costs in these categories are essentially the difference in profits between the two farms. Thus, under this scenario in which higher costs were associated with growing corn, rice earned about $300 per acre more then corn.

7.3.1.3 Comparison Across the Delta and with Sacramento Growers

Table 7-3 compares the profits from Delta growers and an average for growers in the Sacramento Valley. The Delta Rice participants were clearly able to produce a profitable rice crop in 2005. Costs associated with planting the crop such as seed preparation, pre-irrigation and seeding are higher in the Sacramento Valley and thus lower costs in these categories in the Delta provide an opening for higher profit if comparable yields can be achieved and similar profits under conditions of reduced yields.

Yields at both Rindge Tract and Wright-Elmwood Tract were comparable to Sacramento Valley yield averages, yet with lower production expenses. Production costs were 77% to 83% of those for the average production cost estimated for Sacramento Valley Grower. Thus, during 2005, these two Delta growers who achieved similar yields paid roughly $130 to $170 less per acre in production costs.

Yields at Bouldin Island were only about two thirds those typically achieved by Sacramento Valley growers. Yet production costs at Bouldin were about $340 less per acre.

Table 7-1. Costs and Profits of Growing Rice and Corn at Bouldin Island, 2004 and 2005.

		Rice		Corn	
		2004	2005	2004	2005
1. Field Preparation	A. Levees				
	B. Water Control Structures	$5	$15		
	C. Ditches	$5	$5	$15	$5
	D. Disking, Level, & Plow	$25	$30	$25	$30
	E. Other Costs?				
2. Plant Crop	A. Seed	$25	$20	$40	$40
	B. Planting	$2.50	$2.50	$2.50	$2.50
	C. Other Costs?				
3. Growing Crop	A. Fertilizers	$20	$20	$30	$30
	B. Herbicides	$40	$75	$20	$20
	C. Irrigation & Pumping				
	D. Other Costs? (Tools & Supplies)	$5	$5	$5	$5
4. Harvest	A. Crop Harvest	$85	$80	$50	$50
	B. Hauling			$50	$50
	C. Store & Dry	$110	$97.5	$5	$5
	D. Other Costs?				
5. Overhead	A. Salaries, Insurance, RD Fees	$65	$65	$65	$65
	B. Other Costs?				
	Expense Total	$387.50	$415.00	$307.50	$312.50
	Yield Per Acre (cwt or tons)	75cwt	63cwt	4.8 tons	5.1 tons
	Price/cwt or ton	$8/cwt	$9/cwt	$97.5/ton	$89/tons
	Income / acre	$600	$567	$468	$454
	Estimated Profit or Loss / acre	$212.50	$152.00	$160.50	$141.40

Table 7-2. Costs and Profits of Growing Rice and Corn at Wright-Elmwood Tract, 2004 and 2005.

		Rice		Corn	
		2004	2005	2004	2005
1. Field Preparation	A. Levees	$50	$50	$9	$10
	B. Water Control Structures	$24	$0		
	C. Ditches	$0	$0	$5	$5
	D. Disking, Level, & Plow	$25	$25	$50	$55
	E. Other Costs?				
2. Plant Crop	A. Seed	$25	$25	$40	$40
	B. Planting	$15.00	$15.00	$40.00	$40.00
	C. Other Costs?				
3. Growing Crop	A. Fertilizers	$90	$90	$75	$25
	B. Herbicides	$100	$100	$45	$45
	C. Irrigation & Pumping	$15	$15	$70	$40
	D. Other Costs? (Tools & Supplies)			$5	$5
4. Harvest	A. Crop Harvest	.95cwt	.95cwt	.65cwt	.65cwt
	B. Hauling *Storage*	1.55cwt	1.55cwt	.4cwt	.4cwt
	C. Store & Dry				
	D. Other Costs?				
5. Overhead	A. Salaries, Insurance, RD Fees	$55	$55	$55	$55
	B. Other Costs?				
	Expense Total				
	Yield Per Acre (cwt or tons)	75cwt	85cwt	110cwt	110cwt
	Price/cwt or ton				
	Income / acre				
	Estimated Profit or Loss / acre	$316.00	$363.00	$35.00	$35.00

To compare profits with those in the Sacramento Valley, an income of $11/cwt based upon U.S. Cash Market Prices shown on January 2006 (Oryza, 2006) was assumed. These prices vary and the price is currently $12.25/cwt. From 1988 to last year, average rice prices in California varied between around $5.25 to $10.50/cwt (Table 7-3, USDA, 2005). Growers at Rindge Tract and Wright-Elmwood Tract received slightly higher prices then those shown in Table 7-3 in part because of the high quality of the rice harvested. Lower prices would reduce profits to Delta and Sacramento Valley growers uniformly.

Based upon the $11/cwt price Delta growers had higher profits with rice then the average Sacramento Valley grower (Table 7-4). The highest profits were achieved at Rindge Tract, where rice earned an estimated $384 per acre. The lowest profits were achieved at Bouldin Island, where rice earned an estimated $278 per acre. The profit range was higher then the estimated $230 per acre estimated for growers in the Sacramento Valley.

Table 7-3. Average price received by farmers by month and marketing year.

(USDA, 2005).

Appendix table 19--Rough rice: Average price received by farmers by month and marketing year 1/

Item	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
Month:									
August	7.49	7.41	6.66	7.16	6.60	5.14	6.87	7.77	10.10
September	6.97	7.59	6.21	7.67	6.41	5.16	6.82	8.01	10.00
October	6.85	7.41	6.02	7.65	6.40	6.01	6.52	8.84	9.66
November	6.81	7.03	6.29	7.84	6.40	7.94	6.63	9.21	9.41
December	6.68	7.05	6.13	7.98	6.38	8.78	6.60	9.45	9.82
January	6.58	7.44	6.39	7.84	6.35	8.92	6.83	9.36	9.95
February	6.67	7.57	6.75	7.97	6.06	9.99	6.74	9.19	10.10
March	6.60	7.55	7.07	7.78	5.63	10.10	6.67	9.20	10.20
April	6.74	7.41	7.43	7.46	5.50	9.80	6.75	9.35	10.30
May	6.78	7.28	7.44	7.18	5.23	9.90	6.87	9.73	10.20
June	7.05	7.18	7.43	6.97	5.02	8.76	7.06	9.77	9.90
July	7.45	7.05	7.21	6.99	4.90	7.69	7.19	9.81	10.00
Season average price:	6.83	7.35	6.68	7.58	5.89	7.98	6.78	9.15	9.96
State: 2/									
Arkansas	6.90	7.46	6.75	7.69	5.93	7.97	6.52	9.14	10.20
California	6.15	6.27	5.93	6.65	5.64	8.27	6.97	8.79	7.91
Louisiana	6.90	7.81	6.73	7.67	5.88	7.65	6.71	9.09	10.60
Mississippi	7.02	7.57	6.99	8.48	5.82	8.37	7.00	9.25	10.50
Missouri	7.22	7.54	7.21	7.81	5.91	8.03	6.72	9.06	10.30
Texas	7.24	8.02	7.41	8.15	6.17	7.69	7.12	9.73	10.80
Type:									
Long grain	6.96	7.59	6.94	7.83	5.87	7.93	6.87	9.37	10.60
Medium & short grain	6.47	6.71	6.19	7.00	5.91	8.09	6.70	8.82	8.37

Item	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04 3/ 4/	2004/05 3/ 4/	2005/06
Month:									
August	9.94	9.01	6.91	5.72	5.01	3.94	5.93	8.96	6.54
September	9.92	9.42	6.17	5.53	4.67	4.09	6.56	8.47	6.95
October	10.00	9.31	5.91	5.57	4.39	4.03	7.15	7.60	6.94
November	9.82	9.02	5.96	5.72	4.25	4.24	7.80	7.36	7.34 5/
December	9.77	9.10	6.01	5.69	4.29	4.46	8.55	7.43	
January	9.57	9.09	5.98	5.86	4.30	4.66	8.57	7.16	
February	9.75	9.02	5.82	5.72	4.16	4.24	8.23	6.79	
March	9.67	8.93	5.64	5.66	3.99	4.31	8.45	6.88	
April	9.40	8.49	5.75	5.68	3.94	4.61	8.65	7.06	
May	9.38	8.21	5.82	5.40	3.98	4.84	8.82	6.97	
June	9.58	8.25	5.69	5.14	3.92	5.43	9.30	6.94	
July	9.58	8.26	5.59	5.32	3.81	5.31	9.37	6.78	
Season average price:	9.70	8.89	5.93	5.61	4.25	4.49	8.08	7.33	7.75-8.05 6/
State: 2/									
Arkansas	9.87	8.87	5.71	5.60	3.93	4.16	7.70	7.15	NA
California	7.95	9.19	6.97	4.99	5.28	6.32	10.40	6.95	NA
Louisiana	10.20	8.87	5.99	5.82	4.47	4.14	7.68	7.85	NA
Mississippi	10.40	8.99	5.49	5.68	4.15	4.94	7.34	7.30	NA
Missouri	10.00	8.75	5.60	5.40	3.70	3.90	7.20	7.00	NA
Texas	10.90	9.32	6.04	5.82	4.61	4.16	7.35	8.20	NA
Type:									
Long grain	10.20	8.79	5.70	5.84	4.10	4.15	7.60	NA	NA
Medium & short grain	8.52	9.18	6.62	5.15	4.82	5.90	9.94	NA	NA

NA = Not available.

1/ August 1 to July 31 marketing year. 2/ / Marketing year for Arkansas and Mississippi--August-July, California--October-September, Louisiana and Texas--July-June. 3/ Revised monthly prices reported in the August 2005 *Agricultural Prices*. 4/ State prices are from the July 2005 *Agricultural Prices* 2004 Summary. Prices by class are from the January 2005, *Agricultural Prices*. 5/ Mid-month estimate.

6/ Season-average price range reported in the November 2005 WASDE, WAOB, USDA.

Source: *Agricultural Prices*, National Agricultural Statistics Service, USDA.

Table 7-4. Economic Comparison between Delta Farmers and Sacramento Valley Averages, 2005.

Economic data from 2005 was used for this comparison. Comparison assumes a price of $11/cwt (Oryza, 2006)

			Bouldin Island	Wright-Elmwood Tract	Rindge Tract	Sacramento Valley Averages
1	**Field Preparation**	Checks, Water Control Structures, Laser Level, Disking, etc.	$50	$75	$83	$70
2	**Plant Crop**	Seed Costs, Pre-Irrigation, Planting, etc.	$22	$40	$30	$300
3	**Grow Crop**	Fertilizers, Herbicides, Pesticides, Irrigation, Water Management, etc.	$100	$205	$257	$300
4	**Harvest**	Harvest, Hauling, Storage, Drying, etc.	$178	$213	$0	$40
5	**Overhead**	Salaries, Insurance, RD Fees, & Other Costs	$65	$55	$258	$50
		Total Expenses / Acre	**$415**	**$588**	**$628**	**$760**
		Yield (*cwt = Hundred Weight/acre)*	63	85	92	90
		Estimated Income / Acre (~ *$11/cwt*)	$693	$935	$1,012	$990
		Profit or (Loss) / Acre	**$278**	**$348**	**$384**	**$230**

7.3.2 Climate data

One of the goals of this project was to determine the potential to grow rice in the Delta. The climate data indicated that rice variety M104 would achieve maximum yield potential. Climate data for our two instrumented sites is shown in Table 7-5 by season and year. Twitchell Island site represents a location slightly further west then Bouldin Island. Lodi represents a site to the east of Wright Elmwood Tract.

The climate data indicate rice production can occur further west then our study fields according to the CIMIS weather station data. Averaged air temperatures are very similar between both sites. More westerly locations in the Delta have higher wind speeds, slightly higher summer precipitation and slightly higher minimum air temperatures.

During rice production, microclimates created by the water also may affect production. Water temperature may be of similar importance for growing rice. Table 7-6 shows average water temperature during the growing season (June – September) at experimental plots for this study. Inflow water was warmer in the experimental plots at Bouldin Island then in the experimental plots at Wright-Elmwood Tract, averaging about 23 °C for 2004 and 2005 as opposed to about 22 °C for the same period of time. Outflow waters in 2004 from the plots were about 19.5 °C at Bouldin as opposed to about 21.5 °C for the plots at Wright Elmwood Tract. For 2005, outflow water temperatures from the experimental plots at both farms were about 21.5 °C. These data suggests that water further west in the Delta is slightly warmer. However, similar air temperatures seem to result in outflow waters being about the same.

From our data, yields did not appear to be negatively affected by the temperature differences, either air or water. Yields were higher at Wright-Elmwood Tract then Bouldin Island for both 2004 and 2005 (Table 7-7. Though many factors affect yield, cooler temperatures, whether air or water, would tend to decrease yields. However, our data shows higher yields at Wright-Elmwood Tract compared to Bouldin Island. All temperature effects would seem to favor Bouldin Island: higher inflow water temperature, high average minimum temperature, higher average air temperature. Nonetheless, lower yields at Bouldin Island suggest that these effects were minimal and yields were more dependent upon other factors.

Table 7-5. Average of monthly average weather data. (*From CIMIS database.)

CIMIS Station	Season	Tot Precip (in)	Avg Sol Rad (Ly/Day)	Avg Max Air Tmp(F)	Avg Min Air Tmp (F)	Avg Air Tmp(F)	Avg Dew Point(F)	Avg Wind Speed (mph)	Avg Soil Temp (F)
Twitchell	Sum 04	0.15	614.0	84.3	57.7	69.9	50.9	9.4	70.2
	Win 05	2.35	273.4	61.6	41.8	51.3	43.2	6.1	55.6
	Sum 05	0.25	561.8	82.9	56.2	68.6	50.6	9.0	70.2
Lodi W.	Sum 04	0.01	540.0	85.9	53.4	69.3	55.0	2.7	70.7
	Win 05	2.53	256.3	63.6	42.1	52.3	46.3	2.2	56.0
	Sum 05	0.35	579.6	84.2	52.5	68.1	55.0	2.5	70.0

Table 7-6. Summer Water temperatures at Study Plots, 2004 and 2005.

Location	Year	In (deg C)	Out (Deg C)
Bouldin Island	2004	22.45	19.62
	2005	23.51	21.66
Wright-Elmood Tract	2004	20.80	21.45
	2005	22.89	21.65

Table 7-7. Rice yields by year at Bouldin and Wright Elmwood Tract.

Rice yields shown are from field measurements made by UC Davis on study plots. These estimates are slightly different then estimates made by farmers (Tables 7-1 through 7-4) because of differences in methods and because these data are only for the study plots.

Farm Year	Yield (cwt) @ 14% moisture		
Bouldin Island	N	Mean	SD
2004	25	59	8
2005	20	48	19
Wright-Elmwood Tract			
2004	15	69	9
2005	15	65	20

7.3.3 Soil Data

The soils in this study were typical peat type soils common to the Delta. At Bouldin Island, the average peat thickness in the tested fields was over 110 cm as compared to Wright Elmwood Tract where the average peat thickness was just under 80 cm (Figure 7-3). Using a t-test, these average depths differed significantly ($p<0.01$; Table 7-9). Soil C contents on our study plots ranged from 12 to 26%.

Composite soil samples were used for comparing percent nitrogen and percent carbon. On average, soil carbon content at Wright-Elmwood Tract and Bouldin Island were about 17.5% and did not differ significantly by farm ($p>0.05$; Table 7-8). As organic matter is approximately 58% organic carbon, the soils were about 30% organic matter on average. Bouldin Island soils had higher nitrogen concentrations and these differences were significantly different between the farms ($p<0.05$).

Table 7-8. Carbon and Nitrogen Content of Peat Soils at Bouldin Island and Wright Elmwood Tract.

Percent carbon differs significantly between locations, but percent nitrogen does not.

Location	N[1]	%C			%N		
		Mean	SD	significance $p < 0.05$[2]	Mean	SD	significance $p < 0.05$[2]
Bouldin Island	65	17.92	4.94	a	1.29	0.28	b
Wright-Elmood Tract	45	17.38	5.04	a	1.18	0.25	a

[1]Number of samples.

[2]Different letters show if treatments (Location) are significantly different (p<0.05).

Table 7-9. Peat thickness at the different experimental plots.

farm	plot	avg depth of peat by plot (cm)	avg depth of peat by farm (cm)	SE	***
Bouldin Island	NRH1	98.28	111.24	4.72	a
	NRH2	112.00			
	NRL1	124.49			
	NRL2	108.24			
	OR	113.19			
Wright Elmwood Tract	Corn	75.56	77.40	9.78	b
	NRH	96.00			
	NRM	62.39			
	NRL	75.67			

***Different letters indicate a significant difference (t-test, P<0.01).

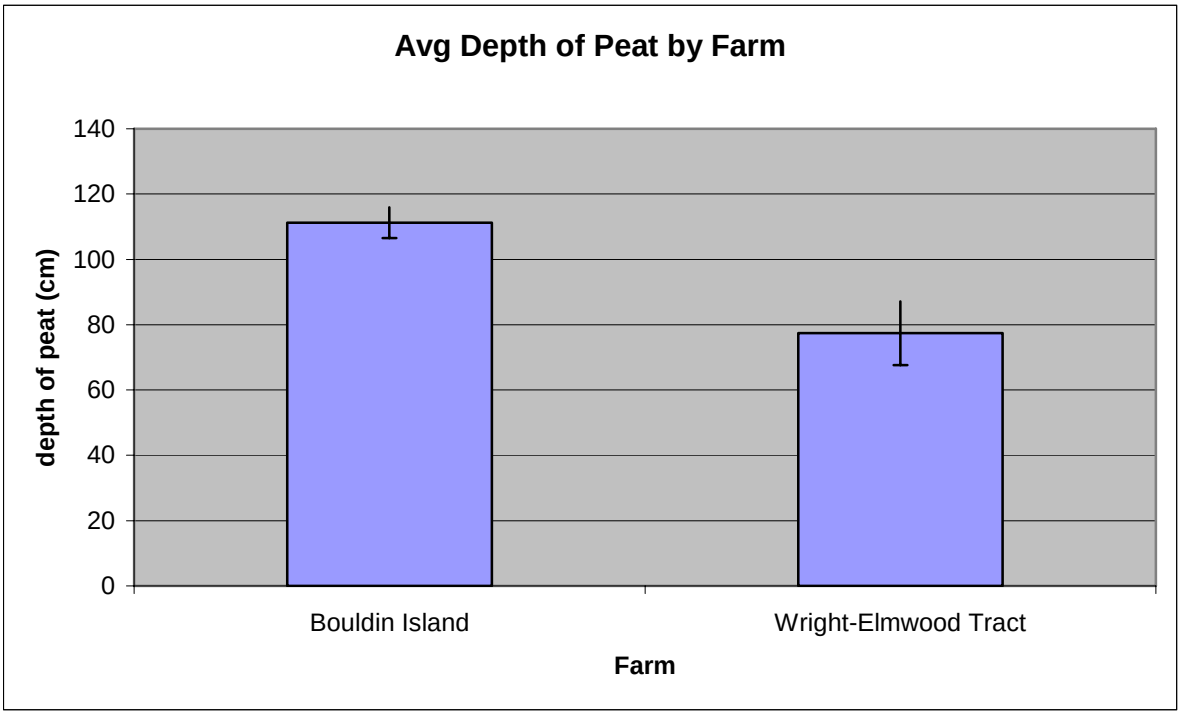


Figure 7-5. Average peat thickness at Bouldin Island and Wright-Elmwood Tract.

Figures 7-4 and 7-5 show percent carbon and percent nitrogen by horizon: top 0 – 15 cm, 15 – 30 cm, and 30 – 45 cm. On average, percent carbon and percent nitrogen were lower in the top two horizons at Wright-Elmwood Tract (15 – 16%) as compared to Bouldin Island (about 17.5%). This trend reversed at the lowest horizon for which composite samples were taken (30 – 45 cm). This trend was also reflected in percent nitrogen. In the first two horizons, percent nitrogen was about 1.1% at Wright-Elmwood Tract and about 1.25% at Bouldin Island. In the deepest horizon, both farms had an average percent nitrogen of about 1.35%. The carbon:nitrogen (C:N) ratio was in the range of 14:1 to 15:1 for both farms.

In general, both locations had similar percent carbon on average. However, the distribution in the soil horizons was different for both farms. Both carbon and nitrogen content were similar throughout the profiles at Bouldin Island whereas at Wright-Elmwood Tract, those constituents were higher in the deeper soils. Both farms had about 30% organic matter in the soils on average, assuming that 58% of organic matter is carbon.

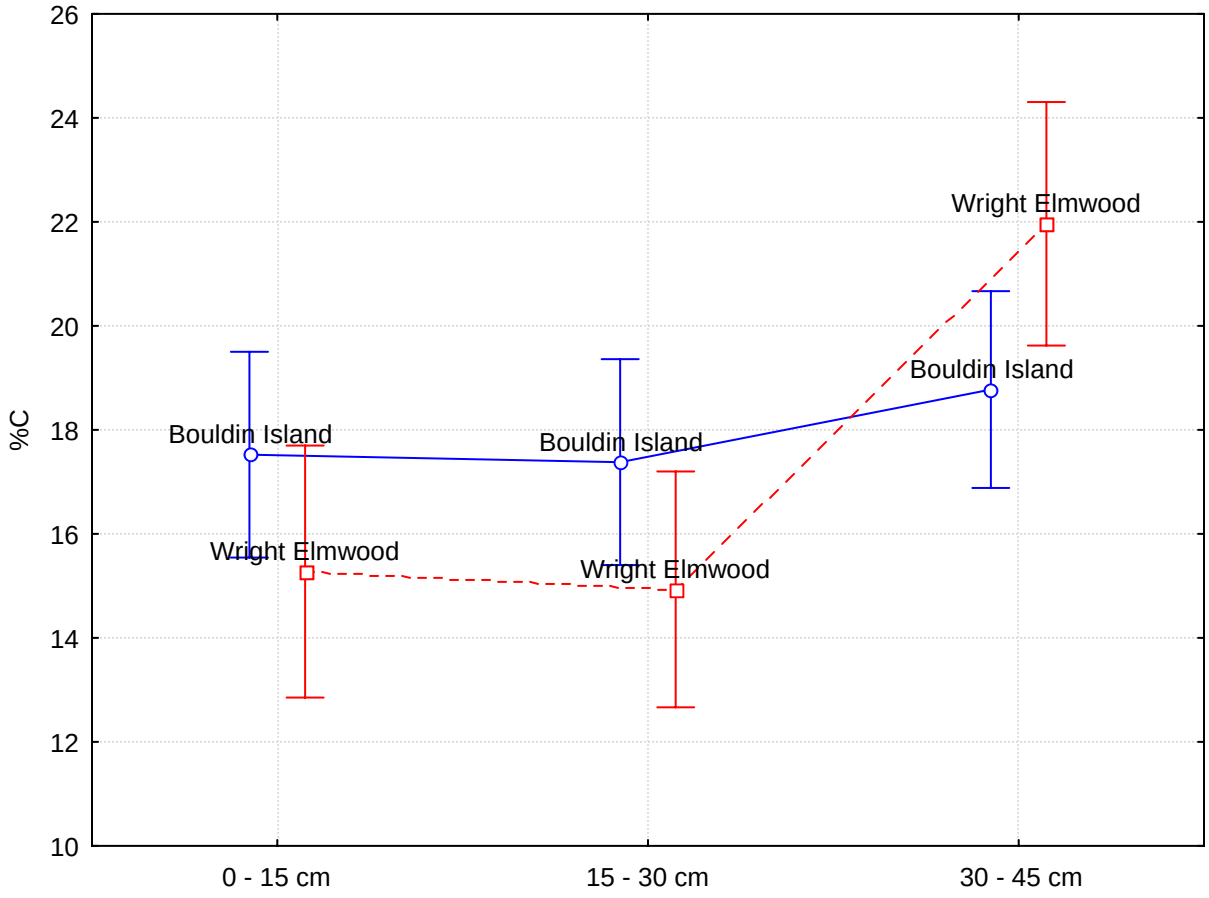


Figure 7-6. Peat Carbon Content by Horizon at Bouldin Island and Wright Elmwood Tract Experimental Rice Plots.

Data is from new and established rice fields at Bouldin Island and from new rice fields at Wright Elmwood Tract. Vertical bars represent 95% confidence interval.

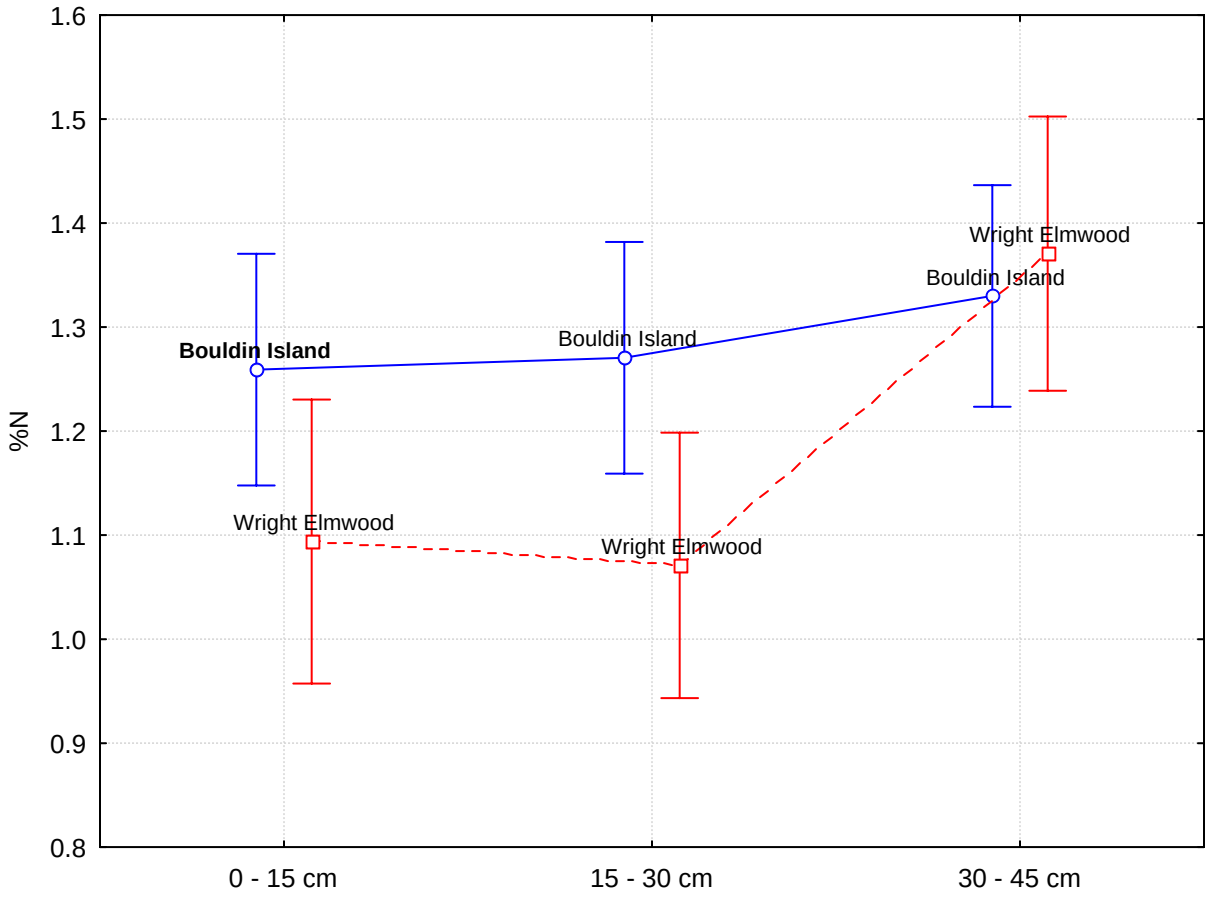


Figure 7-7. Peat Nitrogen Content by Horizon at Bouldin Island and Wright Elmwood Tract Experimental Rice Plots.

Data is from new and established rice fields at Bouldin Island and from new rice fields at Wright-Elmwood Tract. Vertical bars represent 95% confidence interval.

7.3.4 Specifications and Cultural Practices

Table 7-10 shows the timing of different activities for implementing rice and Table 7-11 provides specifications for setting up the checks and water control structures. Slightly different practices were used at each farm.

1) Before seeding, soils were roughened to a depth of about 5 to 6 inches (12 to 15 cm) for seedbed preparation at Muzio Farm on Wright Elmwood Tract. At Bouldin Island, soils

were ploughed to twice that depth. These differences may have resulted in the differences in organic carbon content at both farms by depth horizon.

2) Pre-irrigation is required at Wright-Elmwood Tract but not at Bouldin Island. Bouldin Island is at lower elevations (fields at about -13 to 14 ft-NAVD) then Wright-Elmwood Tract (fields at about -8 to -9 ft-NAVD) and thus has a greater upward subsurface flow from surface flows.

Two factors complicated rice production at Bouldin: rice pond bed slope and uniformity, and the surface water network.

7.3.4.1 Bed slope and uniformity

First, the pond beds were more level at Wright-Elmwood Tract farm then at Bouldin Island. Figure 7-6 shows results of our surveys taken during 2004 ("Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots", November 2005). At the Bouldin Fields, some fields had bed elevations that varied by up to 0.5 to1.0 ft during 2004. At Wright-Elmwood Tract, the bed elevations typically only vary by about 0.2 to 0.3 ft. The great differences in bed elevation at Bouldin Island complicated water level management during critical times of the year, creating challenges for both weed control and later season water management.

7.3.4.1.1 Weed control

A critical time for weed control in the Delta is at the initiation of rice seeding. Before seeding, soils are turned to bury weeds. and then seeded with a grain drill and placed to a depth of about one inch. Weeds are put at a competitive disadvantage by both burying the non-germinating seeds by several inches and the application of the herbicide on germinating weed seeds. Once the sprouting rice reaches a height of about six inches, herbicides are applied to existing weed and fields are flooded to just below the height of the rice. This further suppresses weeds and promotes rice as the weeds are put at a photosynthetic competitive disadvantage. It is critical during this step to properly manage the water levels. If the specifications regarding field slope and uniformity are not initially met during the conversion, or if fields go out of level later, precise water depth control throughout a rice field is not possible. Variations in field elevation make hydrologic management of water very difficult impacting rice growth and encouraging weed problems. and in some cases not possible, impacting production.

7.3.4.1.2 Late season water management

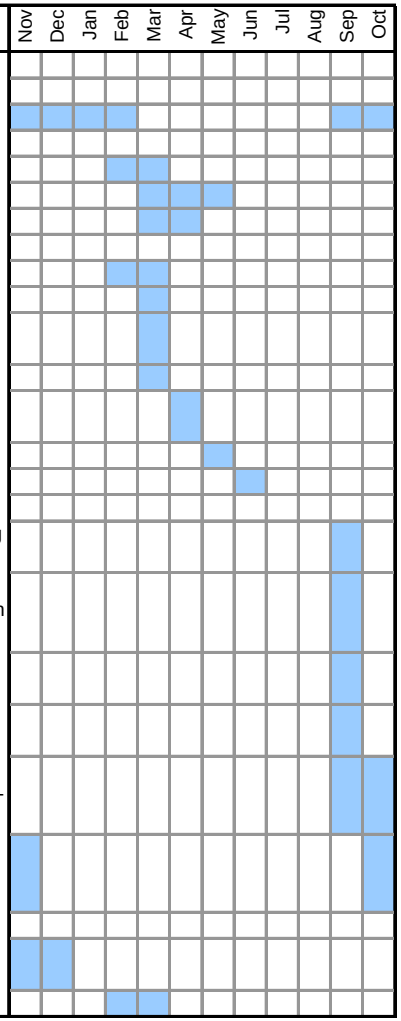
Late in the season, from about August onward, water levels are slowly raised to control the microclimate around the rice head. This management begins when the rice is in the sheath and begins to head out, termed as "in the boot". Water levels are raised to a level to create a microclimate and prevent the rice flowers and seeds from getting to hot or to cold during this critical period. This management is thus to enhance the rice flowering to seed and prevent "blanking", when no seed is created. Precise water management thus allows temperatures near the head to be regulated by the field's water temperature and to minimize swings in temperature that promote blanking. More leveled fields enable better water level management at this time.

7.3.4.2 Surface Water Network

Surface water network at Bouldin Island was much more complicated then that at Wright-Elmwood Tract. The network was difficult to manage to precisely control water deliveries to the different fields and thus created challenges when managing irrigation.

Table 7-10. Cultural Practices used at Bouldin Island and Wright Elmwood Tract

Task	Muzio	Bouldin	Comment
Rice			
1 Select and order variety for next year's crop	Dec		
2 Field Construction and Modifications			Start date depends upon field wetness.
Leveling	Feb-Mar	Feb	
Installation of water control structures	Mar-May	Mar-May	
Installation of berms	Mar-Apr	Feb-Mar	
3 Spring Field Preparation		Mid-March	
Touching up fleld (leveling)	Feb-Mar		Approximately every four years.
Roughening surface for seeding[1]			
Rototilling or disking	Mid March	Mid March	Give rice a head start on weed seeds by burying seeds. Discing goes to a depth of about 5 to 6 inches.
Plouging followed by plaining	NA	Mid March	Loosen compacted organic soils. Goes to a depth of 10-12 inches
Pre-irrigate	mid April	NA	Pre-irrigate to moisten soil for better seed propagation. Not conducted at Bouldin farms as soils are damp enough.
4 Planting	early May	early May	Plant with a grain drill
5 Flooding	7-Jun	1-Jun	
6 Draining			
Stopping water flow	9-Sep	13-Sep	Stop water to fields at different times based upon rice maturity and planting date. Rice continues to mature through dough stage.
Pulling boards (~2-3 wks after stopping flow)	16-Sep	20-Sep	Drain slow to start by progressively pulling boards. Loose about 1 in every 5 days thru evapotranspiration and and leaking out through ditches. When rice at medium dough stage pull boards. Typically about 2 to 3 weeks after stopping water flow. Takes about two weeks to drain field after pulling boards.
7 Drying			Drying usually takes about 2 or 3 weeks after standing water has been eliminated.
8 Harvesting	mid/late Oct	mid/late Oct	Harvesting depends upon plant date. Typically begins late September and ends around mid-October. Harvest at about 20% moisture. Can harvest 30-40 ac/d per tractor.
9 Chopping straw and/or disking	late Oct or early Nov. (chopping, no disking)	late Oct (disking, no chopping)	Turn straw into soils to knock down straw and promote decomposition. Can do it as early as the day following harvest. Typically around mid-October.
10 Post-harvest Winter Flooding			Can start immediately after harvest.
Begin	late Nov. or early December	mid-October	
End	early March	February	



Notes
1. Different methods appropriate.

Figure 7-8. As-Built Drawing of Implemented rice plots during 2004 at Bouldin Island.

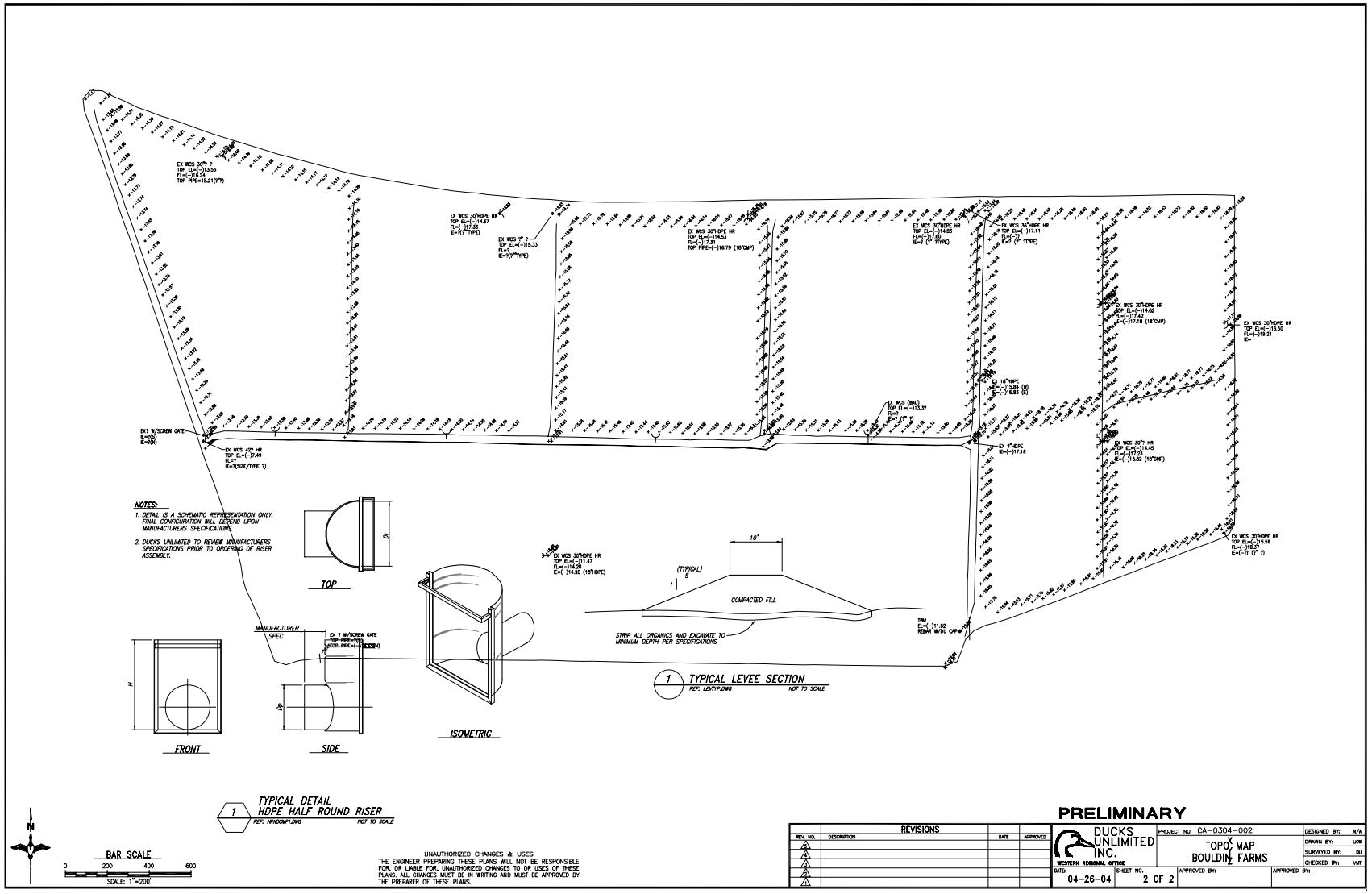


Figure 7-9. As-Built Drawing of Implemented rice plots during 2004 at Wright Elmwood Tract.

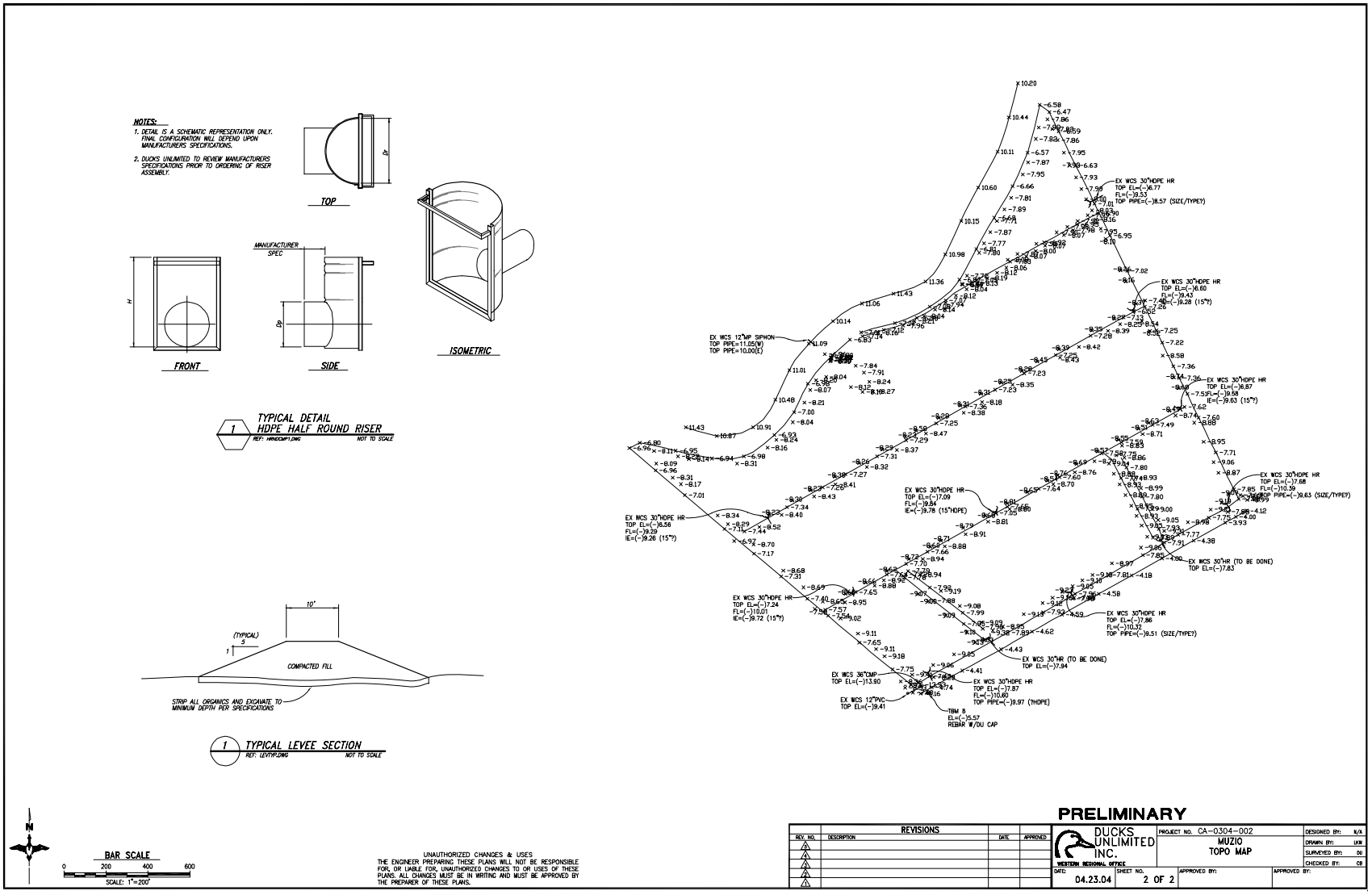


Table 7-11. Specifications for rice fields

Variable	Specification[1]	Comments
Water Structures		
Levee Crown Width		
Checks	2 - 10 feet	Dependent upon soil type and farmer practices. Check levees for this project are on the order of 10 feet wide and are driveable. Peat soils require wider levees as the soil easily erodes.
Pond Levees	10 - 20 feet	These levees are often adjacent to supply or drain ditches. Organic soils erode easily and therefore levees may be wider than typically found in mineral soils.
Levee Slope	3:1	Minimum recommended slope. Minimizes erosion.
Levee Freeboard	8-10 inches	Above maximum water level.
Field Fall	0.05%	0.05 ft (0.6 inches) per 100 feet
Water depth uniformity throughout the field	Depths should vary by about 0.2 to 0.3 feet throughout the pond	Water depth (an bed elevation) is an important tool in suppressing weeds and optimizing microclimates in the late summer.
Outflow/check structures[2]		
Type	risers	Also called water boxes and weirs. Risers provide water level control. "Half-round" type risers are commonly used for water management in the Delta for both rice fields and managed wetlands.
Board width	30"	Used for fields approximately 20 - 30 acres in size.
Riser Height	30"	Minimum height used for checks and outflow levees.
Flashboards	2x2; 2x4; 2x6	Different size boards provide different degrees of level control.
Inflow structures	risers and valves	Risers provide level and flow control. Valves only provide flow control. Selection depends upon system hydrologic design.
Drain water structures		
Type	risers	Also called water boxes and weirs. Risers provide water level control. "Half-round" type risers are commonly used for water management in the Delta for both rice fields and managed wetlands.
Board width	30"	Used for fields approximately 20 - 30 acres in size.
Riser Height	~ 6 - 8 feet	Depends upon drain configuration
Flashboards	2x4; 2x6	Different size boards provide different degrees of level control.

Notes

1. Specifications are approximations. For more firm recommendations, farmers should contact the farm advisor and rice experts in their area.

2. Local supplier for risers and pipe is Poly Riser and Pipe in Willows CA, 530-934-3281

7.4 Discussion

Rice production has occurred in the Sacramento Valley since the beginning of last century. The California Agricultural Experiment Station has devoted considerable effort to outreach and research to make rice culture a viable agricultural crop in California. For this reason, there is a large database to assist growers in solving issues related to rice production. For example, rice variety M103 and M104 were specifically developed for conditions such as those found in the Delta. Improvements in rice cultural practices have led to the most productive rice yields in the world.

Figure 7-8 shows rice yields in the Sacramento Valley during the last 25 years (USDA 2006). Rice yields have stagnated since 1990 because of restrictions on open field burning of rice residue after harvest (Bird et al. 2001). The elimination of open field burning has created new management issues relating to weed and disease incidence (Eagle et al., 2000). Rice yields in San Joaquin County are generally lower than the Sacramento Valley because of cooler climatic conditions. Rice yields on our experimental plots (Table 7-7) were comparable to north state rice farms.

Yields at Bouldin Farms were lower than both at Wright Elmwood and Rindge Tract, which were comparable to Sacramento Valley yields (Table 7-4). However, despite the lower yields at Bouldin Farms, profits were comparable to those of the Sacramento Valley and that result was due to much lower expenses then typically found in the Sacramento Valley and the other two Delta growers. Profits at Bouldin Island for rice were higher then for corn for both 2004 and 2005. Thus, even though yields were not optimized at Bouldin, lower expenses enabled adequate profits for the grower to continue in rice production.

Our data does not suggest that either climate or soils caused differences in rice production between sites. Climate differences are very small at all these sites (Table 7-5) and summer water temperatures in the fields appear to converge towards a temperature in equilibrium with the air temperature (Table 7-6). Soils do not differ significantly in the upper 45 cm with regard to carbon content between Wright-Elmwood Tract and Bouldin Island (Table 7-8), and though nitrogen does differ significantly ($p<0.05$), the differences are relatively small and the C:N ration is in the range of about 14.5 for both Bouldin Island and Wright-Elmwood Tract. These small differences in climate and soil suggest that the large differences in yields result from cultural practices.

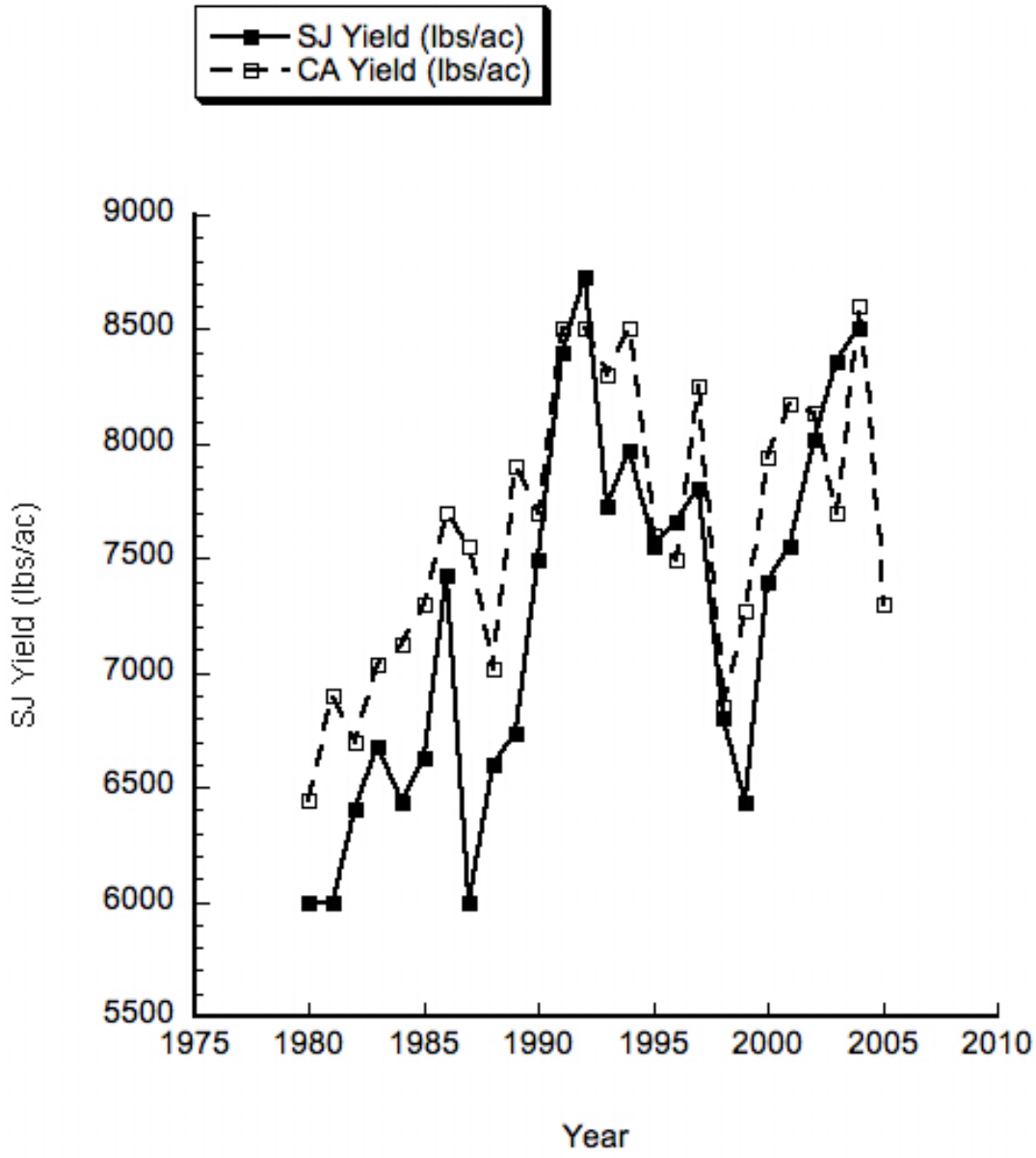


Figure 7-10. California and San Joaquin County

7.4.1 The effects of weed pressure on yields

Weed pressure at Bouldin was considered the main factor causing the reduction in yields at Bouldin from 2004 to 2005. As discussed in Section 7.3, yields dropped by 12% between 2004 and 2005 and cultural practices were very similar both years. However, during 2005, rains in the early summer created ideal conditions for weeds. Relatively uneven fields hindered early weed suppression through water level management and untimely rains hindered herbicide effectiveness. By July, some weeds were over five feet high, shading out, and thus out

competing, the rice. This factor is considered the main reason for the drop in yield at Bouldin Island between 2004 and 2005.

It is important to note that Bouldin fields may have become more out of level each successive year. Bouldin Island has a very deep peat layer, oftentimes over 8 feet deep, as compared to Wright-Elmwood Tract where the peat layer is generally less than 3 feet deep. Peat expands when it is wet and shrinks when dry. Thus leveling can potentially go in and out of specification throughout the season, and identifying the ideal time in the spring to level the fields is challenging.

7.4.1.1 Level seed beds and the need to meet field fall slope

The experience at Bouldin in 2005 shows the importance of creating level rice beds within the fields to allow adequate water management for weed control. Rice bed level depends upon several factors:

- the precision of the leveling itself,
- the space between rice checks,
- and the timing of the leveling and the subsequent effects of wetting or drying of the peat on bed level.

At Bouldin Island, all these factors likely contributed to the bed level problem. If peat expansion or shrinking is causing a field to get out of level, then management actions to help mitigate that problem might be re-leveling the fields yearly as part of a maintenance effort, and/or spacing check levees closer together to allow a looser specification of the field fall slope (Table 7-11). Check levees do not want to be spaced so closely that they hinder the efficiencies of the tractors during field preparation, seeding, the application of fertilizers or herbicides, or during harvesting.
Rotations

Rotations may be another way to help control weeds and soil pathogens problematic to other vegetable crops. Weeds were not a problem at Rindge Tract after the conversion into rice. Rotating between rice and other crops may help control crop specific weeds.

7.4.1.2 Herbicides

A timely managed herbicide program may be the only alternative to controlling weeds if early seed bed preparation, water management and rotations do not provide adequate weed control. Many herbicides used in rice production are limited by period of time water can be held in patties. . Delta Islands are constantly drained through pumping to offset the positive flow of subsurface waters onto the islands because of lands subsided through oxidation of the organic peat soils. New herbicide chemistries being developed are less restrictive and fit into the rice cultural practices required in the Delta.

7.4.2 Precise water management to promote rice yields late in the season

2004 and 2005 rice yields at Bouldin Island were lower than those measured at Wright-Elmwood Tract on Wright Elmwood Tract. Yields were comparable between Wright Elmwood Tract and Rindge Tract in 2005. Thus, Bouldin Island rice yields appear to be lower than those that can be achieved in many farms in the Delta. Our team believes these lower yields are due to the system design and challenges in implementing cultural practices. One factor causing lower overall yields maybe less then optimal water management late in the season when the rice is going to boot. Water management was less precise at Bouldin Island then at Wright-Elmwood Tract because of the level of the fields and because Bouldin Island hydrologic network was more difficult to manage:

- Wright-Elmwood Tract drew directly from a siphon whereas Bouldin Island diverted a slip stream from a supply network (i.e., diverted a small flow from a larger stream). This design was very temperamental.
- Rice fields at Bouldin Island drew from the inflow ditch in parallel whereas Muzio fields received water in serial. The Bouldin Island design complicates equal distribution of water to the different fields and creates greater variance in the flows to the fields.

Additionally, Muzio Farm at Wright-Elmwood Tract documented precisely the water management steps taken each year and used those records to aid in managing the water the next year.

All these factors may have contributed to the generally lower yields achieved at Bouldin Island.

Partially offsetting the lower yields and income at Bouldin were the lower expenses. There is apparently a balance between capital investments, annual operation and maintenance costs, and acceptable income.

7.4.3 The effects of drain management on rice production

High drains were implemented on the test plots to reduce subsurface flow and thus reduce loading of DOC and nutrients from rice fields. Table 7-12 shows rice yields for the high and low drain treatments at Bouldin Island and at Wright-Elmwood Tract plots during 2004 and 2005. At both sites, the high drain treatment tended to produce higher yields though these differences were not statistically significant ($p<0.05$). This trend was generally true for both years. For both 2004 and 2005, higher drain treatments at higher yields at Wright-Elmwood Tract. At Bouldin Island, this trend occurred in 2004, but in 2005 the higher drain treatments had a lower yield. This corresponded with the year in which weeds were a large problem at Bouldin Island.

Our data shows the higher drain water levels raised groundwater levels. These higher groundwater levels may benefit rice production, presumably through reducing water stress on the plant. Thus groundwater management that reduces subsurface loading of DOC and nutrients may also improve rice production. More data are needed to verify the above hypothesis.

Table 7-12. Rice Yields for High and Low Drain Treatments.

Rice yields shown are from field measurements made by UC Davis on study plots. These estimates are slightly different then estimates made by farmers (Tables 7-1 through 7-3, 7-5) because of differences in methods and because these data are only for the study plots.

	N	Mean	Std.Dev.	p
Bouldin Island				
Low	20	54	13	0.7670
High	15	56	11	
Wright-Elmwood Tract				
Low	10	65	4	0.0620
High	10	71	9	

1. Data is only for newly established rice fields with distinct drain treatment

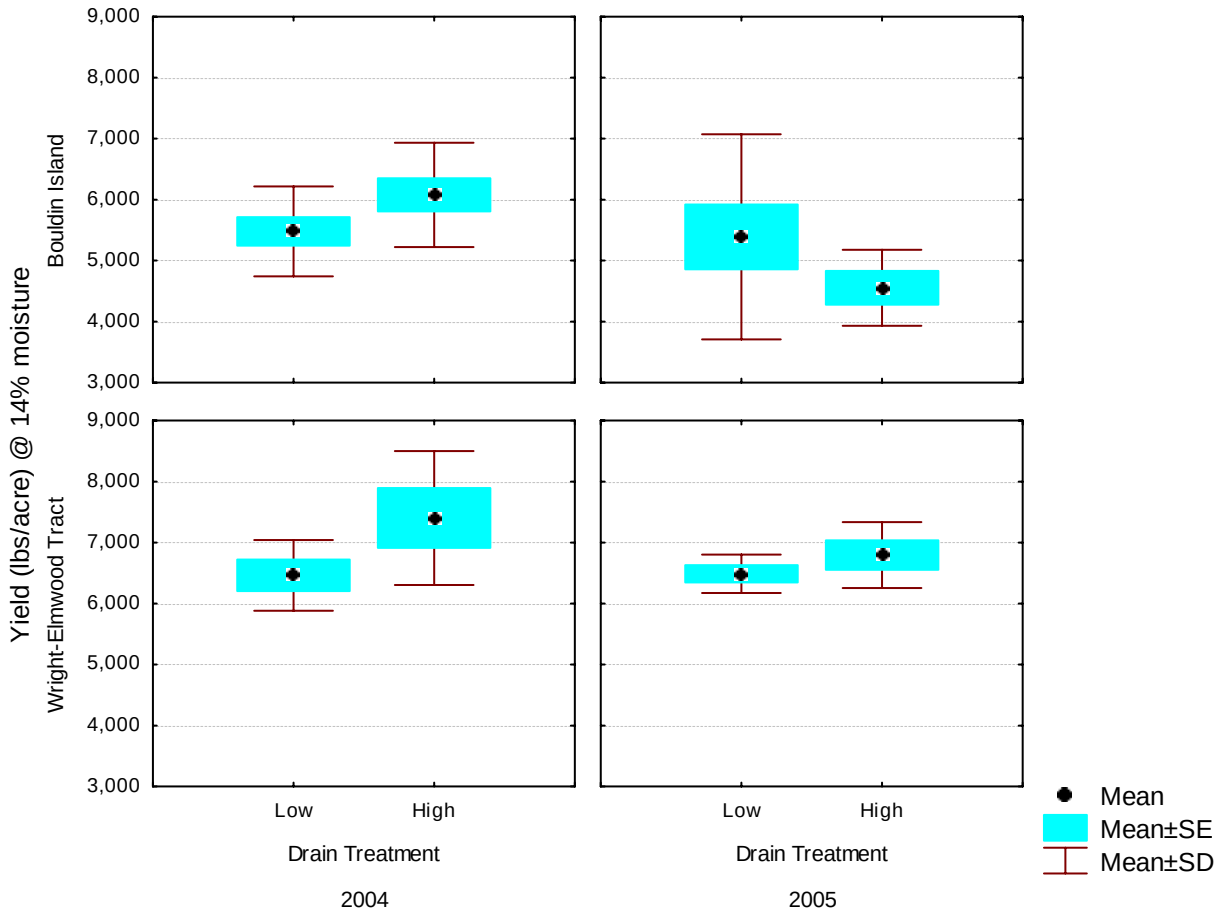


Figure 7-11. Yields By Year and Drain Treatment for Bouldin Island and Wright-Elmwood Tract

Rice yields shown are from field measurements made by UC Davis on study plots. These estimates are slightly different then estimates made by farmers (Tables 7-1 through 7-4) because of differences in methods and because these data are only for the study plots.

7.5 Conclusion

Based on information presented here and from personal communications between the project team members and the project participants, rice production in the Delta at this small scale of approximately 300 acres has been profitable. Production expenses were less than those of estimated for the Sacramento Valley, while yields remained comparable. Our analyses support the contention that rice can be grown throughout the Delta, from as far west as Twitchell Island to the eastern edge. Newer rice varieties seem to be able to successfully accommodate the albeit small climate differences. Soils at Bouldin Island and Wright Elmwood Tract were peat soils and were similar in organic content and carbon content. Nitrogen differences were small and all soils had similar C:N ratios.

Profits are a function of income and expenses. Though lower yields were achieved at Bouldin as compared to the other two farms, expenses were also lower. Thus, profits similar to those that can be achieved in the Sacramento Valley were achieved for all the farmers through two different strategies:

- A reduction in expenses, and
- A maximization of income.

For all growers, rice continued to be more profitable then growing corn.

Cultural practices appeared to be the key to maximizing yields. Good management of water levels during the early season to suppress weeds and later in the season to maximize the flowering of rice to seeds seemed important for optimizing yields. Being able to implement these practices required good leveling of the fields that meet the specifications presented in this chapter. Meeting those objectives depends upon the design of the rice fields and its implementation. Yet in the Delta, areas of thicker peat may create challenges because of shrinking and expansion of the peat during drying and wetting cycles. Complicated hydrologic networks, sometimes artifacts of historic draining and supply networks on the islands, also complicate water management and retrofitting water control structures to these systems may only be partially successful in achieving the goal of maximizing yields.

Weed control appears to be a very important requirement to achieve high rice yields. In 2005 at Bouldin Island, weeds were especially problematic in part due to early summer rains. Good hydrologic management appears to be a good tool to control weeds.

Finally, our data suggests that the tested drain management of maintaining high water levels in the drains may improve yields.

The project participants have indicated their enthusiasm with rice through this project, and have expressed their appreciation for the conversion cost-share and technical assistance that was provided. Though the contract for the Delta Rice Project will soon terminate, the project

participants are proponents of rice production on their agricultural operations, and will continue rice production in upcoming seasons.

7.6 Chapter References

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8 Project management performance evaluation for the Delta rice project.

Our primary management goal of this project has been to complete our experimental objectives as detailed in the original Scope of Work and discussed again in the QAPP, the monitoring plan and the PAEP:

- Investigate and develop hydrologic BMPs for rice production on experimental subplots in order to reduce DOC, DBP precursors (DBPPs).
- Investigate and develop hydrologic BMPs for rice production on experimental subplots in order to reduce nitrogen (N) export from rice fields.
- Investigate how broadly these BMPs can be applied to rice production throughout the Delta.

To accomplish these objectives, we have attempted to answer the following questions:

- What are the concentrations of key constituents of concern (COC) (NO_3, NH_4, DOC, THMFP and TDS) surface and subsurface drainage waters from rice plots under different land and water management practices?
- What are the surface and subsurface COC loads and how do they vary in time and under varying land- and water-management practices?
- What are the factors and processes affecting variations in loads?
- How can COC loads from rice fields be minimized?

In addition to the above primary objectives, there were a number of secondary objectives for this project: evaluating wildlife usage and evaluating the economic feasibility of rice production in the Delta.

As discussed in Chapter 4, all the objectives for this project were met. These accomplishments were made under severe scheduling constraints as discussed below.

The late start date impacted our project in many ways, causing delays in some deliverables and requiring the project team to modify the approaches in order to meet the technical objectives for the project. **Nonetheless, this project achieved all its objectives and has favorable reviews from the TAC (Appendix A.2).** Both the participating farmers and the San Joaquin Cooperative Extension have committed to continuing to cooperate on investigations to further manage water flow from Delta rice if proposal PIN 9234 (submitted in the 2006 Consolidated Call) is funded.

This report details our findings regarding water quality effects and loading (Chapter 5), wildlife usage of Delta rice (Chapter 6) and the economic feasibility of Delta rice (Chapter 7). The Executive Summary provides an overview of these findings and recommendations for managing surface and subsurface DOC, THMFP and nitrogen loading are presented in Chapter 3.

Appendix A.9 presents all the data for this project and summaries of the different data are presented in the appendices as well.

In this report are highlighted these accomplishments and the responses of the various collaborators because to make this project successful, flexibility was needed in the approach. Our primary management goal has been to keep the field studies moving in order to secure two growing seasons of data despite the truncated schedule and delayed contract.

8.1 Implementation of Delta Rice Project as Related to Farmer Participation

Successful implementation of the Delta Rice Project required active participation and support from growers interested in implementing rice in the Delta. Ducks Unlimited had worked with Delta growers on earlier studies and found in pilot studies on approximately 10,000 acres that rice production in the Delta could be competitive with other crops. Deliverable 6.1 for this project presented economic data from Del Rio Partners and Bouldin Farms supporting the contention that rice presented more favorable economics for Delta growers then did corn.

8.1.1 Farmer Participation

Six farmers were interested in participating in this project in 2004 and three farmers were interested in 2005 (Deliverable 14.9 – Survey Summary Response).

8.1.1.1 Farmer Selection

During the 2004 selection, the process was a two-step process: all applicants were initially considered and then a short list developed of farmers selected for site visits by the principal investigators. Initial screening during this phase of the selection process was based upon the location of the farm along an east-west gradient in the Delta, the requirement for organic soils, sufficient area for implantation of the experiments, and farmer interest. The second phase furthered narrowed the list based upon the results of the site visit in which logistical issues were primarily considered.

Table 8-1 presents the selection criteria and qualitative analyses of the sites. Due to the limited number of applications submitted, the significance of some criteria was reduced or eliminated when compared to initial establishment of the ranking process. The final farms selected were Bouldin Farms and Muzio Farms after a visit to all the promising sites. Other farms eligible for evaluation either dropped out of the program's consideration, were eliminated due to not adequately meeting the selection criteria, or appeared to lack the commitment necessary.

From the 2004 process, the project team was not able to select the three farms as was the initial goal. Thus, two farms were selected in 2004 and a third farm was selected in 2005. For the farmers selected in the winter of 2004, water quality effects from growing rice are the primary focus, with additional effort to characterize wildlife use and quantify rice production and economics. On these farms, experimental plots were established to identify the effects of

different crops (e.g. rice, corn) and hydrologic management practices on the export of dissolved organic carbon (DOC), disinfection byproduct precursors (DBPP) and nutrients.

For 2005, the project team sought to select a third farmer who would be new to rice farming. For that farm, the team would again collect wildlife, economic and cultural practice information, and document the issues associated with growing rice by a farmer new to the crop. The team would not implement any additional experimental plots or monitor DOC, DBPP or nutrient loads since there were already sufficient study plots for that purpose.

Table 8-2 shows the farms that applied in 2005. Jack Klein Trust was selected from the 2005 pool for a number of reasons (:

- Met the technical requirements for the project and was easy to establish;
- Was clearly interested in growing rice and was ready to proceed;
- Primary business was farming so would have credibility in the farming community; and
- Interested in considering rice as part of a crop rotation, offering another economic opportunity to Delta farmers;

Details are provided on the selection process in the following deliverables:

- Deliverable 6.4 - Farmer Selection Summary
- Deliverable 6.4B - Farmer Selection Summary for 2005 Growing Season).

Thus, based upon the opportunities and constraints associated with farmer selection, two farms were selected in 2004 and a third in 2005. This approach was approved by the SWRCB. Bouldin Farms on Bouldin Island and Muzio Farm on Wright-Elmwood Tract were selected in 2004 for implementation of the experimental plots for testing hydrologic management practices on water quality concentrations and loads, as well as studying wildlife effects, documenting rice conversion practices, and quantifying the economics of growing rice in the Delta. Jack Klein Partnership was selected for 2005 for studying wildlife effects, documenting rice conversion practices and quantifying the economics.

8.1.1.2 Farmer Contributions

Bouldin Farms and Muzio Farm both provided experimental plots for testing the different drain management practices. This support went beyond simply providing the plots for our testing as additional support was required of the experiments. Additional support provided as in-kind services is listed below:

- Both farms provided background information at the beginning of the project and throughout it on irrigation management practices for their respective farms and on the drain network utilized throughout the farms.
- Both growers provided information on the cultural practices used including initial leveling information and initial specifications used in setting up rice fields; seed bed preparation information; and a general application schedule of chemical use.
- Both growers coordinated their cultural practices on the experimental plots with our project needs. This coordination included coordinating flooding schedule with installation

of piezometers; coordination end of season field work with removal of piezometers; coordinating irrigation scheduling with our installation, operation and removal of boards in surface water and drain weirs;

- At Bouldin Island, the project team worked with the farm irrigator during the summer seasons. Bouldin Island drainage network was very complicated and required upgrades throughout the season to enable implementation of the projects and cleaning of downstream drain ditches of weeds to allow testing of the different hydrologic regimes;
- Both farms provided open access to the experimental plots and their entire farms for monitoring wildlife and to understand how the plots were integrated into the system;
- Both farms provided the project team with information on yield and economics.
- Both growers openly discussed their practices and problems throughout the project.

Information from Muzio Farm at Wright-Elmwood Tract and Bouldin Farms at Bouldin Island were incorporated into a guideline on establishing rice in the Delta (Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots, SWRCB Agreement No. 03-165-555-0, November 1, 2004). This information was used by Jack Klein Trust on Rindge Tract in 2005.

At Jack Klein Partnership Trust, no experimental plots were installed and so no experimental assistance was required. However, as discussed earlier, the project team conducted wildlife monitoring and needed information on yields, economics and cultural practices. These were provided to use openly and in a timely fashion.

8.1.2 Data and information collected during the study

The experimental design discussed above was submitted in the Draft QAPP and Monitoring Plan (Deliverable 3.1, Draft submitted July 2004) and remained unchanged in the final QAPP and monitoring plan (approved December 2004).

This design in the approach affected this project though on the balance the effects were positive.

3) Deciding to go only with two farmers instead of three in 2004 allowed this project to proceed with the first year of data collection using interested and enthused partners. In these types of research projects in which private farmers are participating, having committed and enthusiastic growers is paramount to success. Late contracting greatly hindered the farmer selection process and insisting upon three farmers for 2003 would have compromised the science conducted as none of the other farmers both met the technical criteria and were highly committed. Focusing our studies at Wright-Elmwood Tract and Bouldin Farms provided opportunities to work with interested, flexible and committed growers.

4) The original experimental design in the proposal focused on testing two drain management regimes across three farms. Only having two farmers restricted our sample collection to two farms rather then three. This decision had technical implications with regard to data collected as initially conceived in the proposal:

a) **Feasibility of growing rice throughout the Delta as it pertained to climate**. The decision to go with two farms did not affect our assessment with regard to climate effects. Our two sites bookend the climate extremes in the Delta with Wright-Elmwood at the eastern edge and Bouldin Island near the western edge.

b) **Assess organic soil affects on water quality.** The project team was only able to assess the effects of soils from two farms on water quality. Soil effects are not strictly an east-west gradient issue. Effects from soils could be from the amount of carbon, nitrogen and other organic materials; peat depth; underlying soil layer lithology; elevation below sea level and the resulting effects of the hydraulic gradient on groundwater flow through the soils; and other factors. The project team was not able to test the effects of soils from the three farms, but was able to study the effects of soils from two very different sites on water quality.

   i) Wright-Elmwood Tract has an elevation about 5 feet higher then Bouldin Island, has head pressure (ft), and thus has less groundwater flow pressures;
   ii) Wright-Elmwood Tract peat soils are much shallower then those at Bouldin Island and are underlain by sandy clay loam and clays, whereas Bouldin Island peat soils are underlain by sand.
   iii) Bouldin Island has uneven distribution of organic carbon throughout the soil profile whereas Wright-Elmwood organic carbon is more evenly distributed;
   iv) Bouldin Island peat soils are higher in percent organic carbon;

   These soil characteristics make these two sites fairly different with regard to soils. Conversely, the study plots within a farm have relatively similar soils. Thus, from considering within farm and between farm effects, the project team was able to distinguish differences in constituent load export between farms and relate those to soil effects.

   The effects of soils would be more robust with additional farms. However, our assessment in Chapter 5 shows soil effects are secondary to flow effects.

c) **Assessed changes in effects between new and established rice fields on water quality.** As a rice field ages, different water management regimes and the associated differences in redox chemistry might affect the availability and quality of DOC loads. Focusing on two farms rather then three made it possible for the project team to investigate DOC loads from an established rice field and compare those to new rice fields.

d) **Variance between replicates.** Focusing on two farms has allowed the project team to compare the effects of high drain and low drain management on replicate fields at Bouldin Island and to understand the variance in surface water data for a single hydrologic treatment.

e) **Focusing on two farms with very different irrigation networks allowed troubleshooting and design recommendations for irrigation management.** Bouldin Island is very similar to typical Delta Islands with relatively small plots and a complex

network of irrigation and drainage ditches whereas Wright-Elmwood Tract irrigation and drainage network has been modernized. Focusing only on the two farms enabled the project team to recommend surface water management improvements between 2004 and 2005. These changes affected surface water loads.

In the balance, by just focusing on two farms, the project team was able to focus the project's resources on better understanding the effects of both subsurface and surface water management on water quality and export loads, and able to recommend changes from 2004 to 2005 on water management. The study was perhaps less robust with regard to assessing soil effects though Chapter 5 shows that soil effects were a secondary factor and the export of DOC and THMFP loads.

Table 8-1. 2004 Site Selection Criteria and Qualitative Analysis

	Criteria	Motivation	2003 Farms/Landowners								
			Eugene Muzio, Muzio Farm	Topper Van Lobensels			Nuss	John Meek	Ralph Heringer, Bouldin Farming Co	Spaletta	Maple
Step 1: Primary selection criteria for determining necessity of site visit.	**1 Along East-West gradient**	Demonstrate viability of growing rice in different microzones throughout the Delta	**Yes - Eastern**	**No**	**No**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	
	Map location identified		Wright Tract	North Location: North Delta	Central Location: Near Locke	South Location: New Hope Tract	Empire Tract	Venice Island	Bouldin Island	McDonald Island	Grand Island
	County		SJ	SJ	SJ	SJ	SJ	SJ	SJ	SJ	Sacramento
	Degree-days available for rice production[1]		Adequate	Unknown	Unknown	Unknown	Unknown	Unknown	Adequate	Unknown	Unknown
	Differing air and water temperatures		Assumed	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed
	2 Organic soils	Characterize organic soils and their effect on DOC export. Organic soils are in place where subsidence issues are relevant	**Yes**	**No**	**Unknown**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	
	Rindge series		Yes	No	No	No	Yes		Yes	Likely	
	15-30% organic carbon		Higher	No	No	No	Higher		Higher	Likely	
	3 Sufficient area for implementation of experiment	Necessary for experimental component of project.	Yes	Yes	Yes	Yes	Yes	Unknown	Yes	Yes	Yes
	4 Farmer interest	Farmer interest critical for successful implementation of project and cooperation with investigators. Very critical criteria and necessary for implementation of study at any site.	High	Dropped Out/ Out of Area/Mineral Soils			Landowner interest moderate to poor. Landowner completely unfamiliar with project and its goals. No farmer for land currently. Farm in the middle of management and ownership change.	Dropped Out of Consideration	High	Dropped Out of Consideration due to lack of readiness and uncertainty with farming plan for the 2004 growing season.	Submitted Application too Late for Consideration
	Step 1 Assessment: Selected For Site Visit?		Yes	No			Yes	No	Yes	Yes	No
Step 2: Field Visit and Assessment	**5 New farm parcel to rice production.**	Would like a farmer new to rice. Document their experiences	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unknown
	Previously corn		Yes				Yes	Yes	Yes	Yes	Yes
	6 Constructibility and logistics	Feasibility of implementation	Yes				Yes		Yes	Yes	
	flatness of terrain; amount of grading required		Yes				Yes		Yes	Fair	
	Configuration of ~100 acre parcels		Yes				Yes		Yes	Yes	
	Farmer has personnel and equipment ready for conversion.		Yes. Started converting fields.				Unknown		Yes. Started converting fields.	Yes	
	7 Test plot feasibility		Yes				Yes		Yes	Yes	
	Available sizes for test plots		Good				Good		Good.	Good.	
	Good hydrologic configuration		Open to modifications						Can slightly modify current configuration.	Will need to install drains for experiments and may require leveling	
	8 Accessible	Wildlife and water quality monitoring easier.	Yes				Yes		Yes	Yes	
	Nearby road for easy sampling access		Yes				Yes		Yes	Yes	
	Good view points for wildlife viewing		Yes				Yes		Yes	Yes	
	9 Proximity to corn (for waterbird/wildlife	Nearby or adjacent to rice fields to compare wildlife and water quality.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
	Step 2 Assessment.		Selected	Did not get pass Step 1 assessment. Did not meet project criteria regarding organic soils. Dropped out from consideration before site visit by PIs. No site visit was made to the location.			Not selected by project team because of poor readiness and lack of enthusiasm/commitment by landowner.	Did not pass Step 1 assessment. Dropped out early in the process. No site visit.	Selected	Dropped out. Site ranked fairly high though readiness and study understanding were concerns.	Submitted after deadline for 2003. We did not have adequate time to consider before site visits by PIs.
Notes											
1. Based upon history of growing rice in the region											

Table 8-2. 2005 Site Selection Criteria and Qualitative Analysis

	Criteria	2004-05 Farms						
		Solicited but did not apply				Solicited and submitted application		
		Bank of Stockton	Spaletta	Meek	Marcucci and Mussi	Jack Klein Trust Partnership	The Clavius Club	Maple
Step 1: Primary selection criteria for determining necessity of site visit.	**1 Along East-West gradient[1]**							
	Map location identified	Empire	McDonald	Venice	Jones	Rindge Tract Island, 8 mile Road	McDonal Island Rd.	Grand
	County	SJ	SJ	SJ	SJ	SJ	SJ	Sacramento
	Degree-days available	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Unknown
	Differing air and water temperatures	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed	Assumed
	2 Organic soils[3]	**?**	**Yes**	**Yes**	**Yes**	**Peat**	**Peat**	**?**
	3 Sufficient area	**Possible**	**No**	**Yes**	**Yes**	**Possible**	**Yes**	**?**
	4 Farmer interest[2]	Did not attend solicitation meeting	Did not attend solicitation meeting	Did not attend solicitation meeting	Attended solicitation meeting.	Attended solicitation meeting.	Attended solicitation meeting.	Attended solicitation meeting.
	Step 1 Assessment: Selected For Site Visit?	No	No	No	No	Yes	Yes	No
Step 2: Field Visit and Assessment	**5 New farm parcel to rice production.**							
	Farmer new to rice	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Previously corn		Yes	Yes		Potatos	Corn	
	6 Constructibility and logistics							
	Feasibility of implementation	**?**	**Yes**	**Yes**	**Jones Tract is currently partially flooded and growers land is partially submerged.**	**Monitoring of outflows will require input on field design. Grower has agreed to work with the project team on modifications needed for monitoring.**	**Difficulty in providing supply water. Trees may interfere with implementation.**	**Depends upon location on Grand Island**
	Farmer has personnel and equipment ready for conversion.	Yes	Yes	Yes	Yes	Yes	Currently hiring farm manager for Clavius Club. Equipment may need to be rented for rice production.	Yes
	7 Test plot feasibility							
	Available sizes for test plots		NA	NA	NA	NA	NA	NA
	Good hydrologic configuration					Acceptable	Acceptable	
	8 Accessible for wildlife monitoring							
	Nearby road for easy sampling access					Yes	Yes	
	Good view points for wildlife viewing		Yes			Yes	Fair.	
	9 Proximity to corn (for waterbird/wildlife					Yes	Yes	
	Step 2 Assessment.				Did not pass Step 1 assessment because of flooding to property. Should consider if further funding is available for continuing project.	Grower and owner are very interested. Rice would be part of crop rotation so we may be able to address other opportunities for growing rice in the Delta. Grower is part of the agricultural community.	Owner is very interested but grower is only moderately interested. Also some personnel and equipment issues are complicating the logistics of this site.	

1. Goal of East-West gradient is to demonstrate viability of growing rice in different microzones throughout the Delta
2. Farmer interest critical for successful implementation of project and cooperation with investigators. Very critical criteria and necessary for implementation of study at any site.
3. Characterize organic soils and their effect on DOC export. Organic soils are in place where subsidence issues are relevant

Table 8-3. Schedule submitted with Final Proposal

(PIN 645, Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic and Straw Management BMPs, June 7, 2002.)

Task No. Deliverables	Target Completion Dates
Task 1: Project Administration	
1.2 Quarterly/Monthly Progress Reports	10th of each quarter/month
1.5 Contract Summary Form	December 2003
1.6 List of subcontracted tasks, Good Faith Effort documents, quarterly/monthly Utilization Reports	December 2003 10th of each quarter/month
1.7 Subcontractor Documentation	December 2003
1.8 Expenditure/Invoice Projections	Every 6 months
1.9 Project Survey Form	August 2006
Task 2: CEQA/NEPA Documents and Permits, if applicable	
2.1 CEQA/NEPA Documentation	January 2004
2.2 Permits	January 2004
Task 3: Quality Assurance Project Plan, if applicable	
3 QAPP	January 2004
Task 4: Field Selection and Conversion to Rice	
4.1 Map, farm size and farm contact information	March 2004
4.3 Conversion plan, expenses, and schedule	August 2004
Task 5: Implementation of Study Plots	
5.1 Experimental design	March 2004
5.3. Site maps describing study plots	August 2004
Task 6. Water and Soil Sampling	
6.2 Database (flow data)	February 2006
Task 7. Water and Soil Sample Analysis.	
7.2 Proof of ELAP Accreditation	March 2004
7.6 Database (water quality and soils data)	February 2006
7.7 Statistical evaluations	February 2006
Task 8. Wildlife Surveys	
8.3 Wildlife utilization and comparison	March 2006
Task 9. Rice Production Rates	
9.1 Cost/income analysis	December 2005
9.2. Annual production rates	December 2005
Task 10. Data Analysis	
10.2 Hydrologic, nitrogen and carbon budgets	April 2006
10.3 Regression analysis, plots, ANOVA	April 2006
10.3 Recommended hydrologic BMPs	April 2006
10.4 Qualitative comparison with corn and wetlands	April 2006
Task 11. Technical Assistance and Outreach	
11.2. Outreach work plan. Eight workshops.	May 2006
Task 12. Peer reviews.	
12.1 Technical memos from the peer review panel.	June 2006
Task 13: Draft and Final Reports	
13.1 Draft Report	April 2006
13.2 Final Report	June 2006

*Assumes contract starts September 2003.

8.1.3 Success on Conversions

Conversions were conducted successfully on all farms. Photo documentation at Bouldin Island and Muzio Farm on Wright-Elmwood Tract document the first year of rice production at these farms (Deliverable 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots, November 2004). Yield information can be found in Chapter 7.

The conversion on Jack Klein Partnership Trust also was successful. San Joaquin County Cooperative Extension provided support to Jack Klein to convert from potatoes to rice under a strategy of implementing rice as part of a crop rotation to help with controlling nematodes and weeds. Our rice expert also provided input to Jack Klein Partnership Trust during 2005, especially with regard to scheduling of water management and harvesting. Several deliverables from 2004 were made available to Jack Klein Partnership Trust to help with the conversion:

- Deliverables 8.3 Conversion Documentation, 9.3 Implementation Plan, & 9.6 Documented Implementation of Study Plots; November 2004; and
- Deliverable 14.1 - Farmer Information Memorandum.

These documents as well as information and documents provided by the San Joaquin Cooperative Extension were helpful to Jack Klein Partnership Trust during their first year of rice production. Yield information from the 2005 growing season is found in Chapter 7. Jack Klein Trust is planning on expanding their rice production next year and making it part of their crop rotation.

8.1.4 Technical Advisory Committee

Three experts were selected for participation on the Technical Advisory Committee (TAC). Names for possible participants were developed in two ways. The Principals for this project developed a list of experts in three areas: hydrology, rice agronomy and carbon chemistry. Additionally, the outside organizations shown in Table 8-4 were contacted for names. The project team was not able to get feedback from the CALFED Science Program on recommended TAC members or on formation of the committee. Several project members have worked closely with CALFED on other projects and so the project team based the formation and operation of the TAC on that experiences.

From these two methods, a complete list of possible TAC members was developed and then three were selected from that list as discussed in Deliverable 5.2 (August 2004):

- Mick Canevari, a UC Farm advisor, representing rice production, agronomy and nutrient management;
- Professor Robert Qualls of the University of Nevada Reno, representing water quality and soil chemistry; and
- Dr. Thomas Harter, representing groundwater and hydrology.

The TAC members were met with individually to discuss the project during the summer and fall 2004. The decision to meet with them individually was based upon their availability and their

different familiarity with rice production and the Delta. Mick Canevari had been meeting with our group since the commencement of the project and so we had discussions with him throughout the project. Professor Qualls came down and toured the sites during Fall 2004, meeting with Mick Canevari during our field meeting to solicit the third farmer for 2005. Professor Qualls was given a tour of both Bouldin Island and Wright-Elmwood Tract such that he could understand the project. Dr. Harter is familiar with San Joaquin County so the project team met with him at his office to discuss this project and the hydrology.

8.1.4.1 Experimental Design Review

Background information on this project sufficient to review the experimental design was provided to the TAC as attachments to two emails. The first email was sent on June 21, 2004 notifying each member that they had been nominated to the TAC and requesting that they confirm their participation. This email provided a copy of a draft of the contract and a copy of the original proposal. The contract includes the SOW for this project, and the proposal provides the vision and an overview for the project. The second email was sent on August 2, 2004 and this email provided a copy of the Draft QAPP and asked them to review Chapters 5 and 6. These two chapters discuss the experimental design and the monitoring plan for this project.

The provided information is shown in Appendix B of Deliverable 5.4:

- Two emails,
- Copy of the proposal,
- Draft contract, and
- Chapters 5 and 6 of the QAPP

Professor Qualls and Mr. Canevari completed their reviews during late summer and early fall 2004, with their comments completed by October 2004. Dr. Harter requested additional information by October 2004 and completed his review with verbal comments in October 2004 which the project team subsequently summarized in Deliverable 5.4 The project team responded to their recommendations for 2005 as discussed in Deliverable 5.4 with the following actions:

- Installed infrastructure at Bouldin Island and Wright-Elmwood Tract for improved surface water management. This included adding weirs at Bouldin Island and developing adjustable weir inserts for Wright-Elmwood Tract. These efforts were to improve surface water management and reduce surface water flows.
- Developed guidelines for farmers relating flow to height over the weirs. These were initially charts but later the project team provided to the farmers a range of heights over the weirs they should target as the charts were too complicated for easy and convenient implementation.
- Removed the restriction when selecting the third farmer that their field be formerly in corn. The project team replaced that requirement with the requirement that the field be previously in a terrestrial row crop such as potatoes, asparagus, wheat and safflower. This action broadened the number of farms eligible for the project and also enabled the project

team to include farms that might be interested in using rice as part of a crop rotation. Based upon our conversations with the Cooperative Extensions and the farmers that applied for participation in 2005, the option of using rice as part of a crop rotation is appealing to many growers from both an economic and agronomic perspective.

These comments had a positive effect on the project, supportive of ideas being developed by the project team and ensuring relevance to the farming community.

8.1.4.2 Draft Report Review

The TAC was also required to provide comments on the Draft Report. All TAC members were provided copies of the Draft report in January 2006 all reviews were completed by late February. Their reviews and our response to them addressing their comments are included in the appendix of this report.

Table 8-4. Organizations Solicited when forming the TAC

Organizations were contacted in February 2004 to solicit names for the Technical Advisory Committee.

Organization	Section	Name	Title	Phone	email	Reference
DWR	Municipal Drinking Water Program	Rich Bruer		916-651-9687	rich@water.ca.gov	Steve Deverel
California Urban Water Agencies (CUWA)		Steve Macaulay	Executive Director	916-552-2929	cuwaexec@mindspring.com	Steve Deverel
DWR	Levees & North Delta Branch	Curt Schmutte	Chief	916-651-7016	schmutte@water.ca.gov	Roger Fujii
San Joaquin RCD		John Meek	Chairman	209-333 - 8146	jmeek@jmeek.com	Greg Green
CALFED	Science Program	Kim Taylor	Science Program Manager	916-825-6264	kimt@water.ca.gov	Philip Bachand
CALFED	Drinking Water Program	Sam Harader		916-445-5466	sharader@calwater.ca.gov	Philip Bachand
San Joaquin Cooperative Extension	San Joaquin County	Mick Canevari	Farm Advisor	209-468-2085	wmcanevari@ucdavis.edu	Olen Zirkle
California Department of Food and Agriculture	Office of Agriculture and Environmental Stewardship	Steve Shaffer	Director	916-653-5658	sshaffer@cdfa.ca.gov	Philip Bachand
UC Davis	Agronomy and Range Science	James Hill	Extension Agronomist	530-752-3458	jehill@ucdavis.edu	Philip Bachand
UC Davis	LAWR	Stuart Pettygrove	Soils Specialist	530-752-2533	gspettygrove@ucdavis.edu	Philip Bachand
USGS	Bay-Delta	Brian Bergamaschi	Organic Geochemist	916-278-3053	bbergama@usgs.gov	Philip Bachand
Central Valley Regional Water Quality Control Board		Jeanne Chilcott	Chief	916-464 4788	ChilcoJ@rb5s.swrcb.ca.gov	Philip Bachand
USDA	Watershed Planning Geologist	Vernon Finney		530-792-5665	vern.finney@ca.usda.gov	Philip Bachand
UC Davis	Civil and Environmental Engineering	Jeannie Darby	Professor	530-752-5670	jdarby@ucdavis.edu	Philip Bachand
USDA	Modesto	Michael Mcelhiney	District Conservationist	209-491-9320 x 102	michael.mcelhiney@ca.usda.gov	Philip Bachand
UC Davis	Civil and Environmental Engineering	Lev Kavvas	Professor	530-752-2518	mlkavvas@ucdavis.edu	Philip Bachand

8.1.5 Outreach

For this project, a number of different outreach meetings were held:

- Solicitation meetings in which other groups such as the San Joaquin Cooperative Extension participated to provide information on growing rice in the Delta and solicit interested growers for participation in the project;
- One-on-one farmer outreach meetings in which information on the agronomics of growing rice or on managing rice hydrology were provided;
- Presentations at conferences to provide information to technical, professional and academic organizations; and
- Small workshops pulling together local organizations to discuss current studies and the methods used.

The outreach meetings for this project thus fell into two categories: providing agronomic and project information to the growers; and providing outside groups and interested parties with technical information and data on the project.

The outreach meetings schedule and format were changed from what was originally envisioned. The outreach meetings to provide agronomic and project information to the growers were changed to tailor them to farmers needs, making them more useful for the participating farmers. There are several characteristics of the farm operations at Bouldin Island, Wright-Elmwood Tract and Rindge Tract that make one-on-one meetings more useful to the growers, some of them listed below:

- Bouldin Island irrigation network is more complex then that at the other two locations and the plot sizes are smaller. These differences make water management more complicated.
- Wright-Elmwood Tract irrigation is managed by the grower whereas the other farms had employees managing their irrigation.
- Bouldin Island and Wright-Elmwood Tract are pioneers in rice production in the Delta and have to some extent developed their own agronomic methods. Information to the growers was tailored to their individual needs.
- Rindge Tract grower was growing rice for the first time and using rice as part of a crop rotation. The management practices used were based upon input from the San Joaquin County Cooperative Extension and our rice expert.
- The experimental designs and study plots somewhat differed at the different locations because of logistical constraints unique to each location. Different technical actions with regard to water management and training were required for the different locations.

Table 8-1 lists the outreach meetings held. The majority of the outreach meetings were one-on-one meetings with the participating growers. These meetings were primarily discussions

between our group and the growers in which we provided information on growing rice, information on the project and its progress, and guidance on managing surface and subsurface hydrology.

8.1.5.1 Solicitation Meetings

Two solicitation meetings were held for this project, one to solicit farmers for 2004 growing season and one to solicit a 3rd farmer for 2005 growing season. The solicitation meetings reached farmers broadly spread throughout the Delta. Most applicants who identified the soils were on peat soils and water used by the farmers was either directly from the Delta or from rivers feeding into the Delta like the Mokulomne River or the Middle River. In 2004, two of the six applicants were currently growing rice on a total of 700 acres, and most growers were currently growing corn. Other crops being grown by the applicants were alfalfa, wheat and tomatoes. Applicants had learned of the project from Ducks Unlimited directly, from the San Joaquin Resource Conservation District, or from the newspaper. Two farmers were selected based upon the selection criteria (Deliverable 6.4, Farmer Selection Summary, September 29, 2004). Applicants in 2005 had no current rice growers and were farming additional crops such as turf, asparagus, grapes, milo, and potatoes. All applicants had heard from the project from the San Joaquin County Cooperative Extension. As in 2004, all applicants found the material presented adequate and all applicants submitted their application for consideration. One grower was selected in 2005 (Deliverable 6.4B, Farmer Selection Summary for 2005 Growing Season, December 14, 2004).

8.1.5.2 One-on-one outreach meetings

During the project, the project team had over twelve days where they met individually with farmers participating in the study (Table 2-1). At these meetings the project team provided information on the project and its findings; advised on hydrologic management and infrastructure improvements designed to improve on water quality; and advised on cultural practices such as seedbed preparation, weed management and drain scheduling. These meetings were always one-on-one discussions with the growers and at these meetings the project team solicited input from the farmers on how to better coordinate the projects activities and schedules with that of the farmers.

The project team informally polled the growers on these outreach meetings after 2004 and in response to those discussions increased the frequency of these meeting in 2005. Muzio Farm at Wright-Elmwood Tract found the meetings during 2004 with our rice expert to be useful, especially with planning for the management of rice during transitions to different growing stages.

The project team again spoke with the growers in 2005 after the completion of the 2005 growing season. Muzio Farm again spoke of how our rice expert was helpful with regard to the timing of actions such as water management and planning for harvesting. Muzio Farm agreed to participate with the project team if the upcoming proposal (PIN 9234) was funded. Our focus at Muzio Farm would be to continue to improve water management through better controlling

inflows and managing those flows in relation to evapotranspiration rates measured at a more local location.

Bouldin Farms at Bouldin Island did not find our rice expert as helpful but was planning on changing some of their practices the following year to improve rice production. They agreed to work with the project team if PIN 9234 were funded and the plan at Bouldin Island would be to redesign the water distribution and drainage network at Bouldin Island for more effective water management.

In 2005, the new grower, Jack Klein Partnership Trust at Rindge Tract utilized the written materials on growing rice from this project (Deliverable 14.1) and worked closely with San Joaquin Cooperative Extension, our rice expert and local PCAs. The grower at Rindge Tract found the services of both the Cooperative Extension and our rice expert very helpful. Specifically, the San Joaquin Cooperative Extension provided materials on growing rice both in written form and at a February 2005 outreach meeting. Our rice expert helped greatly with the water application rates and practices and with harvesting. Jack Klein Trust found our written materials very helpful and informative and felt that the information provided both in written form and orally helped them have good production and quality in 2005.

8.1.5.3 Conference and Field Day Presentations

In all there were three poster presentations at scientific and technical conferences:

- The Annual Rice Field Day in Biggs, CA during August 2004;
- The annual meeting of the California Chapter of the Agronomy Society of America in Modesto in early February 2005 (Science and Policy Issues in California Agriculture); and
- The November 2005 annual conference sponsored by the Soil Science Society of America, the American Society of Agronomy, and the Crop Science Society of America.

The goal of these conferences and field days were to provide information and data to the scientific and grower communities with regard to this project.

8.1.5.4 Local Regional Agricultural Water Quality Stakeholder Meeting

Finally, the project team participated in a local stakeholder meeting held in October 25, 2005 by the UC Davis SAFS (Sustainable Agricultural Farming System) program. This meeting was a small gathering of regional agricultural water quality stakeholders currently involved with runoff monitoring. The focus of this meeting was to discuss monitoring objectives of different stakeholders, technical hurdles, results if available and significance of the effort. Several organizations were represented at the meeting including the CALFED Drinking Water Program, local RCDs, NRCS, CDFA, and University of California, Davis The meeting ranged from small-scale experimental plots to large watershed studies. The discussion of sampling methodologies was found useful as well as the opportunity to improve communication between stakeholders and to build relationships.

Table 8-5. List of Workshops for Rice Project

Outreach Meeting	Date				Meeting Focus	Attendees	Survey Form
	Bouldin Island	Muzio's Farm	Jack Klein Trust	Other			
Farmer Soliciation Meeting				29-Jan-04, Walnut Grove & Stockton	Solicit Farmers for 2004	Rice Team Representatives, Interested Farmers	X
Kick-off meeting with farmers	9-Mar-04	15-Mar-04			Meeting to discuss experimental goals and design	S. Deverel & P. Bachand met with E. Muzio and R. Heringer at their respective farms.	
Grower meeting	6-Jul-04	8-Jul-04			Discuss timing of hydrologic management, any grower issues or questions on growing rice, and coordination with project experimental goals	P. Bachand and J.D. Garr met with E. Muzio and R. Heringer at respective farms.	
Grower meeting	9-Sep-04	9-Sep-04			Discuss upcoming rice production schedule	P. Bachand and J.D. Garr met with E. Muzio and R. Heringer at respective farms.	
3rd Farmer Soliciation Meeting		7-Oct-04			Solicit 3rd farmer to participate in project. Discuss current project status and how rice fits into the Delta as a possible crop.	M.Canevari (SJ Cooperative Extension), G. Green, P. Bachand, R. Qualls (UNR), E. Muzio, and interested growers	X
Hydrologic Upgrades		April 05			Meet with E. Muzio to discuss weir insert design for installation during Summer 05	D. Mourad met with E. Muzio on two occasions to go over design issues.	
Cultural Practices; Kick-off meeting for 3rd Farmer	11-Apr-05	11-Apr-05	11-Apr-05		Advise growers on cultural practices for planting preparation and planting. Meeting to discuss project goals as they relate to third farmer and discuss support to grower for 2005	J.D.Garr met with E. Muzio and R. Heringer at respective farms. P. Bachand and J. D. Garr meet with B. Rogan, L. Casale, and M. Canevari (SJ Cooperative Extension) for K/O meeting for 3rd farmer.	
Hydrologic Upgrades		May 05			Meet to discuss improved management and infrastructure for surface water control	P. Bachand and R. Heringer	
Hydrologic Upgrades		3-Jun-05			Installed weir inserts and trained E. Muzio on their use.	D. Mourad and E. Muzio	
Cultural/Agronomic Practices	13-Jun-05	13-Jun-05	13-Jun-05		Check crop field progress. Advise project growers.	J. D. Garr met with all growers at respective farms.	
Cultural/Agronomic Practices	6-Jul-05	6-Jul-05	6-Jul-05		Check crop field progress. Advise project growers.	J. D. Garr met with all growers at respective farms.	
Cultural/Agronomic Practices	13-Jul-05				Bouldin crop progress and advise. Discuss weed problem.	J.D.Garr met with R. Heringer at Bouldin Farms.	
Cultural/Agronomic Practices	29-Jul-05	29-Jul-05	29-Jul-05		Meet and advise project growers on site	J. D. Garr met with all growers at respective farms.	
Cultural/Agronomic Practices	23-Aug-05	23-Aug-05	23-Aug-05		Project visit all three project farms	J. D. Garr met with all growers at respective farms.	
Cultural/Agronomic Practices	1-Sep-05	1-Sep-05	1-Sep-05		Advise on timing of draining fields with all growers; on site	J. D. Garr met with all growers at respective farms.	
Cultural/Agronomic Practices	9-Sep-05	9-Sep-05	9-Sep-05		Field progress check: drain timing and crop progress	J. D. Garr met with all growers at respective farms.	

8.1.5.5 Distribution of Final Report Executive Summary

The Executive Summary for this report is being sent directly to the list of interested parties that was developed for this project (Table 8-6). An electronic version of this final report will be made available upon request.

Table 8-6. List of Interested Parties Updated in May 2005

Organization	Dept	Name	Title	Phone	email	Address
CALFED	Science Program	Johnnie Moore	Lead Scientist		johnniem@calwater.ca.gov	650 Capitol Mall, 5th Floor, Sacramento, Ca. 95814
CALFED	Science Program	Zach Hymanson	Program Manager		zachary@calwater.ca.gov	650 Capitol Mall, 5th Floor, Sacramento, Ca. 95814
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8.1.5.6 Outreach Summary

The outreach program evolved through this study.

With regard to working with the farmers, the project team moved away from very formal farmer outreach programs, to more informal one-on-one meetings. We took this approach understanding that each grower had different needs and to better respond to those needs***. Jack Klein Trust told the project team that if the outreach program was to get farmers interested in growing rice then it was a success.*** He had a good experience growing rice, had good profits and quality, believed that it was helping with nematode management, and was planning on continuing to grow rice. He was planning on increasing the acreage of rice and including it as part of his crop rotation. These actions are consistent with the other participating farmers who are also planning on increasing their acreage of rice.

Another component of outreach was to have the growers improve water management. This component was a success as well. Wright-Elmwood agreed to, implemented and is planning to continue using the weir inserts to better manage flows on and off the fields. Bouldin Farms installed additional weir boxes in 2005 to better manage flows though other factors compromised their performance. Both farmers are interested in continuing work on additional research as outlined in a pending proposal to the SWRCB (PIN 9234).

Finally, the project team has had good working relations with the Cooperative Extension. Cooperative Extension has committed to continuing to collaborate and support the project team if PIN 9234 is funded.

For the technical outreach, our team has participated in several scientific, technical and grower forums and believe that we have met the requirements to get the information out as well.

8.1.5.7 Outreach Materials

Outreach materials for this project are available from Ducks Unlimited and Contra Costa Water District. This material includes posters presented at the Technical meetings and the materials provided to Jack Klein Trust. This material is in Appendix A.7.

8.2 Measures of Effectiveness Related to Project Management and Implementation

Several effectiveness measures were used to evaluate project management and implementation. These measures are described this section.

8.2.1 Evaluation of following the schedule and compliance with the original SOW

The quarterly progress reports (Deliverable 1.2) documented the progress during this project of meeting the schedule as outlined in the original Scope of Work and progress in complying with that SOW.

In general, the activities have followed the SOW. Some changes in approach were made after approval by the SWRCB as has been discussed in Section 8.1.1 and 8.1.2 regarding changing the experimental design and in Section 8.1.5 regarding our approach to outreach.

Table 2-1 shows the deliverable schedule for this project.

As discussed earlier, our primary emphasis was on pushing the field work forward to secure two growing seasons of data and to gather all other field data necessary to meet the project's technical objectives and goals. Key deliverables were produced in a timely fashion to keep the project moving forward:

- A draft QAPP was submitted to the Board in early July, a few weeks after the signing of the contract between the State and CCWD in order to secure permission from the Board for Summer 2004 data collection;
- TAC comments were solicited by December 2004 so that modifications in the project could be implemented for the 2005 growing season;
- The implementation plan for converting to rice (Deliverable 9.3) was submitted by November 2004 so that it could be utilized by the 2005 grower as guidelines for converting to rice; and

8.2.2 The Draft Final Report was submitted in January 2006. Document identifying farmers participating in project

Several deliverables document farmer participation in the project. Deliverable 6.6 (Land owner agreements) documents the agreement the three farmers signed to participate in the project. Deliverable 8.1 (Photo documentation) documents the first growing season at both Bouldin Island and at Wright-Elmwood Tract. Deliverable 8.3 (Conversion documentation) provides as-build drawings showing the implementation of the fields and study plots at Bouldin Island and Wright-Elmwood Tract. Deliverable 12.1 (Cost/Income Analysis and Production Rates) details the economics behind rice production in the Delta and these are discussed as well in Chapter 7. Deliverables 14.8 (Workshop presentations) have been provided to the State Board throughout the project and detail agendas of many of the one-on-one workshops held during this study as part of the outreach effort and to coordinate activities between the growers and this project team.

8.2.3 Conversion document including maps describing rice field conversion

Deliverable 8.3 documents the conversions of the rice plots at Bouldin Island and Wright-Elmwood Tract. Deliverable 8.3 documents the completion of implementation of the study plots.

8.2.4 Photo documentation showing one season of rice production in the Delta for converted fields

Deliverable 8.1 provides a list of photographs taken to photo document the conversions at Bouldin Island and Wright-Elmwood Tract in 2004 as well as implementation of the experimental plots at those sites.

8.2.5 Implementation plan including maps showing experimental plot implementation

Deliverable 9.1 provides the experimental design that was implemented for the experimental plots at Bouldin Island and at Wright-Elmwood Tract in 2004. Deliverable 9.3 is the implementation plan of those experiments. Deliverable 9.5 documents through photographs the implementation of the study plots in 2004. Deliverable 9.6 provides as-built drawings and documentation on the completed implementation of the study plots.

8.2.6 Outlines for eight workshops and list of participants

Section 8.1.3 discusses the outreach and documentation of outreach. Deliverable 10.4 provides additional information on outreach and discusses survey results when surveys were used.

8.3 Project Management Summary

As originally proposed, the project was designed to be conducted over a 3-year period. Contracting delays resulted in the contract being executed in June 2004, nearly nine months later than anticipated. At the same time, the SWRCB and RWQCB staff did not offer a completion date extension. The late start date then compressed the period to complete the same scope of work and although all of the scope was completed, this caused many of the deliverables to be submitted later than planned. Another administrative factor that added constraints to this research was the lack of flexibility within the contract to accommodate changing field conditions. Unanticipated field conditions are inherent to field work (especially in the Delta). Many suggestions made by the research team that would have improved the quality of the research could not be accommodated because such changes were reported to require a contract amendment – even small changes that were consistent with the intent of the scope. Considering the length of the contracting process, completing an amendment was not viable. Changes that were allowed involved an arduous administrative process.

We have met the deliverables as stated in the contract and all goals and objectives have been met for this project. This report in part documents our meeting those objectives, goals and deliverables. This project represents an enormous effort given the compressed time frame for its implementation and the difficulties of implementing applied research projects of this scale in the Delta, where many logistical and infrastructure constraints exist.

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Appendices

A.1 List of Participants

The following organizations worked together on this project:

1. Contra Costa Water District, submitting organization
2. University of California Davis, subcontractor
3. U.S.G.S Water Resources Division, California District, subcontractor
4. Hydrofocus, Inc, subcontractor
5. Bachand & Associates, subcontractor
6. Ducks Unlimited, subcontractor

Contra Costa Water District was the submitting organization and the project manager. There are five principal investigators for the project: Dr. Philip Bachand, environmental engineer from Bachand & Associates; Dr. Steve Deverel, hydrologist from Hydrofocus, Professor Will Horwath, soil scientist from UC Davis; Jacob Fleck, soil scientist from USGS; and Greg Green, biologist from Ducks Unlimited. Figure 4.1 shows the staff organization for this project and it is summarized below. There expertise is shown in Table A1-1.

Table A.1-1. Expertise of research organizations involved in project

Organization	Expertise
Hydrofocus	Surface and groundwater hydrology - data collection, analysis, modeling
Bachand & Associates	Environmental engineering, developing water quality BMPs, water quality and treatment in semi-natural aquatic systems
Professor Horwath, UCD LAWR	Carbon and nutrient cycling in agricultural systems, BMP development
USGS Water Resources	DOC transport and quality, THM and disinfection product formation and transport
Ducks Unlimited	Restoration, agricultural advisor for rice systems

A.2 Technical Advisory Committee Comments and Responses

A.2.1 TAC Comments

The following are the comments on the Draft Final Report as provided by the Technical Advisory Committee in either emails or as attachments.

A.2.1.1 Comments By Thomas Harter, UC Davis

From: "Thomas Harter" <thharter@ucdavis.edu>
To: "Philip Bachand" <phil@swampthing.org>, dbrun@ccwater.com
Date: Tue, 21 Feb 2006 16:23:55 -0800
Subject: Re: Comments on the rice project Reply-to: thharter@ucdavis.edu

Phil, Desiree:

My apologies for the delay in reviewing your draft final report (SWRCB Agreement No. 03-165-555-0). I have read and reviewed the report. As a technical reviewer for this project, I am focusing primarily on the design, analysis, and interpretation of the groundwater hydraulic data.

1. Overall, the draft final report contains detailed information on the geography, geology, and hydrology of the study sites with a sufficient number of tables and graphics to illustrate the information given. However, the report lacks a concise descripction of the conceptual model of the hydrology of the field sites, which the authors use to interpret their loading data. See following comments.

2. In section 5.2.2.2 or somewhere prior to that section, a thorough yet concise overview should be inserted on the conceptual model of the hydrologic cycle at the two sites (Bouldin Island and Muzio Farms). The conceptual model should identify, where (in the conceptual model) measurements are made. This is best done using conceptual illustrations. Illustrations should include the concept of "groundwater contributing area" and how groundwater loading is estimated either by the budget method or by the tile drain method (p.52: "subsurface hydrologic loads were measured directly with a weir"). The conceptual model would clearly define terms such as "surface water outflow", "subsurface loading", "subsurface outflow", "subsurface drain flow". As is I am a bit confused about these - forcing me to go back and forth and see what these terms may mean or where they are first mentioned.

3. In section 5.3.1, I understand that future versions will discuss the margin or error of individual hydrologic budget items, and will also need to include a description of the margin of error of estimating groundwater contributions by the budget method.

4. Section 5.3.5.1 (groundwatercontributing areas) must be moved to section 5.3.1.

5. Section 5.3.1 then would conclude with a discussion of the hydrologic budget, the temporal changes, and the accuracy of computing groundwater loading based on hydrologic budget estimation and/or tile drain discharge.

6. Section 5.3.3. would have to strongly build on the conceptual outline provided per above mentioned comment.

7. Page 88: What is the meaning of the strong changes in water-levels with respect to interpreting groundwater loading? The groundwater loading areas were computed using a specific date. Large changes in water levels may significantly alter groundwater recharge/discharge. How is that addressed?

Specific Comments:

p.2: "....Subsidence in the Delta primarily results..."

p.2: " ....compared to different water management regimes:"

p.2: "...What are the concentrations of key constituents of concern (COC)[...] in surface and subsurface drainage...."

p.3: "...These farms represent a southeast-northwest...."

p. 92: I don't understand this sentence: "...Variations in DRAIN(-WATER) DOC concentrations have substantially less of an effect on DOC DRAIN concentrations and loads". I read this as: "A does not have an effect on A." ???

p. 100: "During 2004 and 2005..."

p. 100: how is the second and fifth bullet different? Is subsurface load different from subsurface drains? Again, this could be helped with a good conceptual picture at the beginning of section 5.3.

Otherwise, I find this draft final report technically correct.

Regards,
Thomas Harter

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A.2.1.2 Comments By Mick Canevari, UC San Joaquin County Cooperative Extension

As follows is the text included in an email attachment from Mick Canevari on 2/13/06 (Delta rice review 2-12-06).

Reviewer Canevari

Reducing Non-point DOC and Nitrogen Exports from Rice Fields:
Draft Report

This project is very important in addressing several issues important to the Delta and surrounding counties. The Delta is the hub to 75% of the states water for distribution to municipalities and Agricultural users. The state and local communities are concerned about the California Delta and its agriculture - a valuable resource of national importance. Farming is the center piece of the Delta requiring Best Management Practices to sustain the environment but equally the economic viability of the areas major industry, Agriculture.
For that to be successful, identifying cultural practices conducive to wildlife habitat and respectful of recreational participation by the public while addressing water quality is imperative for its future success.
This project met those specific objectives by pulling together involvement by organizations with different resources and expertise to collaborate in a unified objective. Having the involvement of Delta rice farmers was paramount to access and quantify methods for improving water quality as it relates to DOC and related constituents that are a by product of the soil makeup.
The main outcome of the report spells out the linear relationship of irrigation and water movement through the upper horizon of peat soil and its impact on DOC concentrations. It also substantiates the relationship of DOC to THMFP.
I had the opportunity of visiting the experimental sites on Muzio farm on an average of 2-4 times a month which provided a visual opportunity to experimental design and the research operation. The research areas and experimental design were consistent with stated objectives and appropriate for proper statistical analysis.
The project was conducted in an efficient manner under close supervision of PI's with involvement of the grower. The project sites were also reflective of a cross section of Delta soils and environment including the third site at Rindge Tract.
There were some unexplained issues and inconsistencies when comparing the two sites that were significant by treatments for DOC loads. I'm not sure if this was due to differences in grower site management or experimental design. Knowing the sites, I would suggest the Muzio farm data is stronger and reproducible.
In summary, the project was designed and carried out using sound scientific principals having statistical relevance. More importantly, this project is an important platform to the future of agriculture in the Delta, water quality and wildlife habitat, all or which are important to the stakeholders of California.

I have listed some specific and or general comments below for the PI's to address.

Page 1 last sentence titrate? Or nitrate?

Page2. Show data from Twitchell Island on reducing subsidence explain in more detail

Page 18 explain the justification of temporal variation within plot design.

Page 9 was silica determined in seed or straw or both?

Page 23 3.1.5. Explain blanking?

Page 23 3.1.4. more explanation

Page 30. # 3 Recycling and holding water? Rice soils need a drying cycle.

Page 69 5.23 Difficult to understand the rationale given for Bouldin Is and Muzio farm for DOC?

Page 65 good explanation by graph and correlation.

Page 110 7.1 "Rice reversing subsidence" about that statement until we have substantial data?

A.2.1.3 Comments By Robert Qualls, UN Reno

As follows is the text included in an email attachment from Robert Qualls on 2/03/06 (Review Reducing Non-point DOC1).

Reviewer: Qualls

Reducing Non-point DOC and Nitrogen Exports from Rice Fields:…Draft Report.

Overall

Overall it is a great and important project. It is very thorough in scope, incorporating not only experimental manipulation in two farms (two islands) but also including a whole suite of chemical and hydrological measurements. In addition, the importance and scope is expanded to include the added benefits of increased waterfowl usage and finally the agricultural economics of switch in production. Also, it is very complete and well written especially for a draft!

The heart of the report, (given the principal goal of reducing DOC and therefore THMFP in the water supply, is sections 5-3 and 5-4. They really hit the nail on the head on pointing out that the key is minimizing hydrologic flowthrough of the peat. That is that **concentration** of DOC in water that has "equilibrated" with the peat is hard to control, but hydrologic load is nearly directly proportional to DOC loads. Also, the very linear relationship of THMFP to DOC concentration, links this importance of hydrologic flowthrough directly to "loads" of THMFP produced and then the effects on drinking water sources.

This work in conjunction with the literature sources reinforces my simple view that the field with a certain depth of peat soil can be viewed as a giant chromatography column that is loaded with a very large pool of a sparingly water soluble organic. As water flows through the column it equilibrates with the column by desorption until the concentration reaches an equilibrium. So, the more water that flows through, the more organic is desorbed and since there is a very large pool it is only very slowly depleted. The role of decomposition of the peat is partly that it concentrates the pool of soluble material on a column of adsorbant material that is shrinking. There can be some more subtle variations on the analogy. For example as the report points out, the concentration of potentially soluble organic material is most concentrated near the surface (in the peat and in the crop resudue) and surface flow in, with a few days time to equilibrate and surface output may produce the highest concentration.

My main comment on the results is the question of whether variation over time in the loads (month to month) is interfering with finding significant differences in the loads integrated over the year. For example in Table 5-8, I wasn't sure if DOC load in outflow and subsurface drainflows was integrated over the entire period of study (e.g. g DOC/ac/yr over the entire two years), or if it was just the means of instantaneous loads taken each month. I assumed that the number was mean of the instantaneous loads calculated from water load times concentration each sampling date. It also seems to me that the median of the monthly instantaneous loads would bias the data toward the months with lower loads, while I would think mean of monthly

instantaneous loads would be nearly the same as the integrated load over the entire time period. In other words months with higher concentrations or loads should carry more weight since they contribute more to the total annual load.

The question of temporal variation within a plot: may interpretation of the variation indicated as a standard deviation in Table 5-8 and for example the quartile ranges in Fig. 5-7 are that they reflect month to month variation at one 'plot" (field). I was afraid that that variation used in the Mann-Whitney tests would complicate finding differences between the corresponding rice and corn treatments. For example, the a given corn plot might be higher every month in DOC load than the corresponding rice plot, but using since they vary a lot month-to month, that might cause them to appear not-significantly different. Perhaps a paired t-test or repeated measures ANOVA would separate temporal variation from differences due to treatment. I realize that the non-normality of the data is a problem in using these parametric tests, but could a log transform of the load data fix the normality problem? (Maybe not, maybe you've already tried this). But all in all, I tended to put more stock in the differences in the mean values than might have been indicated by the Mann-Whitney test.

I'll follow these general comments with some page-by-page specific ones below:

Page 1
Introduction: Very good rationale
second paragraph: May need some explanations of water inputs and out puts.
Last sentence of last paragraph: Define titrate????

Page 2
Under Statement of Purpose first bulleted point: Change to – High water levels in drains
Bottom of page under first treatments #1: Acronym (COC) really confusing

Page 3
Last sentence: Is it significant????

Page 6
Table 1-1: Good Summary

Page 7
Second to last paragraph: Effects of flooding in winter increase in water flow through????

Page 8
Table 1-3: Is Corn only termed a low drainage treatment?

Page 13, 14, &15
Charts: Nice charts of fields especially indication of surface flow.

Page 15
Under paragraph of Wildlife surveys: Maybe say why about the first sentence.

Page 17

Reference "Aguilar": Good find of this very pertinent reference.

Page 23
Under Recommendations: Seems like sort of a mixture of how to do the study better and BMP's
Under 3.1.4: A little more explanation

Page 24
Under 3.3.2 first sentence change "then" to than.

P. 30, How would application of N lead to export of more DOC … more production of litter?

P. 31, para. 2 last sentence, a very interesting study, maybe a little more detail and emphasis.

P. 32. Maybe add something here about how variations in soul type correspond to treatment plots. Also a little preview of how deep the peat is would help here although I realize it is presented in results.

P 37-42. In general the methods seem very good, assiduous and are explained well.

P. 44 para. 1. Would log transformations have helped? I know that water quality and load data are often log-normal. Then the parametric tests would have more power, and paired t tests or repeated measures ANOVA could be used.
Use of CIMIS stations for ET x crop coefficient – good!

Fig. 5-6. Maybe add again in legend what the interpretation of positive values represent.
Quite a high rate of inflow at B!-NRL2!

Table 5-5 Seems to me in comparison to other peatlands and ag. areas on peat the DOC concentrations are not terribly high.
NO3 data: A lot of denitrification in summer??

P. 52. Table 5-9 is probably 5-8.

Table 5-7 Maybe a little caption pointing out what positive and negative mean, and what gross and net indicate (an equation for net?).

Table 5-8. I wasn't sure whether these data are instantaneous loads calc. as flow x conc. And then averaged over time or integrated over the entire study period. Also check significant digits.

P. 65: para. 1 and 2 very important
Fig. 5-19. Just echoes DOC data.
Fig. 5-20 surprizingly strong correlation.
What is DDO

Fig. 5-24: Is the slope different for surface vs. subsurface flow. If so could that reflect solar radiation effects?

Table 5-9. Good comparison
Nitrogen loads: would be interesting to see plot of DON vs. DOC with different symbols for surface and subsurface, and treatments. I.e. is DON just echoing DOC trends in all cases.

P. 79 lines 13-14 interesting!

Fig. 5-32. the very low soil C% at BNRH1 how might that have affected the results?

Fig. 5-36 Wow, MU NRL and MU NRM are much lower at 46 to 89 cm.

Fig. 5-38. Useful plot.

Fig. 5-46. Shows the principle: relatively similar DOC concentrations, its water flow that matters.

Fig. 5-11. DOC in Muzio deepwells much lower, link with low % C in Fig. 5-33-34??

P. 93 Table 5__?

Para. 4. I strongly agree!

P. 99. 9th sent. From bottom, *previously* (?) oxidized soils

P. 101 bullet 6 Qualify surface (?)

Table 6-1. What are the units?

Although its not my area, Chapt.7 seems easy to read and is understandable.

A.2.2 Project Team Responses to Comments

A.2.2.1 Responses to Professor Qualls' Comments

Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices

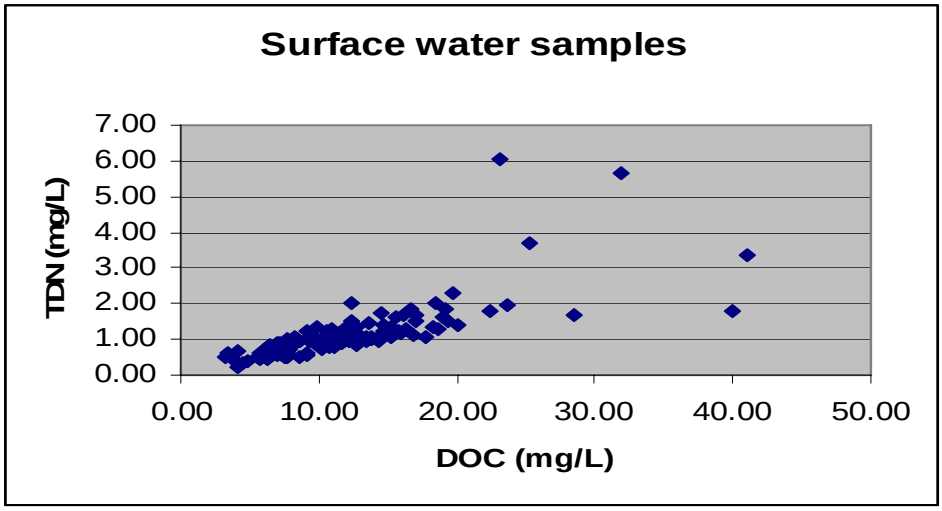
Technical Advisory Committee

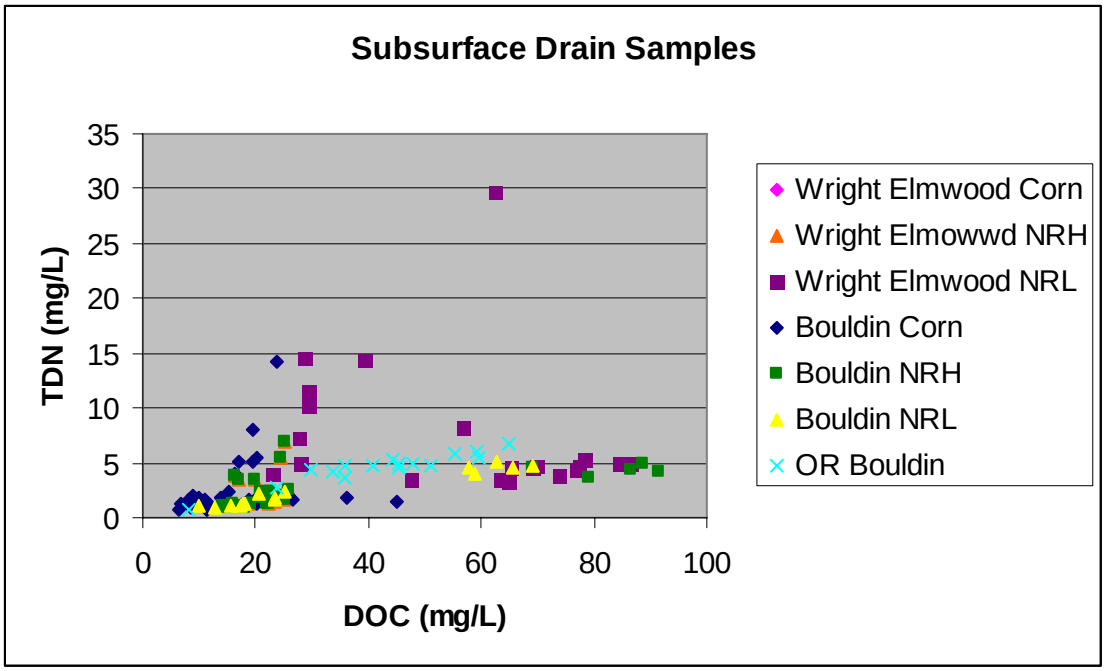
Responses to Comments from Professor Robert Qualls
University of Nevada, Reno
March 2006

Comments from Professor Qualls helped result in a technically improved and more readable report. Specifically, Professor Qualls' review pointed to a need to further analyze the load data relative to determination of significant differences. Professor Qualls' point about temporal variability in loads and additional statistical analysis using a paired t-test or ANOVA is well taken. However, the Final Report did not have the time to do this analysis prior to completion of the project. The project team plans to explore alternative data analysis for publication of a journal article. Below, responses are given to Professor Qualls' specific comments.

- In Figure 5-6, the Final Report added additional explanation that explains the interpretation of the positive and negative values for the hydrologic budget calculations. Also, relative to Table 5-7, the Final Report added explanation of net and gross loads.
- Relative to Table 5-5, nitrate concentrations are indeed low due to denitirification. The Final Report added verbiage to point this out.
- All the loads reported are instantaneous. Discussion was added to explain this.
- Professor Qualls' made an interesting point about possible solar radiation influence in the TTHMFP/DOC relation for surface water and drainwater sites. The regression equations are not significantly different. The slope for the surface water samples was slightly higher.
- In the methods section 5.2, the Final Report included a detailed water-management discussion and definitions of terms. The Final Report also described the conceptual model for flow to drainage ditches. Professor Qualls' comments indicated that the notations such as DDO, SWO and SWI were confusing and these were edited.
- Professor Qualls' comment about DOC-nitrogen covariance is noteworthy. The Final Report was not able to include this in our data analysis for the final report but it merits further investigation. The Final Report included graphs that show the relation of TDN to DOC. It is interesting that there appears to be a correlation of DOC and TDN at levels below 40 and 5 mg/L for both surface-water and drain-water samples.

- Relative to Professor Qualls' remaining specific comments, the Final Report changed to verbiage to correct editorial problems related to description of flows and loads and drain DOC concentrations.





A.2.2.2 Responses to Dr. Harter's Comments

Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices

Technical Advisory Committee

Responses to Comments from Dr. Thomas Harter
Department of Land, Air and Water Resources
University of California, Davis

March 2006

Comments from Dr. Harter helped result in a technically improved and more readable report. Specifically, Dr. Harter's review pointed to the need for a description of a conceptual model and better definition of terms for site hydrology and water management. Dr. Harter also expressed a need for future versions of the report to discuss the error associated with load estimates and included specific comments. Responses to specific comments are given below.

- In the methods section 5.2, the Final Report included a detailed discussion about water management and definition of terms. The Final Report also described the conceptual model for seepage to drainage ditches.
- In the loads section 5.3, the Final Report included discussion and quantification of the error in drain flows and loads. Because there is a propagation of error in measuring of low velocities and flows, a statement of statistical significance relative to differences in the high and low drains on Bouldin Island was not possible.
- In the discussion section 5.4, the Final Report included a conceptual model diagram and explanation of groundwater flow to drainage ditches in relation to the spatial distribution of groundwater DOC concentrations.
- In the groundwater section, you questioned the meaning of the groundwater changes relative to contributing areas. The Final Report used groundwater contour maps to show groundwater flow to drainage ditches and to delineate approximate contributing areas. There is some uncertainty in the estimate of these contributing areas and The Final Report added discussion of this. The hydrographs show relatively stable conditions during most of the growing season between July and mid September and then dramatic water-level decreases when the fields were drained for harvest. The Final Report assumed that the contributing areas are relatively stable only during the growing season which is the primary period when drain flow occurs.

- Relative to the remaining specific comments, the Final Report changed to verbiage to correct editorial problems related to description of flows and loads and drain DOC concentrations.

A.2.2.3 Responses to Mr. Canevari's Comments

Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic Management Practices

Technical Advisory Committee

Responses to Comments from Mr. Mick Canevari
County Director/Farm Advisor
San Joaquin Cooperative Extension

March 2006

Comments from Mr. Canevari helped result in a technically improved and more readable report. Specifically, Mr. Canevari's review focused on the relationships between DOC, THMFP and flows; the need to identify rice cultural practices that enable economic viability but also are conducive to wildlife habitat and water quality; and the importance of collaborating with the agricultural community.

Mr. Canevari noted inconsistencies when comparing the two sites with regard to the effects of water level management. That issue has been a main focus of our review of the data and preparation of the Final Report. Temporal pressure transducer data, mapped groundwater contours in relation to drain water elevations, and the direct measurements of drain water flows and loads from Wright-Elmwood Tract all point to the conclusion that raising drain levels reduced subsurface flows. The data was carefully reviewed and the Final Report concluded that the 2005 high and low drain data for the new rice was incorrect due to an overestimation of flow through the v-notch separating the high drain from the low drain. The Final Report surmises that the overestimation of flow is because the v-notch weir was operating very high and was outside the calibration curve we developed for v-notch weirs. Chapter 5 of the Final Report discusses this issue and its implications as follows:

- Chapter 5 includes calibration curves for the v-notch and rectangular weir;
- The limits of the calculated calibration constants were included and compared to published values;
- Chapter 5 includes a discussion on sources of errors;
- Chapter 5 broadens the discussion section to include implications on project.

Responses to Mr. Canevari's specific comments as are follows:

- The Final Report was not able to provide the data on Twitchell Island subsidence due to time limitations. The Final Report provides a reference for that data and will discuss it in more detail in future publications.
- In the methods section for Chapter 5, the Final Report added text discussing seasonal changes in water management and additional discussion on seasonal effects was added to the Executive Summary.
- The Final Report added a definition of blanking.
- The Final Report clarified the recommendations with regard to managing for evapotranspiration. More details on that are discussed in Chapter 5 with regard to the relationship between constituent loading and surface and subsurface flows, and with regard to managing to reduce surface water flows.
- The Final Report added text in the Recommendations with regard to drydown periods needed for harvesting and weed management.
- The Final Report added text to qualify our subsidence discussion in Chapter 7.

A.3 Water Quality Data Summary

A.3.1 Surface Water Summary

Tables A.3-1 through A.3-4 provides summary statistics (e.g. median, standard deviation, 25th and 75th quartiles, and number of analyses) for field parameters, nitrogen species, dissolved organic carbon, disinfection byproducts and UV254 analyses for samples taken at field inflow (SWI), field outflow (SWO) and drainage ditch (DDO) locations for both Bouldin Island and Muzio Farm on Wright-Elmwood Tract. Locations sampled represent new rice fields with high and low water management in the drains, established (or old) rice fields with low water management in the drains, and corn fields with low water management in the drains.

Table A.3-1. Field Water Quality Parameter Summary

FarmID	PlotID	Point	DO mg/L						pH					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	2.331818	11	2.518844	0.230000	0.520000	4.310000	6.545455	11	0.269346	6.350000	6.530000	6.680000
BI	NRH1	SWI	7.455000	8	1.019159	6.890000	7.400000	8.235000	7.337143	7	0.273661	7.100000	7.360000	7.490000
BI	NRH1	SWO	5.847500	8	2.280118	3.910000	5.990000	7.550000	6.640000	8	0.229534	6.460000	6.630000	6.750000
BI	NRH2	SWI	6.672667	15	1.850237	6.210000	6.930000	7.920000	7.127067	15	0.360255	6.820000	7.160000	7.400000
BI	NRH2	SWO	6.037000	10	5.574436	2.950000	4.460000	7.940000	6.590000	10	0.189620	6.510000	6.590000	6.640000
BI	NRH	DDO	0.938182	11	0.770218	0.440000	0.730000	0.920000	6.210000	11	0.218906	5.970000	6.180000	6.430000
BI	NRL1	SWI	7.866000	10	1.350335	7.320000	7.600000	8.510000	7.198750	8	0.332885	6.915000	7.245000	7.465000
BI	NRL1	SWO	5.350000	10	3.370612	2.180000	5.200000	5.540000	6.896000	10	0.607494	6.500000	6.820000	6.940000
BI	nrl2	SWI	6.033000	10	2.433279	4.450000	5.265000	8.210000	7.059091	11	0.267935	6.800000	7.000000	7.240000
BI	nrl2	SWO	4.531667	6	2.945535	1.730000	5.160000	5.450000	6.801667	6	0.140202	6.670000	6.880000	6.900000
BI	NRL	DDO	2.913000	10	2.989564	0.600000	2.170000	3.800000	6.481111	9	0.219114	6.300000	6.420000	6.630000
BI	OR	SWI	6.363333	9	2.683855	3.780000	7.020000	8.700000	6.903333	9	0.495379	6.590000	6.750000	7.020000
BI	OR	SWO	6.368182	11	1.752186	4.880000	5.530000	8.040000	6.889091	11	0.463561	6.520000	6.650000	7.380000
BI	OR	DDO	0.460000	14	0.301432	0.300000	0.355000	0.560000	6.311875	16	0.244574	6.075000	6.305000	6.500000
MU	corn	DDO	2.588000	10	3.519545	0.250000	0.585000	4.730000	6.930000	11	0.532935	6.700000	6.780000	6.830000
MU	SJR	Siphon		0					5.920000	1	0.000000	5.920000	5.920000	5.920000
MU	NRH	SWI	4.791875	16	2.264380	2.840000	4.155000	6.580000	6.826667	15	0.325350	6.640000	6.850000	7.100000
MU	NRH	SWO	4.335000	16	2.565546	2.155000	3.660000	6.520000	6.818750	16	0.379682	6.525000	6.800000	6.990000
MU	NRH	DDO	1.339286	14	1.803635	0.370000	0.420000	1.580000	6.830000	13	0.192180	6.690000	6.780000	7.020000
MU	NRL	SWI	4.898182	11	2.775362	3.020000	3.650000	7.600000	6.922727	11	0.313659	6.690000	6.890000	7.110000
MU	NRL	SWO	3.748125	16	2.642610	1.140000	2.955000	6.975000	6.740625	16	0.278004	6.555000	6.685000	6.865000
MU	NRL	DDO	1.948421	19	1.927881	0.400000	1.180000	3.180000	5.877000	20	0.362696	5.645000	5.890000	6.135000
MU	NRM	SWI	4.876154	13	2.532069	2.850000	4.380000	7.380000	6.828461	13	0.303338	6.620000	6.750000	7.040000
MU	NRM	SWO	3.467647	17	2.892405	1.110000	2.330000	4.780000	6.889412	17	0.331351	6.650000	6.870000	7.110000
Total			4.179236	275	3.171844	1.150000	3.660000	6.930000	6.726204	275	0.474243	6.460000	6.700000	7.000000

FarmID	PlotID	Point	EC uS						temp deg C					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	458.991	11	153.5846	405.500	480.200	568.000	18.9857	14	5.2485	14.70000	18.87500	21.60000
BI	NRH1	SWI	157.386	7	21.2252	143.100	149.900	174.500	23.0300	10	0.9229	22.60000	23.00000	23.80000
BI	NRH1	SWO	162.633	9	21.6215	146.900	155.400	178.700	20.2111	9	1.6737	19.50000	20.10000	20.80000
BI	NRH2	SWI	155.573	15	22.4228	141.200	145.500	175.400	23.3294	17	0.7959	22.85000	23.30000	23.90000
BI	NRH2	SWO	216.910	10	43.3785	173.300	216.850	256.600	20.2409	11	1.6116	19.10000	19.90000	21.30000
BI	NRH	DDO	337.715	13	198.2107	184.500	266.000	505.000	18.2933	15	3.4817	15.60000	19.40000	21.20000
BI	NRL1	SWI	163.850	8	18.5275	149.200	163.200	175.100	22.9312	8	0.7573	22.55000	22.97500	23.50000
BI	NRL1	SWO	187.564	11	37.5140	157.400	179.500	214.000	21.0605	11	4.2631	18.75000	19.30000	22.55000
BI	nrl2	SWI	283.982	11	418.7375	141.800	155.200	176.200	23.0318	11	0.8057	22.40000	23.00000	23.70000
BI	nrl2	SWO	229.100	7	41.8282	213.100	227.000	242.700	19.0062	8	1.6470	18.12500	18.75000	19.67500
BI	NRL	DDO	417.140	10	317.0986	209.600	262.350	685.000	18.8292	12	3.5547	16.35000	19.00000	21.22500
BI	OR	SWI	171.233	9	30.4167	143.000	175.100	203.000	22.6500	9	1.6504	22.60000	23.00000	23.90000
BI	OR	SWO	198.727	11	29.9280	174.700	193.200	221.700	23.8409	11	4.7443	20.60000	22.85000	25.60000
BI	OR	DDO	504.780	15	93.4323	427.600	498.000	580.000	18.7438	16	3.7820	15.47500	20.75000	21.47500
MU	corn	DDO	704.318	11	169.3216	600.000	642.500	816.000	18.3679	14	5.7579	14.70000	16.90000	22.70000
MU	SJR	Siphon	574.000	1	0.0000	574.000	574.000	574.000	24.6000	1	0.0000	24.60000	24.60000	24.60000
MU	NRH	SWI	453.567	15	84.9281	394.000	461.200	537.000	20.5353	17	5.3025	18.20000	20.40000	24.00000
MU	NRH	SWO	491.269	16	87.2031	436.900	507.500	541.500	18.8969	16	5.5559	15.50000	20.20000	23.10000
MU	NRH	DDO	1067.315	13	119.5201	971.000	1065.000	1152.000	116.9667	18	421.7947	15.60000	18.50000	20.60000
MU	NRL	SWI	450.473	11	76.9824	422.600	465.000	499.500	21.6083	12	4.0745	19.05000	20.22500	23.12500
MU	NRL	SWO	464.987	15	84.9976	427.300	466.000	535.000	19.4531	16	5.0868	15.45000	19.87500	22.97500
MU	NRL	DDO	1708.421	19	477.7502	1508.000	1630.000	1841.000	18.4342	19	3.3416	15.10000	19.60000	20.20000
MU	NRM	SWI	511.808	13	99.6512	458.400	489.000	524.000	18.8165	13	5.9050	17.55000	19.90000	22.65000
MU	NRM	SWO	540.440	15	109.6420	475.700	520.000	570.000	18.4063	16	5.3879	14.97500	19.55000	21.42500
Total			493.078	276	431.1082	183.650	427.300	562.000	25.9297	304	102.5811	18.10000	20.42500	22.85000

Table A.3-2. Nitrogen Species Summary

FarmID	PlotID	Point	NH4 mg-N/L						NO3 mg-N/L					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	0.152853	14	0.266043	0.041223	0.080713	0.137253	0.329759	13	0.524127	-0.009164	0.159529	0.392000
BI	NRH1	SWI	0.100137	7	0.076537	0.035744	0.066854	0.176329	0.330686	7	0.114583	0.227925	0.301331	0.416000
BI	NRH1	SWO	0.128252	9	0.333614	0.008905	0.012945	0.032297	0.078892	9	0.123114	-0.000675	0.010501	0.180000
BI	NRH2	SWI	0.075653	15	0.039163	0.041502	0.057865	0.120676	0.303765	14	0.122696	0.216468	0.251486	0.360000
BI	NRH2	SWO	0.025719	11	0.020707	0.013183	0.018720	0.031397	0.045613	11	0.106076	-0.012973	0.009882	0.048813
BI	NRH	DDO	0.380270	11	0.443717	0.065985	0.096785	0.785562	0.084950	13	0.165115	-0.010705	0.009049	0.200000
BI	NRL1	SWI	0.035964	8	0.020006	0.029067	0.035398	0.048227	0.300681	8	0.142019	0.227241	0.287159	0.385026
BI	NRL1	SWO	0.013219	9	0.013873	0.000267	0.013768	0.026392	0.041203	11	0.127295	-0.025266	-0.017095	0.055980
BI	nrl2	SWI	0.037739	10	0.012996	0.025009	0.036934	0.047754	0.299900	10	0.110834	0.237879	0.274284	0.339636
BI	nrl2	SWO	0.020250	9	0.022928	0.005171	0.020686	0.027635	0.055869	8	0.139740	-0.022759	-0.013599	0.124042
BI	NRL	DDO	0.447000	11	0.629855	0.053753	0.093450	1.203600	0.183949	11	0.354428	-0.007641	0.031203	0.233558
BI	OR	SWI	0.275512	11	0.823307	0.007133	0.020701	0.054292	0.215514	8	0.160297	0.107913	0.247367	0.300329
BI	OR	SWO	0.099033	10	0.241009	-0.000623	0.005493	0.032297	0.046203	11	0.151446	-0.026827	-0.017183	0.001745
BI	OR	DDO	1.611318	15	0.901305	0.716495	1.608455	2.367207	0.126579	15	0.133728	0.005389	0.097730	0.219126
MU	corn	DDO	0.523339	13	0.394567	0.233017	0.473077	0.695553	2.302793	15	3.540635	-0.001806	0.114871	4.047433
MU	SJR	Siphon	0.078346	1	0.000000	0.078346	0.078346	0.078346	0.015815	1	0.000000	0.015815	0.015815	0.015815
MU	NRH	SWI	0.030772	14	0.064604	0.008728	0.012931	0.019992	0.055831	15	0.119945	-0.020631	-0.003215	0.141334
MU	NRH	SWO	0.112035	16	0.320205	0.007477	0.021217	0.055846	0.045156	16	0.109575	-0.022337	0.000415	0.071071
MU	NRH	DDO	0.295570	15	0.361447	0.055400	0.126478	0.355633	0.374982	14	0.789459	-0.005636	0.028620	0.272979
MU	NRL	SWI	0.029479	11	0.014109	0.013642	0.030349	0.041132	0.101938	13	0.143433	-0.004209	0.072238	0.176000
MU	NRL	SWO	0.259124	14	0.808946	0.027635	0.038793	0.060807	0.045987	15	0.125583	-0.020882	-0.006630	0.048053
MU	NRL	DDO	0.563664	19	0.263981	0.358704	0.536567	0.746972	4.292572	19	6.710713	0.186987	0.574629	7.959122
MU	NRM	SWI	0.015111	13	0.017264	0.003221	0.008346	0.019471	0.048351	14	0.127220	-0.026545	-0.011022	0.143822
MU	NRM	SWO	0.259840	15	0.831419	0.013642	0.023275	0.084670	0.041900	15	0.115163	-0.018821	-0.010108	0.047266
Total			0.270335	281	0.560988	0.018285	0.043425	0.161047	0.531036	286	2.184183	-0.010705	0.048433	0.289899

FarmID	PlotID	Point	tdn mg-N/L					
			Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	1.248645	13	0.502692	0.829000	1.192832	1.27710
BI	NRH1	SWI	0.680752	7	0.200063	0.455959	0.694536	0.81300
BI	NRH1	SWO	0.797979	8	0.287417	0.620510	0.687333	1.00427
BI	NRH2	SWI	0.680553	15	0.169694	0.517672	0.720716	0.77800
BI	NRH2	SWO	0.957856	12	0.323793	0.747639	0.886915	1.15430
BI	NRH	DDO	2.187573	11	1.577416	1.136118	1.349440	4.37750
BI	NRL1	SWI	0.831781	10	0.415083	0.584000	0.728817	1.15265
BI	NRL1	SWO	0.842606	10	0.491691	0.468061	0.795557	1.10577
BI	nrl2	SWI	0.654111	10	0.143732	0.533734	0.619261	0.76161
BI	nrl2	SWO	1.089402	11	0.478533	0.694025	0.927713	1.53679
BI	NRL	DDO	2.352226	11	1.551760	1.084207	1.559176	4.57877
BI	OR	SWI	0.747834	10	0.249024	0.591400	0.670079	0.75374
BI	OR	SWO	0.851949	11	0.475801	0.467000	0.671680	1.09013
BI	OR	DDO	4.588588	15	1.462079	4.117699	4.817084	5.51304
MU	corn	DDO	3.972962	13	3.783778	1.257787	1.905229	5.08483
MU	SJR	Siphon	1.420500	1	0.000000	1.420500	1.420500	1.42050
MU	NRH	SWI	0.924041	15	0.418966	0.739827	0.853165	1.01295
MU	NRH	SWO	1.195330	17	0.731614	0.807071	0.953252	1.31300
MU	NRH	DDO	2.313759	14	1.172925	1.517000	1.975875	2.61990
MU	NRL	SWI	0.844825	13	0.221254	0.686553	0.817000	0.97407
MU	NRL	SWO	1.443967	15	1.198149	0.931722	1.146237	1.37046
MU	NRL	DDO	7.810648	19	6.362982	4.444650	4.896533	10.14142
MU	NRM	SWI	1.127310	13	0.427309	0.880858	1.143589	1.21448
MU	NRM	SWO	1.333648	15	0.621759	0.982000	1.109985	1.47158
Total			1.921509	289	2.679012	0.739827	1.065000	1.71940

Table A.3-3. Carbon and Disinfection Byproduct Precursor Data Summary

FarmID	PlotID	Point	DOC mg/L (analyzed by UCD)						DOC mg/L (Split samples by USGS)					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	12.0335	13	5.55271	8.3948	11.6796	15.3580	8.8500	4	3.38871	6.1500	8.8500	11.5500
BI	NRH1	SWI	1.6814	7	0.07981	1.5803	1.7079	1.7388	1.5000	1	0.00000	1.5000	1.5000	1.5000
BI	NRH1	SWO	8.6413	9	2.14269	6.7725	7.9646	10.5087	10.0000	1	0.00000	10.0000	10.0000	10.0000
BI	NRH2	SWI	1.7963	14	0.17988	1.7247	1.7968	1.8840	1.7500	2	0.21213	1.6000	1.7500	1.9000
BI	NRH2	SWO	12.0977	11	4.00655	8.6270	11.6092	14.6483	11.5667	3	5.99361	5.2000	12.4000	17.1000
BI	NRH	DDO	35.9116	11	29.65035	18.2428	19.3027	69.0261	79.8000	1	0.00000	79.8000	79.8000	79.8000
BI	NRL1	SWI	5.1613	8	7.64285	1.8609	1.9123	4.2039	1.8000	2	0.28284	1.6000	1.8000	2.0000
BI	NRL1	SWO	9.1300	10	5.70786	3.8659	8.2528	15.7027	7.7000	2	3.81838	5.0000	7.7000	10.4000
BI	nrl2	SWI	2.4525	10	0.32482	2.3063	2.4212	2.5900	1.9000	1	0.00000	1.9000	1.9000	1.9000
BI	nrl2	SWO	11.5956	7	6.13677	7.0670	8.6873	18.4518	8.6500	2	3.60624	6.1000	8.6500	11.2000
BI	NRL	DDO	30.7198	10	23.78293	12.5887	20.4775	57.7745	13.9500	2	8.69741	7.8000	13.9500	20.1000
BI	OR	SWI	9.5352	10	15.03287	1.9727	3.4680	9.5378	1.9000	1	0.00000	1.9000	1.9000	1.9000
BI	OR	SWO	9.4274	11	5.12767	5.7682	6.9684	13.4837	4.7667	3	1.04083	3.6000	5.1000	5.6000
BI	OR	DDO	41.9572	15	16.18500	33.7657	44.4304	55.4704	35.4000	1	0.00000	35.4000	35.4000	35.4000
MU	corn	DDO	16.2837	12	10.18305	8.8416	14.9130	19.4610	9.2667	3	2.24796	6.8000	9.8000	11.2000
MU	SJR	Siphon	10.0668	1	0.00000	10.0668	10.0668	10.0668	4.7000	1	0.00000	4.7000	4.7000	4.7000
MU	NRH	SWI	9.5034	15	4.31746	6.8079	7.4801	9.7276	6.3667	3	0.20817	6.2000	6.3000	6.6000
MU	NRH	SWO	11.6224	16	4.87005	7.6748	10.0744	14.8477	7.4750	4	0.80571	6.9500	7.3000	8.0000
MU	NRH	DDO	21.6138	16	2.98815	20.5611	22.2953	23.1224	19.2250	4	2.89525	17.0000	19.6500	21.4500
MU	NRL	SWI	7.6699	12	3.81057	6.0287	6.4405	7.1681	6.4800	5	1.16919	5.8000	6.1000	6.4000
MU	NRL	SWO	13.8408	15	6.18070	9.6345	12.6832	17.1083	13.6000	1	0.00000	13.6000	13.6000	13.6000
MU	NRL	DDO	55.5705	18	22.93426	29.3887	62.9135	76.8689	52.9250	4	28.20619	29.2000	49.4000	76.6500
MU	NRM	SWI	11.9102	13	4.07038	7.7610	11.6141	15.0955	6.5000	1	0.00000	6.5000	6.5000	6.5000
MU	NRM	SWO	15.3218	15	7.72157	11.7942	12.9774	14.4376	13.2333	6	3.81873	11.5000	11.6000	12.3000
Total			18.8238	279	25.53422	6.5320	11.6116	19.3504	20.1377	58	33.63855	5.8000	8.6000	15.5000

FarmID	PlotID	Point	THMFP ug/L						STHMFP uM/mM					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	1089.974	7	671.005	493.130	666.500	1728.000	8.52010	7	1.377593	7.349458	7.64539	9.99359
BI	NRH1	SWI	149.800	3	1.157	149.030	149.240	151.130	8.75372	3	0.481835	8.321995	8.66566	9.27352
BI	NRH1	SWO	831.508	6	223.281	718.120	794.940	1026.650	9.35755	5	0.357150	9.155134	9.30608	9.41407
BI	NRH2	SWI	151.632	6	16.478	146.470	154.760	161.540	8.37990	7	0.923922	7.894129	8.50852	8.76243
BI	NRH2	SWO	871.332	6	268.801	626.960	858.675	1076.950	8.64730	6	0.340532	8.408778	8.49892	8.79703
BI	NRH	DDO	3300.573	8	2411.490	1442.465	1815.500	6045.625	8.14921	6	0.716606	7.408243	8.36462	8.68127
BI	NRL1	SWI	174.620	1	0.000	174.620	174.620	174.620	9.10644	1	0.000000	9.106441	9.10644	9.10644
BI	NRL1	SWO	1259.642	4	458.643	945.675	1381.705	1573.610	9.70305	3	0.245447	9.456265	9.70575	9.94714
BI	nrl2	SWI	205.950	6	8.915	197.360	204.730	215.590	8.28958	5	0.248612	8.131829	8.19696	8.41621
BI	nrl2	SWO	1399.115	4	513.575	1014.990	1519.865	1783.240	9.43578	4	0.282982	9.209739	9.40477	9.66183
BI	NRL	DDO	3522.906	5	1435.174	2380.120	4323.500	4551.330	7.98612	6	1.147366	7.153104	8.01106	8.86213
BI	OR	SWI	186.177	4	8.580	180.915	183.155	191.440	8.83784	4	0.329387	8.587193	8.85737	9.08849
BI	OR	SWO	695.884	5	289.579	471.860	606.840	790.500	10.20295	5	0.654731	9.841484	10.42354	10.51737
BI	OR	DDO	3172.547	9	640.549	2721.000	3385.400	3659.750	7.82603	8	0.575063	7.306665	7.80158	8.27699
MU	corn	DDO	1337.431	12	321.325	1041.600	1379.045	1615.500	8.25548	10	2.155692	7.688731	8.09429	8.38195
MU	SJR	Siphon		0						0				
MU	NRH	SWI	1187.780	6	551.084	881.990	937.050	1466.750	9.60657	8	0.442727	9.163718	9.57992	10.04846
MU	NRH	SWO	1452.933	7	503.002	1032.130	1354.150	1670.640	10.18914	8	1.044913	9.226871	10.51081	10.85934
MU	NRH	DDO	1643.665	8	755.471	1395.465	1873.445	2102.500	7.28698	9	2.907435	7.244184	7.60018	9.19303
MU	NRL	SWI	918.502	5	488.873	668.940	677.650	946.300	9.83756	6	0.636089	9.605289	9.82213	10.09350
MU	NRL	SWO	1418.054	7	673.277	859.230	1174.160	1751.200	9.70981	7	1.085569	9.089431	9.17459	10.63633
MU	NRL	DDO	3863.859	10	1568.842	2193.170	4368.500	5234.750	7.42269	12	0.840743	6.891175	7.43466	7.77833
MU	NRM	SWI	1391.080	6	402.568	1082.250	1247.540	1572.000	10.02897	6	1.154791	9.434185	9.53945	10.67848
MU	NRM	SWO	1511.434	8	526.929	1154.545	1267.410	1881.695	10.03481	6	1.106783	9.290689	9.88489	11.08560
Total			1595.375	143	1373.576	705.330	1277.310	2033.500	8.79844	142	1.484278	7.990577	8.90030	9.62498

Table A.3-4. Particulate and UV254 Summary

FarmID	PlotID	Point	pic mg/l						POC mg/L					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	11.24889	12	11.07296	1.89726	8.504843	20.18852	9.517403	14	9.784004	2.178602	8.792664	14.72384
BI	NRH1	SWI	9.46292	6	5.25533	4.69356	8.344447	12.23242	3.777671	7	2.617677	2.048857	3.118896	6.57354
BI	NRH1	SWO	0.89464	8	2.09491	0.00000	0.499996	1.08525	3.221632	10	2.356437	1.571092	2.389685	5.01522
BI	NRH2	SWI	5.30401	12	5.22148	2.45452	4.081329	6.65973	5.657150	15	4.935317	1.698874	3.187102	9.97315
BI	NRH2	SWO	1.52689	9	3.24241	0.00000	0.183274	1.77557	3.041094	11	5.066427	0.727379	1.295547	4.25170
BI	NRH	DDO	1.83961	11	7.18575	0.00000	0.942685	7.77272	3.144434	12	7.598325	1.483340	2.951529	8.62633
BI	NRL1	SWI	3.56433	7	1.63713	1.98098	3.646086	5.33597	6.946559	9	8.657838	1.395349	3.397508	7.65228
BI	NRL1	SWO	-0.74251	8	1.93262	-2.39991	-0.502959	0.49438	3.860691	10	2.864032	1.458648	3.317252	5.13023
BI	nrl2	SWI	2.80283	8	3.81181	0.27550	2.335349	6.10460	2.797519	11	1.969040	1.139818	2.305210	4.34940
BI	nrl2	SWO	0.76528	6	2.27035	-0.53744	0.000000	1.44040	4.798285	8	7.369876	1.293759	2.718751	3.94042
BI	NRL	DDO	2.92836	10	4.78925	-0.95621	1.518163	5.22080	6.031662	11	4.492037	1.803969	6.163328	7.36720
BI	OR	SWI	0.80531	7	2.69914	-1.12994	2.199010	2.70514	3.531358	11	5.004983	1.849983	3.127572	6.02637
BI	OR	SWO	-0.75260	8	1.89423	-1.23617	0.000000	0.27943	3.538163	11	3.179215	1.315201	2.153063	6.76379
BI	OR	DDO	2.87581	13	2.76068	1.44479	2.717655	4.63661	7.138294	16	3.953305	3.809286	6.050649	9.87129
MU	corn	DDO	6.49201	8	4.18099	3.16467	5.752589	9.87898	5.161304	13	4.993445	2.614291	4.088865	8.02059
MU	SJR	Siphon		0						0				
MU	NRH	SWI	0.54850	12	2.77634	-1.09590	-0.318869	1.04019	3.323161	16	3.767715	1.124258	2.519693	3.80124
MU	NRH	SWO	-0.03028	16	2.42068	-1.58227	-0.283532	0.86917	3.892246	16	5.400108	0.985808	2.047358	4.90245
MU	NRH	DDO	5.09423	12	6.14153	0.82937	2.589893	7.92692	8.682504	17	7.169668	4.170390	6.405280	9.10996
MU	NRL	SWI	0.85178	12	3.18029	-1.17492	-0.066793	2.22691	4.111166	13	3.650743	1.391885	2.889130	7.73113
MU	NRL	SWO	0.67014	14	1.82674	-0.54118	1.110343	2.06526	5.187083	15	4.645913	1.639744	2.837282	8.50119
MU	NRL	DDO	5.19621	18	4.96875	3.32502	4.205499	7.27273	6.555662	20	3.574075	4.205699	5.905082	8.41677
MU	NRM	SWI	0.25833	11	2.30183	-1.87758	-0.888889	2.11416	5.046509	14	5.811974	1.526562	2.933343	6.72847
MU	NRM	SWO	-0.23339	13	1.71749	-0.59636	0.000000	0.98151	3.717738	15	4.711602	0.000400	1.999001	6.12557
Total			2.65960	241	5.24281	0.00000	1.275510	4.24112	5.069440	295	5.441072	1.649893	3.402722	7.65228

FarmID	PlotID	Point	tss mg/l						UV254 cm-1					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	corn	DDO	18.07731	15	17.14623	4.027386	8.94569	27.05969	0.575000	9	0.301336	0.308000	0.590000	0.831000
BI	NRH1	SWI	10.56203	9	6.72169	6.146972	11.09006	11.58427	0.049800	5	0.002950	0.049000	0.049000	0.051000
BI	NRH1	SWO	4.38098	10	3.45425	1.883639	3.67592	6.33580	0.453000	6	0.115632	0.403000	0.449000	0.565000
BI	NRH2	SWI	9.93741	20	7.73863	6.525452	7.87710	12.13403	0.054000	9	0.003500	0.052000	0.055000	0.057000
BI	NRH2	SWO	11.15272	12	24.33728	1.064002	2.87014	7.16219	0.479833	6	0.182005	0.314000	0.484500	0.656000
BI	NRH	DDO	6.98825	15	4.81644	3.487494	5.74502	11.10637	2.450800	10	1.896046	0.927000	1.182500	4.719000
BI	NRL1	SWI	8.68443	12	10.66488	3.129949	6.46361	7.94181	0.059400	5	0.005367	0.058000	0.060000	0.064000
BI	NRL1	SWO	3.47914	12	3.73059	0.577699	2.34107	5.54418	0.591167	6	0.219539	0.392000	0.610500	0.777000
BI	nrl2	SWI	4.87806	12	3.87703	2.580731	4.91611	6.60514	0.079167	6	0.007910	0.073000	0.081500	0.083000
BI	nrl2	SWO	7.50217	11	11.55852	1.155630	3.20256	4.93731	0.568500	6	0.268209	0.338000	0.534500	0.821000
BI	NRL	DDO	10.72583	13	8.26166	5.501881	8.57575	17.21317	1.934000	10	1.115442	1.002000	1.321500	3.294000
BI	OR	SWI	5.15263	10	7.03623	1.890484	4.56172	6.06793	0.069333	6	0.005391	0.064000	0.069500	0.073000
BI	OR	SWO	3.64974	11	4.34971	0.664411	1.51329	9.51919	0.321400	5	0.152182	0.203000	0.273000	0.373000
BI	OR	DDO	11.32255	16	6.57834	6.941502	9.86885	16.32371	2.425200	10	0.774769	1.702000	2.365000	3.049000
MU	corn	DDO	14.25859	17	11.74000	5.542818	10.13384	18.66821	0.644917	12	0.171223	0.501000	0.657000	0.785500
MU	SJR	Siphon		0						0				
MU	NRH	SWI	4.26331	17	4.92061	1.147627	2.90020	5.35045	0.488667	9	0.268655	0.290000	0.433000	0.489000
MU	NRH	SWO	4.88501	19	6.38175	0.556215	4.09442	6.37813	0.616500	10	0.289220	0.385000	0.493000	0.851000
MU	NRH	DDO	13.77550	17	11.91701	6.793478	8.34921	14.56835	1.053091	11	0.201229	0.923000	1.110000	1.214000
MU	NRL	SWI	8.71438	16	12.06842	0.861430	4.08039	11.38035	0.465778	9	0.310010	0.233000	0.289000	0.758000
MU	NRL	SWO	6.70526	19	5.32826	1.803947	6.38388	10.83018	0.676800	10	0.399227	0.341000	0.558500	0.842000
MU	NRL	DDO	13.50083	21	8.56955	8.167067	11.10310	15.63625	2.757083	12	1.393424	1.273500	3.070500	4.035000
MU	NRM	SWI	5.55125	16	6.82764	1.164349	2.66223	8.97261	0.753778	9	0.412946	0.525000	0.552000	0.795000
MU	NRM	SWO	7.11493	16	8.18024	1.128804	4.02618	11.14014	0.765700	10	0.290817	0.527000	0.629500	1.056000
Total			8.75477	336	10.09506	2.173025	6.20564	11.10473	0.930534	191	1.054768	0.301000	0.617000	1.093000

A.3.2 Groundwater Summary

Table A.3-5 provides a summary of major anion and cations measured from deep and shallow wells located at the different established and new rice treatments.

Table A.3-5. Summary of Groundwater Data

FarmID	PlotID	Point	Ca (Soluble) meq/l						K (Soluble) mg/l					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	NRH1	Deep Well	1.7	1	0	1.7	1.7	1.7	4.11	1	0	4.11	4.11	4.11
BI	NRH1	Shallow Well	4.6	1	0	4.6	4.6	4.6	1.64	1	0	1.64	1.64	1.64
BI	NRH2	Deep Well	0.8	1	0	0.8	0.8	0.8	2.1	1	0	2.1	2.1	2.1
BI	NRH2	Shallow Well	2	1	0	2	2	2	1.91	1	0	1.91	1.91	1.91
BI	NRL1	Deep Well	0.9	1	0	0.9	0.9	0.9	3.86	1	0	3.86	3.86	3.86
BI	NRL1	Shallow Well	7.4	1	0	7.4	7.4	7.4	2.78	1	0	2.78	2.78	2.78
BI	nrl2	Deep Well	2.7	1	0	2.7	2.7	2.7	4.44	1	0	4.44	4.44	4.44
BI	nrl2	Shallow Well	8.3	1	0	8.3	8.3	8.3	4.53	1	0	4.53	4.53	4.53
BI	OR	Deep Well	4.75	2	1.767767	3.5	4.75	6	10.56	2	3.97394	7.75	10.56	13.37
BI	OR	Shallow Well	9	2	0.565685	8.6	9	9.4	5.985	2	3.924443	3.21	5.985	8.76
MU	NRH	Deep Well	14.4	1	0	14.4	14.4	14.4	4.85	1	0	4.85	4.85	4.85
MU	NRH	Shallow Well	13.4	1	0	13.4	13.4	13.4	3.68	1	0	3.68	3.68	3.68
MU	NRL	Deep Well	15.1	2	5.515433	11.2	15.1	19	7.485	2	2.298097	5.86	7.485	9.11
MU	NRL	Shallow Well	13.65	2	9.970206	6.6	13.65	20.7	2.53	2	0.410122	2.24	2.53	2.82
MU	NRM	Deep Well	11	2	7.778175	5.5	11	16.5	4.235	2	0.53033	3.86	4.235	4.61
MU	NRM	Shallow Well	18.4	2	0.989949	17.7	18.4	19.1	3.545	2	0.954594	2.87	3.545	4.22
Total				22						22				

FarmID	PlotID	Point	Mg (Soluble) meq/l						Na (Soluble) meq/l					
			Means	N	Std.Dev.	Q25	Median	Q75	Means	N	Std.Dev.	Q25	Median	Q75
BI	NRH1	Deep Well	1	1	0	1	1	1	2.4	1	0	2.4	2.4	2.4
BI	NRH1	Shallow Well	2.8	1	0	2.8	2.8	2.8	2.8	1	0	2.8	2.8	2.8
BI	NRH2	Deep Well	0.7	1	0	0.7	0.7	0.7	1.5	1	0	1.5	1.5	1.5
BI	NRH2	Shallow Well	1.4	1	0	1.4	1.4	1.4	2.6	1	0	2.6	2.6	2.6
BI	NRL1	Deep Well	1	1	0	1	1	1	4.7	1	0	4.7	4.7	4.7
BI	NRL1	Shallow Well	6.9	1	0	6.9	6.9	6.9	7.2	1	0	7.2	7.2	7.2
BI	nrl2	Deep Well	3.7	1	0	3.7	3.7	3.7	2.9	1	0	2.9	2.9	2.9
BI	nrl2	Shallow Well	9.5	1	0	9.5	9.5	9.5	8	1	0	8	8	8
BI	OR	Deep Well	4.45	2	1.767767	3.2	4.45	5.7	9.05	2	3.74767	6.4	9.05	11.7
BI	OR	Shallow Well	12.75	2	7.000358	7.8	12.75	17.7	17	2	17.53625	4.6	17	29.4
MU	NRH	Deep Well	13.3	1	0	13.3	13.3	13.3	10.8	1	0	10.8	10.8	10.8
MU	NRH	Shallow Well	12.3	1	0	12.3	12.3	12.3	20.6	1	0	20.6	20.6	20.6
MU	NRL	Deep Well	8.3	2	0.282842	8.1	8.3	8.5	9.8	2	0	9.8	9.8	9.8
MU	NRL	Shallow Well	6.65	2	5.727565	2.6	6.65	10.7	10.2	2	5.09117	6.6	10.2	13.8
MU	NRM	Deep Well	4.95	2	2.474874	3.2	4.95	6.7	5.6	2	1.41421	4.6	5.6	6.6
MU	NRM	Shallow Well	9.85	2	0.777817	9.3	9.85	10.4	13.1	2	1.27279	12.2	13.1	14
Total				22						22				

FarmID	PlotID	Point	SO4-S mg/L					
			Means	N	Std.Dev.	Q25	Median	Q75
BI	NRH1	Deep Well	12.7	1	0	12.7	12.7	12.7
BI	NRH1	Shallow Well	49.2	1	0	49.2	49.2	49.2
BI	NRH2	Deep Well	4.1	1	0	4.1	4.1	4.1
BI	NRH2	Shallow Well	28.7	1	0	28.7	28.7	28.7
BI	NRL1	Deep Well	7.1	1	0	7.1	7.1	7.1
BI	NRL1	Shallow Well	83.2	1	0	83.2	83.2	83.2
BI	nrl2	Deep Well	2.9	1	0	2.9	2.9	2.9
BI	nrl2	Shallow Well	136.8	1	0	136.8	136.8	136.8
BI	OR	Deep Well	75.6	2	28.5671	55.4	75.6	95.8
BI	OR	Shallow Well	147	2	47.2347	113.6	147	180.4
MU	NRH	Deep Well	290.6	1	0	290.6	290.6	290.6
MU	NRH	Shallow Well	395.1	1	0	395.1	395.1	395.1
MU	NRL	Deep Well	375.3	2	56.1443	335.6	375.3	415
MU	NRL	Shallow Well	327.2	2	251.1643	149.6	327.2	504.8
MU	NRM	Deep Well	175.05	2	160.1597	61.8	175.05	288.3
MU	NRM	Shallow Well	415.45	2	36.1332	389.9	415.45	441
Total				22				

A.4 Soils Data Summary

Table A.4-1 provides percent carbon and nitrogen for soil samples taken at the different rice/hydrologic treatments for both Bouldin Island and Muzio Farm and at the corn field at Muzio Farm.

Table A.4-1. Peat % Carbon and % Nitrogen Data

FarmID	PlotID	%C			%N		
		Means	N	Std.Dev.	Means	N	Std.Dev.
bi	NRH1	18.94744	48	10.20540	1.207125	48	0.353142
bi	NRH2	21.87663	32	8.58207	1.361156	32	0.429615
bi	NRL1	27.78242	55	6.96620	1.633491	55	0.163600
bi	nrl2	23.49381	52	8.00922	1.430500	52	0.281914
bi	OR	20.47586	42	5.63263	1.392262	42	0.242278
MU	corn	19.34022	27	6.32690	1.364148	27	0.194905
MU	NRH	22.26991	45	4.42316	1.338911	45	0.146590
MU	NRL	13.93903	32	5.88524	0.927781	32	0.288236
MU	NRM	18.14371	24	4.46485	1.121458	24	0.167903
All Groups		21.35870	357	8.00087	1.338625	357	0.324055

A.5 Wildlife Counts Summary Data

Table A.5-1 and A.5-2 provide a summary of wildlife counts.

Table A.5-1. Land bird Survey.

Sampling was conducted on one day during each season at each participating farm and at the Consumnes River Preserve.

Season	Year		Agricultural							Managed
			Muzio Farm, Wright-Elmwood Tract		Jack Klein Trust, Rindge Tract[2]		Bouldin Farms, Bouldin Island			Consumnes River Preserve
			Rice	Corn	Rice	Corn	Rice	Corn		Seasonal
Summer	2004		10	9	—	—	70	21		25
Sampling	2005		39	59	26	25	279	20		29
Event		**Total**	**49**	**68**	**26**	**25**	**349**	**41**		**54**
Winter	2004-2005		5	36	—	—	38	2		4
Sampling	2005-2006		0	0	1	0	0	0		1
Event		**Total**	**5**	**36**	**1**	**0**	**38**	**2**		**5**

[1] Landbirds include such birds as raptors and passerines.

[2] Rindge Tract was added in 2005.

Table A.5-2. Water bird Survey

Season	Year	Taxonomical Category	Agricultural							Managed
			Wright-Elmwood Tract		Rindge Tract[1]		Bouldin Island			Cosumnes River Preserve
			Rice	Corn	Rice	Corn	Rice	Corn		Seasonal
Summer	2004	Waterfowl	1	0	—	—	0	0		0
		Other Waterbirds[2]	2		—	—	0	0		20
		Total 2004	**3**	**0**	**—**	**—**	**0**	**0**		**20**
	2005	Waterfowl	36	0	41	0	29	0		103
		Other Waterbirds	8	0	19	0	13	1		33
		Total 2005	**44**	**0**	**60**	**0**	**42**	**1**		**136**
Winter	2004-2005	Mallard	7	0	—	—	0	23		21
		Northern Pintail	1	0	—	—	0	0		308
		Geese	0	0	—	—	0	0		31
		Swans	90	0	—	—	0	0		46
		Total Waterfowl	**98**	**0**	—	—	**0**	**32**		**1558**
		Sandhill Crane	0	0	—	—	0	8		53
		Other Waterbirds	101	0	—	—	314	0		663
		Total 2004-2005	**199**	**0**	—	—	**314**	**40**		**2274**
	2005-2006	Mallard	0	0	0	0	0	0		182
		Northern Pintail	0	0	230	1000	0	1000		2223
		Geese	0	0	1000	19712	3500	0		2750
		Swans	0	0	8489	1500	595	32		0
		Total Waterfowl	**0**	**0**	**9823**	**22212**	**4095**	**11822**		5924
		Sandhill Crane	0	0	0	325	0	0		0
		Other Waterbirds	0	0	250	0	0	225		329
		Total 2005-2006	**0**	**0**	**10073**	**22537**	**4095**	**12047**		**6253**

[1] Rindge Tract was added in 2005.

[2] Other waterbirds include species such as herons and coots.

A.6 Rice Productivity Data

Year	Farm	Plot	Drain Level	Rice	Rep	yield (lbs/acre) @ 14% moisture
2004	BI	OR	Low	Established	1	6880
2004	BI	OR	Low	Established	2	5427
2004	BI	OR	Low	Established	3	5715
2004	BI	OR	Low	Established	4	6664
2004	BI	OR	Low	Established	5	6008
2004	BI	NRL1	Low	New	1	4260
2004	BI	NRL1	Low	New	2	6144
2004	BI	NRL1	Low	New	3	5378
2004	BI	NRL1	Low	New	4	5334
2004	BI	NRL1	Low	New	5	5264
2004	BI	NRL2	Low	New	1	5179
2004	BI	NRL2	Low	New	2	6886
2004	BI	NRL2	Low	New	3	4855
2004	BI	NRL2	Low	New	4	6122
2004	BI	NRL2	Low	New	5	5364
2004	BI	NRH1	High	New	1	5632
2004	BI	NRH1	High	New	2	6449
2004	BI	NRH1	High	New	3	5280
2004	BI	NRH1	High	New	4	5449
2004	BI	NRH1	High	New	5	5376
2004	BI	NRH2	High	New	1	6431
2004	BI	NRH2	High	New	2	7203
2004	BI	NRH2	High	New	3	7589
2004	BI	NRH2	High	New	4	6296
2004	BI	NRH2	High	New	5	5078
2005	BI	OR	Low	Established	1	6222
2005	BI	OR	Low	Established	2	6981
2005	BI	OR	Low	Established	3	1202
2005	BI	OR	Low	Established	4	415
2005	BI	OR	Low	Established	5	4717
2005	BI	NRL1	Low	New	1	7042
2005	BI	NRL1	Low	New	2	4908
2005	BI	NRL1	Low	New	3	7500
2005	BI	NRL1	Low	New	4	2638
2005	BI	NRL1	Low	New	5	5675
2005	BI	NRL2	Low	New	1	6197
2005	BI	NRL2	Low	New	2	2583
2005	BI	NRL2	Low	New	3	6465
2005	BI	NRL2	Low	New	4	4860
2005	BI	NRL2	Low	New	5	6029
2005	BI	NRH2	High	New	1	5090
2005	BI	NRH2	High	New	2	4665
2005	BI	NRH2	High	New	3	4809

2005	BI	NRH2	High	New	4	4728
2005	BI	NRH2	High	New	5	3481
2004	MU	nrh	Low	New	1	7020
2004	MU	nrh	Low	New	2	6786
2004	MU	nrh	Low	New	3	6823
2004	MU	nrh	Low	New	4	7030
2004	MU	nrh	Low	New	5	9357
2004	MU	nrm	Low	New	1	6699
2004	MU	nrm	Low	New	2	5766
2004	MU	nrm	Low	New	3	6609
2004	MU	nrm	Low	New	4	7646
2004	MU	nrm	Low	New	5	7374
2004	MU	nrl	Low	New	1	6721
2004	MU	nrl	Low	New	2	6961
2004	MU	nrl	Low	New	3	6959
2004	MU	nrl	Low	New	4	5835
2004	MU	nrl	Low	New	5	5837
2005	MU	nrh	High	New	1	6837
2005	MU	nrh	High	New	2	6179
2005	MU	nrh	High	New	3	7222
2005	MU	nrh	High	New	4	6326
2005	MU	nrh	High	New	5	7412
2005	MU	nrm		New	1	11351
2005	MU	nrm		New	2	1175
2005	MU	nrm		New	3	6361
2005	MU	nrm		New	4	5737
2005	MU	nrm		New	5	6965
2005	MU	nrl	Low	New	1	6693
2005	MU	nrl	Low	New	2	6538
2005	MU	nrl	Low	New	3	6298
2005	MU	nrl	Low	New	4	6058
2005	MU	nrl	Low	New	5	6853

A.7 Outreach Materials

The attached CD has the following outreach materials developed for this project:

Technical Presentations –

- August 2004 Annual rice field day at Biggs, CA
- Annual meeting of the California Chapter of the Agronomy Society of America in Modesto in early February 2005 (Science and Policy Issues in California Agriculture); and
- November 2005 annual conference sponsored by the Soil Science Society of America, the American Society of Agronomy, and the Crop Science Society of America

Grower materials

- Deliverable 14.1 – Contacts and Technical Publications List
- Deliverable 8.3/9.3/9.6 – Implementation Guidelines
- Spreadsheet relating flow to heights over the weirs for 24 and 30 inch weirs

A.8 Photodocumentation CD

The attached CD has the photodocumentation for the project.

A.9 Database

The included CD has an ACCESS database with all raw data that passed QAQC requirements for the Rice Project.

A.10 Previous Economic Analyses

These economic analyses were conducted for the original proposal (PIN 645) or presented at the solicitation meeting. They are included here for convenience.

PIN 645 PRELIMINARY COST & REVENUE NUMBERS FOR 2001 RICE (DUCKS UNLIMITED 2002)

DELTA WETLANDS
BOULDIN FARMING COMPANY
20101 STATE ROUTE 12
ISLETON, CA 95641

PRELIMINARY COST & REVENUE NUMBERS FOR 2001 RICE

I.	Field Preparation		**Extended Cost Per Acre (ac)**
	A. Disk – Medium Duty (2x) @ $2.50/ac		$ 5.00
	B. Level – Includes borders, supply & drain establishment		100.00
	C. Plow (1x)		8.00
	D. Landplane (1x)		8.00
	E. Disk – Finish		2.50
	Subtotal		**$123.50**
II.	Growing Crop		
	A. Plant		
	1. Seed – m103 variety 150/ac @ $13.00/cwt		$19.50
	2. Machine & Labor		5.00
	Subtotal		**$24.50**
	B. Spray		
	1. Broad Leaf Control - Profinyl		$10.00
	2. Grass Control – Ordram		10.00
	3. Machine & Labor		5.00
	C. Irrigation & Drainage Structures		
	1. Risers 30" x 30" x 15" (3) @ $190.00	570.00	
	2. Drain Culvert 15" x 20" (3) @ $126.00	378.00	
	3. Supply Culvert 18" x 20" (2) @ $165.00	330.00	
	Subtotal	**$1278.00**	
	4. Divided by 100/ac = 12.78 + Installation $2.25		15.03
	D. Flood		
	1. Machine & Labor		5.00
	2. Drain Pump Costs 5.00/ac ft. at average depth 1 foot		10.00
	E. Summer Spray		
	1. Herbicide, Insecticide (maybe unnecessary)		20.00
	Subtotal		**$75.03**
III.	Harvest		
	A. Custom Harvest (B & B) $1.00/cwt average (?) 70/cwt		$70.00
	B. Hauling (Woodland) .50/cwt x 70/cwt		35.00
	Subtotal		**$105.00**
IV.	Overhead		
	A. Managers Salary, Insurance, Professional Fees, Other R & M		$150.00
	Total Cost Per Acre		**$478.00**
	Total Project Cost for 100 Acres		**$47,800.00**

PIN 645. PRELIMINARY FEASIBILITY FINDINGS (DUCKS UNLIMITED, 2002)

To: Ryan Broddrick
From: Jay Dee Garr
Re: Delta Rice Project

DELTA RICE PROJECT– 2000/2001
Bouldin Farming Company
20101 State Route 12
Isleton, CA 95641

The Bouldin Farming Company, managed by Ralph Heringer, is a large Sacramento-San Joaquin River Delta island located approximately 10 miles east of Rio Vista, CA on State Route 12. Bouldin partnered with Ducks Unlimited, Inc. with two goals in mind: first to test the feasibility of rice as a money crop in the cooler climate of the Delta, and second, to see if cultivation of rice slows the degradation of the peat soils common to the area.

The test plot is 100 acres in size. The cost of leveling was **$97.75/acre**. Ducks Unlimited, Inc paid the leveling cost **($10,175)** and the cost of seed **($2,430)**. The remainder of the planting and harvest costs were the responsibility of the grower **($29,136.60)**. According to Bouldin Farming Company figures, the cost of production per acre, including leveling, was **$417.42** for a total of **$41,741.60**.

University of California Extension has determined the average cost of raising one acre of rice in California (2000-2001 growing season) to be $606.00. The full cost of supporting the farm structure of a farm growing rice is $945.00 per acre.

The USDA loan rate for medium grain rice this year is $6.06 per 100 pound sack (cwt). Farms with established rice growing history are receiving about $2.50 over loan in government subsidies. Bouldin Farming Company has no history of farming rice, and will not get this payment from the government. Their rice will be sold on the open market, which means that they will receive less than the loan rate. Bouldin has a contract with Pacific International Rice Mills, Inc. (PIRMI), for $5.15/cwt. They will also get bonus money based on the quality of their crop. Ralph Haringer indicated that PERMI would pay Bouldin about a $1.00 more per 100 pound sack.

Because the nature of peat soils, it was possible to drill the seed into the soil instead of broadcasting it from the air by crop duster as is the normal means of planting in heavier clay soils. Drilling into moist soils is very effective in establishing a stand (high germination).

Total.net production for the season was 8,147.3 cwt or 81.47 cwt/acre. The state average this year is 82 cwt/acre. On the plus side the quality of the crop was excellent. Ralph Heringer indicated that the ranch would make a profit on the rice this year that would surpass the profit made by growing corn. Because of the nature of the rice business and the fact that this ground is not covered by the government crop support system (no history of raising this crop), I feel the profit made by the island's rice crop was due to the fact that Ducks Unlimited, Inc. picked up a significant part of the expenses. If the grower had to pay for all the expenses (not subsidized by D.U. or some other entity) the rice crop at it's current average would take at least five years to show a profit, if then. If Ducks Unlimited, Inc. wishes to keep on subsidizing the leveling of ground for the purpose of growing rice, I am sure we will have fair-sized group of growers that would be very interested.

Information presented by Ducks Unlimited for January 2004 Solicitation Meeting

RICE VS. CORN
SCHEDULE OF RICE / CORN GROSS REVENUE AT VARYING YIELDS AND PRICES

	Rice Price Per CWT			
CWT/Acre	$8.00	$8.50	$9.00	$9.50
60	480	510	540	570
65	520	553	585	618
70	560	595	630	665
75	600	638	675	713 *
80	640	680	720	760

* 1998/99 Reality Range

	Corn Price Per Ton			
Tons/Acre	$85.00	$90.00	$95.00	$100.00
4.00	340	360	380	400
4.50	383	405	428 *	450
5.00	425	450	475	500
5.50	468	495	523	550

* 1998/99 Reality Range

COMPARATIVE GROSS REVENUE
RICE ADVANTAGE - CURRENT REALITY RANGES

	"Low" Price	"High" Price
"Low" Yield	$255	$285
"High" Yield	$255	$285

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DUCKS UNLIMITED ANALYSES OF DELTA GROWER 1999 EXPENSES
RICE/CORN TOTAL COSTS

Growing Costs per Acre	Rice	Corn	Difference
Direct growing costs	$219	$195	$24
Harvest/haul/drying costs (a)	150	98	52
Indirect costs allocated by machinery hours (b)	73	109	(36)
Overhead @ $ 95 per acre (c)	95	95	0
Reclamation district charges	31	31	0
Real estate taxes	15	15	0
Total costs per acre	$583	$543	$40

(a) Calculated at 75 % of current custom rates

(b) Includes Fuel, repairs, machinery depreciation

(c) Management salaries; Administrative services, insurance; fees/taxes; buildings/roads/drain ditch maintenance divided by total acres farmed.

RICE VS. CORN
SCHEDULE OF RICE / CORN NET PROFIT AT VARYING YIELDS AND PRICES

	Rice Gross Revenue Minus Total Costs Per Acre			
CWT/Acre	$8.00	$8.50	$9.00	$9.50
60	(103)	(73)	(43)	(13)
65	(63)	(30)	2	35
70	(23)	12	47	82
75	17	55	92	130 *
80	57	97	137	177

* 1998/99 Reality Range

	Corn Gross Revenue Minus Total Costs Per Acre			
Tons/Acre	$85.00	$90.00	$95.00	$100.00
4.00	(203)	(183)	(163)	(143)
4.50	(160)	(138)	(115) *	(93)
5.00	(118)	(93)	(68)	(43)
5.50	(75)	(48)	(20)	7

* 1998/99 Reality Range

RICE NET PROFIT/ACRE - CURRENT REALITY

	"Low" Price	"High" Price
"Low" Yield	$55	$130
"High" Yield	$97	$177

Note 1: Plus $ 145/acre USDA Rice subsidy based on historical acreage base (not available to Delta)

Note 2: Plus $ 124/acre USDA "Price Deficiency Payment" based on total cwt produced (available to Delta)

CORN NET PROFIT/ACRE - CURRENT REALITY

	"Low" Price	"High" Price
"Low" Yield	($160)	($115)
"High" Yield	($118)	($68)

Note 1: Plus $ 44/acre USDA Corn subsidy based on historical acreage base (available to Delta)

Note 2: Plus $ 46/acre USDA "Price Deficiency Payment" based on total tons produced (available to Delta)