The Economics of Agricultural Drainage

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Table of Contents

Page

Part I: Introduction and Summary 1

Introduction 1

Summary 2

Part II: The Local Stories 4

Preface 4

The Farm Economy 4

The Broadview Story 13
- Irrigation Efficiencies 13
- Changes in Crop Acreages and Crop Water Requirements 14
- Water Deliveries and Drainage 18
- Farm Practices 22

The Firebaugh Canal Story 24
- Irrigation Efficiencies 24
- Water Deliveries, Drainage, and Crop Practices 28

The Pacheco Story 29
- Irrigation Efficiencies 29
- Changes in Crop Acreage and Crop Water Requirements 29
- Drainage 32

The Panoche Story 35
- Irrigation Efficiencies 35
- Changes in Crop Acreage and Crop Water Requirements 35
- Water Delivery and Drainage 38

Part III. Economic and Financial Conditions 41

General Economic Indicators 41
- The U. S. Farm Sector 41
- The California Farm Sector 46

Implications for Drainage 47

Part IV: Conclusions 54

Appendix
Page

Appendix: The Regional Story

Preface and Overview 1

The Surveys 5
- Water Districts Survey 5
- Irrigation Dealers Survey 5

Survey Results 7
- Water Deliveries 7
- Groundwater Pumping 13
- Adoption of Modern Irrigation Technologies 19
- Land Allocation 21
- Irrigation Management on Existing Crops 24
- Institutional Changes 26

List of Figures

Figure No.		Page
1	July-December Rainfall at the Shasta Dam, 1980-91	5
2	CVP Deliveries to Broadview Water District, 1980-91	6
3	Merced County: Per Bale Value of Cotton Production, 1981-90	7
4	Merced County: Per Unit Values of Barley, Wheat, Alfalfa & Rice Production, 1981-90	7
5	Merced County: Per Unit Values of Melons, Tomato & Sugarbeet Production, 1981-90	8
6	Merced County: Government Payments (in Dollars and Percentage of Total Value) for Cotton, 1982-90	8
7	Merced County: Government Payments (in Dollars and as Percentage of Total Value) for Wheat, 1982-90	9
8	Merced County: Government Payments (in Dollars and as Percentage of Total Value) for Barley, 1982-90	9
9	Merced County: Government Payments (in Dollars and as Percentage of Total Value) for Rice, 1982-90	10
10	Broadview WD District Irrigation Efficiencies	13
11	Broadview WD: Crop Agreages, 1981-90	15
12	Broadview WD: Crop Acreages (Cotton & Fallow omitted), 1981-90	15
13	Broadview WD: Crop Water Requirements, 1981-89	16
14	Broadview WD: Crop Water Requirements, 1981-89 (Cotton Omitted)	16
15	Broadview WD: Average Crop Water Requirements, by Crop and Year	17
16	Broadview WD: Average Crop Water Requirements, by Crop and Year (Cotton Omitted)	17
17	CVP Deliveries to Broadview Water District, 1980-91	

(1991 partial) 19

18 Broadview WD: Average Water Deliveries by Month, Pre-drought (1980-86) and Drought (1987-90) 19

19 Broadview WD: Average Water Deliveries by Month, Pre-drought (1980-86) and Drought (1987-90), by Percentage 20

20 Broadview WD: Total (1984-90) and Subsurface Tile (1986-90) Drainage (AF) 20

21 Broadview WD: Volume of Surface & Subsurface Drainwater Released Through Outlet (AF), 1986-91 21

22 Broadview WD: Collected Subsurface Tile Drainage by Month by Month (AF), 1986-91 21

23 Firebaugh WD District Irrigation Efficiencies 24

24 Firebaugh Canal WD: Crop Acreages, 1982-89 26

25 Firebaugh Canal WD: Crop Acreages (Cotton omitted), 1982-89 26

26 Firebaugh Canal WD: Crop Water Requirements, 1982-89 27

27 Firebaugh Canal WD: Crop Water Requirements (Cotton omitted), 1982-89 27

28 Firebaugh Canal WD: Average Crop Water Requirements 28

29 Pacheco WD District Irrigation Efficiencies 29

30 Pacheco WD: Crop Acreages, 1984-89 30

31 Pacheco WD: Crop Acreages, 1984-89 (Cotton omitted) 31

32 Pacheco WD: Crop Water Requirements, 1984-89 31

33 Pacheco WD: Crop Water Requirements, 1984-89 (Cotton omitted) 32

34 Pacheco WD: Total Drainage Discharge 1987-90 33

35 Pacheco WD: Monthly (Oct-Sept) Drainage Discharge 1986 (incomplete)-1990 34

36 Pacheco WD: Distribution (by Percentage of Total) of Monthly (Oct-Sept) Drainage Discharge 1987-1990 34

37 Panoche WD District Irrigation Efficiencies 35

38 Panoche WD: Crop Acreages (Cotton omitted), 1984-89 36

39 Panoche WD: Crop Acreages, 1984-89 36

40 Panoche WD: Crop Water Requirements, 1984-89 37

41 Panoche WD: Crop Water Requirements, 1984-89 (Cotton omitted) 37

42 Panoche Drainage District: Total Drainage Discharge (AF), 1981-90 39

43 Panoche Water District: Average Monthly Drainage Discharges for Pre-drought (1981-86) and Drought (1987-90) Periods 39

44 Panoche WD: Distribution (by Percentage of Total) of Average Monthly Drainage Discharge for Pre-Drought (1981-86) and Drought (1987-90) Periods 40

45 Productivity of U. S. Agriculture and Yield on U. S. 6-Month Treasury Bills, 1980-1991 42

46 Change in Total Assets of U. S. Farm Sector, 1981-1991 42

47 Liquidation Categories for Area Farmers from Survey of U. S. Farm Banks, 1985-1989 (by percentage of total) 45

48 Cumulative Distribution of Profits over Land in the Drainage Area: 1987 Model (Dark) & 1991 Model (Light) 48

49 1987: % Acreage Solvent and in Production in the Drainage Area after an Increase in Drainage Costs 48

50 1991: % of Acreage Solvent and in Production in the Drainage Area after an Increase in Drainage Costs 49

51 1987/Broadview WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 50

52 1991/Broadview WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 50

53 1987/Firebaugh Canal WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 51

54 1991/Firebaugh Canal WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 51

55 1987/Pacheco WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 52

56 1991/Pacheco WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 52

57 1987/Panoche WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 53

58 1991/Panoche WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs 53

List of Appendix Figures

Appendix Figures — Appendix Page

1 Shasta & Oroville Dam Storage Levels as of December 31, 1981-1991 8

2 Selected CVP Canal Deliveries: 1981-1991 8

3 Friant Unit: Surface Water Levels and Groundwater Storage Changes, 1978-88 19

List of Tables

Table No.		Page
1	Farmland Transfer Estimates, 1979-1981 and 1986-1990	43
2	Chapter 12 Case Filings by Selected Farm Production Regions	44
3	Indicators of Financial Stress in Agriculture as Reported by Farm Banks, United States, 1985-1989 (in percentage)	45
4	Economic Indicators for California Agriculture 1988-1991	46

List of Appendix Tables

Appendix Table		Appendix Page
1	Summary Table of Water Sources and Fallowed Acreage	3
2	Broadview Water District Crop Acreage and Applied Water per Acre of Crop	4
3	Water Deliveries by Source	9-12
4	Steps Taken by the District in Response to the 1991 Drought	15
5	Number of Wells and Acre Feet of Pumped Groundwater Supplied by the District	16
6	Groundwater Pumping in CVP Sample, 1987-91	17
7	Westlands WD Water Use	17
8	Friant Unit Contract Water Availability and Groundwater Storage Change	18
9	General Characteristics of Sample, Irrigation Dealers	23
10	Steps Taken by Farmers in Response to the 1991 Drought	25
11	Broadview Water District Tiering Levels, Prices and Results, 1989-91	28

PART I: INTRODUCTION AND SUMMARY

Introduction

The purpose of this study is to address and evaluate the assumptions underlying the 1987 study, *Economic Implications of Regulating Agricultural Drainage to the San Joaquin River,* in light of recent developments. In particular, we attempt to review changes in water use practices, drainage management, and land use patterns that have occurred since 1987 in four San Joaquin Valley water districts: Broadview, Firebaugh Canal, Pacheco, and Panoche. In addition to the drought, local economic conditions have also been an important factor in affecting the behavior of water districts and farmers in the study area. Our analysis must also take both these factors into account when evaluating the original assumptions. Because the data in the four districts are not as detailed as hoped, the study has broadened its scope to look at some of the changes, both economic and as regards drainage, that have occurred in other parts of the state.

Building on the 1987 analysis and using available data from various sources to supplement that analysis, this report concentrates on water-conservation responses by evaluating changes in land allocation, drainage levels, and irrigation practices. At a more general level, the study looks at additional indicators such as on-farm changes in irrigation technologies, crop profitability, trends in deliveries to water district and their subsequent policy and capital program responses, and the financial health of the agricultural sector in the area. Much of this information has been gathered via a survey of agricultural producers, water districts, and irrigation dealers. We anticipate that more specific information will become available concerning the relationship between the ability of farmers to operate profitably and their ability to meet drainage quality requirements—this will allow an updating of the model developed in the 1987 report which formalizes this profitability/drainage relationship.

In order to put this analysis into context, it should be noted that the initial report was written in 1987 and used pre-drought data through 1986. The present assessment looks at what has happened since the drought began. Because cutbacks in Central Valley Project (CVP) water deliveries lagged behind the onset of the drought in 1987, crop prices maintained an important role in decision-making at the farm level. Because water was a critical input to agricultural production, water districts undertook water-conserving actions earlier, whereas the state and federal water projects, because their responsibilities are more conveyance-related, were somewhat slower to adjust. These actions helped alleviate some of the problems due to water scarcity in the early drought period but by 1991, the fifth year of the drought, the scarcity began making its full impact felt.

In addition to the impacts of the drought, the study also addresses to a degree the potential role of water markets by observing the success of tier-pricing programs (programs where use of water beyond some agreed-upon level requires payment of a higher price per unit of water) and by looking at the differential behaviors during the drought of water districts based on whether or not they have a secure supply of water.

These results have important implications for future drainage policies as well as water supply policies.

This study also addresses the importance of farm profitability in the success of drainage quality standards. This is done by evaluating on-farm changes in technology, the impact of credit constraints and the importance of crop profitability on changes in drainage quantity and quality.

By studying all these factors, this report should help the Regional Water Quality Control Board to better understand the impact of uncertainty and risk, land use patterns, and various economic conditions on farm-level response to drainage regulation. With this understanding, the Board can better regulate drainage quality in agriculture.

This report is organized into four sections. This section, Part I, introduces the report and summarizes its results. The second section, Part II, looks at the local farm economy and the specific stories of the four chosen water districts: Broadview, Firebaugh Canal, Pacheco, and Panoche. Part III addresses the general economic and financial changes that have occurred in the agricultural sector at the national and state level since the 1987 study; it also explores the impact of price changes and financial changes on the ability of farmers to absorb increases in drainage costs. The final section, Part IV, concludes the study and makes suggestions for further study. An appendix looks at the broader story by reviewing survey results of water districts and irrigation dealers throughout California; the section also looks at some of the available information about farm credit during the drought period.

Summary

The conclusions of this assessment on the responses to the drought include the following items:

- The principal response in terms of changes in irrigation technologies has been to shorten runs to a quarter mile and, in some cases, to use sprinkler systems for early irrigations.

- Irrigation efficiencies, as measured at the district level, have improved—probably as a result of better irrigation scheduling, more flexible district release policies, reduction of the amount of pre-irrigation, and increasing conjunctive use of groundwater.

- Groundwater use, through the first four years of the drought, was successfully used to supplement the shortfalls in water deliveries, thus allowing a smoother transition to modern irrigation technologies.

- Water is being more efficiently used by altering crop mixes toward crops with lower evapotranspiration levels and, more importantly, to higher value crops with a general movement out of field crops.

These measures have helped contribute to lower levels of total district drainage, but it must also be noted that the lack of precipitation and, subsequently lower runoff, also contributed to the reduction of total drainage. This makes it difficult to determine what is the specific contribution of changes in drainage practices and how much of the improvement in drainage reduction can be attributed to long-run economic rationality and conservation and how much can be attributed to factors beyond the control of agricultural producers and water districts. Movements to modern technologies such as drip irrigation require a long-term financial commitment on the part of the farmer and thus forces a long-run reduction in drainage levels. On the other hand, such actions as shifts in crops and changes in farm management are more prone to reverting back to the pre-drought situation once scarcity has passed. This is especially evident if, as anecdotal evidence seems to indicate, agricultural producers made changes as a response to water scarcity rather than the need to reduce the quantity and to better manage the quality of agricultural drainage.

The experience of recent years demonstrated the importance of institutional arrangements and economic policies and conditions in water management and conservation.

- The districts' response to the drought was affected by their water rights seniority. Districts with junior water rights (least water and highest water cost) were most likely to modify their technology and behavior during the drought while those with senior rights were much slower to adjust and, even then, did so incrementally.

- The use of differential water pricing (tiered pricing) by water districts was successful in inducing water-conserving behavior by farmers, did not increase their water cost much, and provided extra revenues for the district.

- Relatively high output prices and profitability of agricultural activities are essential for successful adjustment of agriculture for water quality regulation and water scarcity. The improved financial health of agriculture between 1988 and 1991 helped to promote the institution of conservation activities and eased the adjustment to the drought. Some of these adjustments might not have occurred during the less financially secure period of the early and mid-1980s.

PART II: THE LOCAL STORIES

Preface

This section looks at the specific changes, both economic and irrigation-related, that have occurred in the four water districts under consideration. First we look at the general farm economy, with respect to prices and production, encompassing the districts in order to provide an economic background in which to evaluate the changes in irrigation and drainage. By doing so, we can begin to determine how much the farm economy was affected by drought and how much was exogenous to the drought—both of which have implications with respect to drainage policy. Next, we look at the specific drainage-related changes that occurred within each of the four water districts.

We will see that the drought has caused dramatic reductions in water use in three of the four districts. The reason for this is that, while many of the districts rely heavily on CVP water delivery, they were among the first to have their deliveries cut back. This has caused farmers in these same districts to be among the first wave of agricultural producers who introduce new irrigation management techniques and technologies into their production. One of the principal results of this is that the drainage quality target levels have been met on most occasions.

The Farm Economy

An important change of context for agricultural drainage issues is the general improvement of the agricultural economy since the writing of the 1987 study. The general credit crisis of agriculture during the mid-1980's has largely dissipated and the agricultural economy is much healthier than it was, the present recession notwithstanding.

Any extended period of dry weather will have a constraining effect on agriculture, but evaluating its impact requires investigating a broad range of issues. The first logical issue is water availability. Given the nature of water collection and delivery in California, an agricultural producer depends on local precipitation, local groundwater, and delivered irrigation water (which, in turn, depends upon precipitation outside the production area). The total availability of water and the make-up of the sources of the water supply influences the nature of drainage issues in that continued dry years lead to drawing down of reservoirs and less flexibility in maintaining irrigation levels and fulfilling water contracts. This engenders greater dependency on groundwater pumping and, ultimately, leading to increasing conflict with urban water users over the allocation and quality of the scarce water resource.

Over the past decade, the onset of the drought might be characterized in two stages: decreased rainfall in the study area followed later by decreased precipitation in the areas which are the sources of most delivered irrigation water. The first stage is demonstrated in the annual rainfall levels at the Shasta Dam in Figure 1. This more stochastic source of water first showed low levels in 1984, three years before the official

start of the drought. The second stage is decreased precipitation elsewhere, measured with the proxy of CVP deliveries to Broadview Water District from 1987 to 1991 (the last year being an estimate) in Figure 2[1]. This figure indicates that the drought did not first affect agriculture (in the form of substantially decreased water deliveries) until 1990.

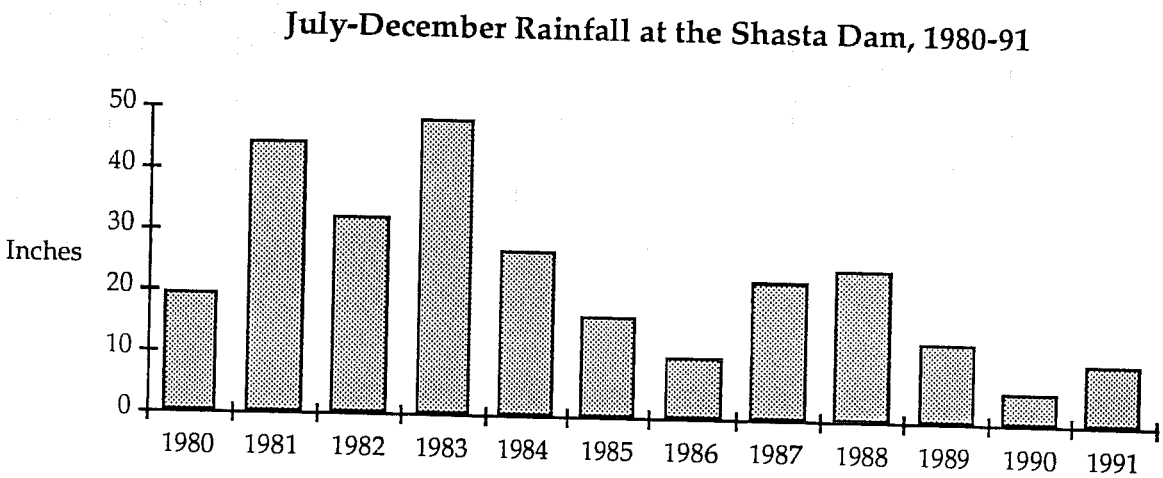


FIGURE 1

Source: USBR, Central Valley Operations Coordinating Office, *Report of Operations* (annual).

[1]Although the first impact is not seen until 1990, the first official drought year was 1987.

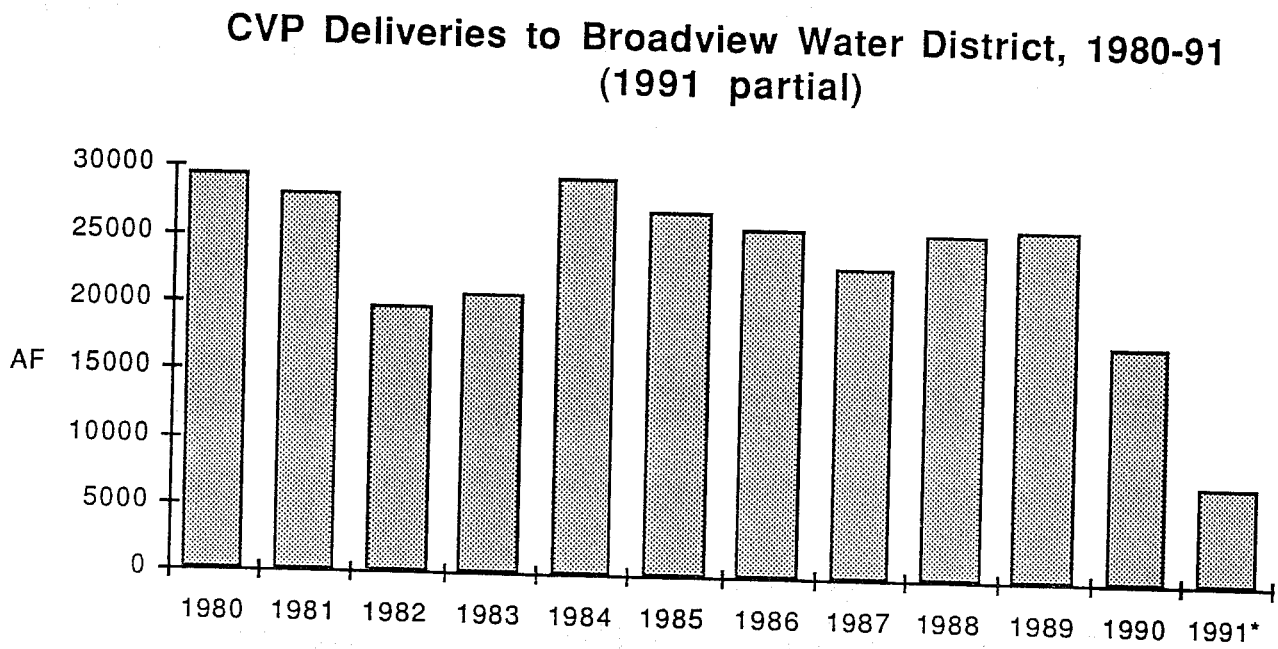


FIGURE 2

Source: Broadview Water District Drainage Operation Plans.

Responses to decreased water availability can include changes in irrigation practices and cropping patterns, e.g. moving to more efficient (and water-conserving) irrigation scheduling and irrigation technologies and shifting out of less water-demanding crops. Additional constraints to changing practices and technologies, though, are crop prices and levels of government support programs.

Since crop prices (and our proxy, unit crop values) are generally exogenous to a regional water situation (assuming a competitive national market), a crop with a very high value in the market and very high water needs may still continue to be produced, even in a drought situation. The situation may also warrant a move towards investing in more advanced and water-conserving technologies. Although specific crops will be discussed in the individual water district descriptions, Figures 3 through 9 below present the general movement of per unit values for the principal crops dealt with here. The choice of Merced County was based on its inclusion of or proximity to the four water districts under study and because the county data separated out actual production payments from government payments.

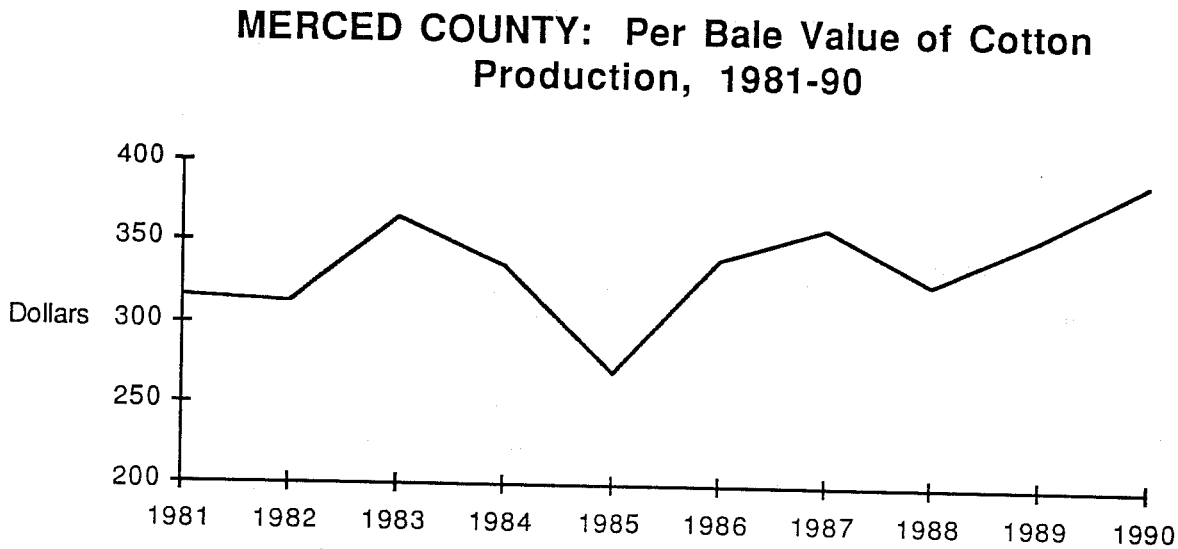
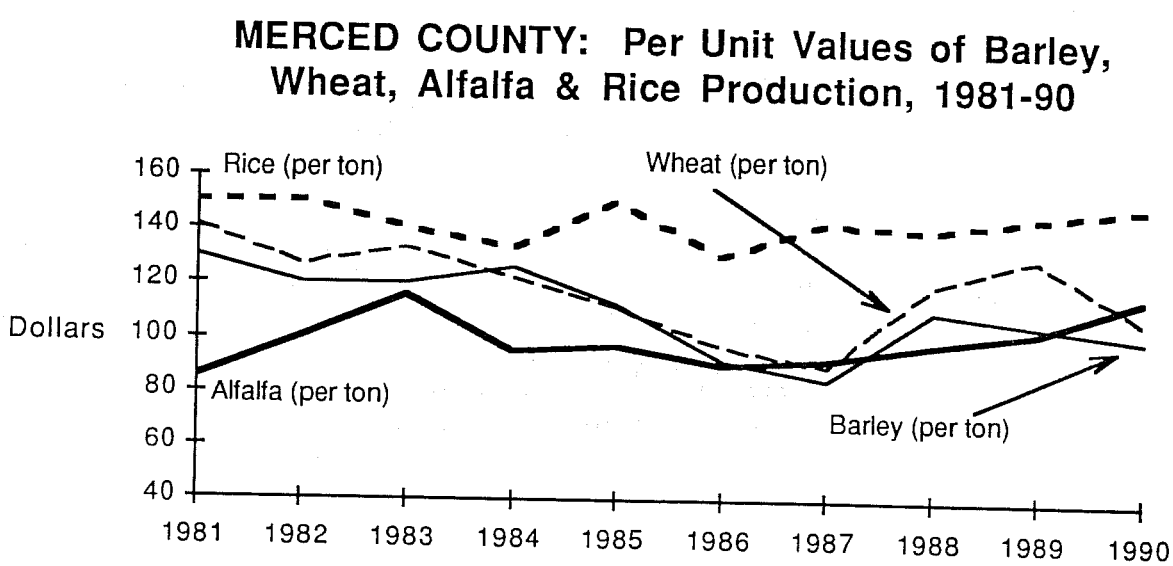


FIGURE 3

Source: Merced County Agricultural Commissioner's annual reports.



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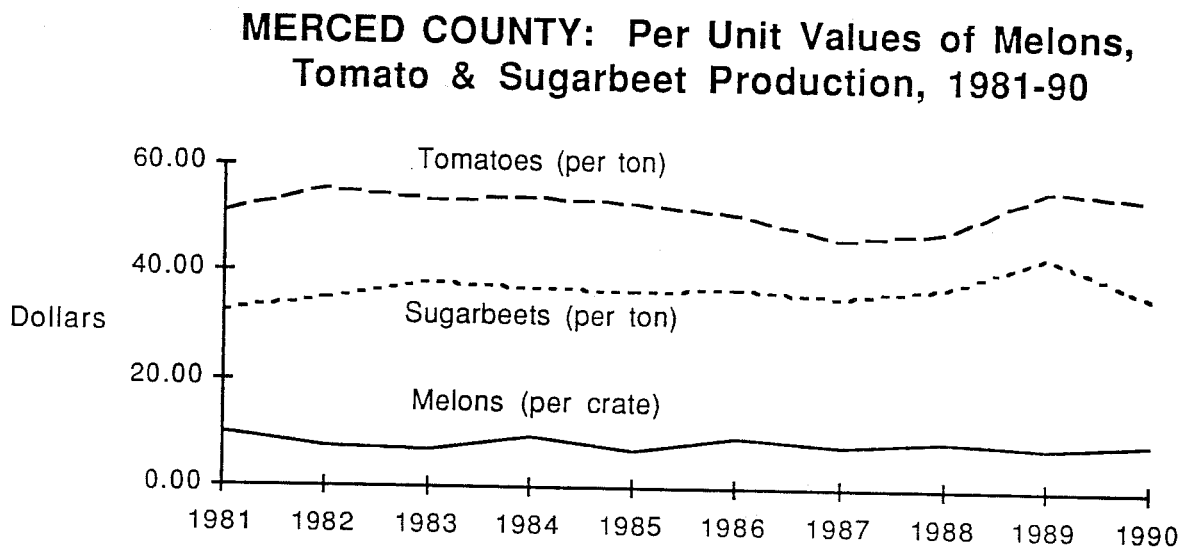
Source: Merced County Agricultural Commissioner's annual reports.



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Source: Merced County Agricultural Commissioner's annual reports.

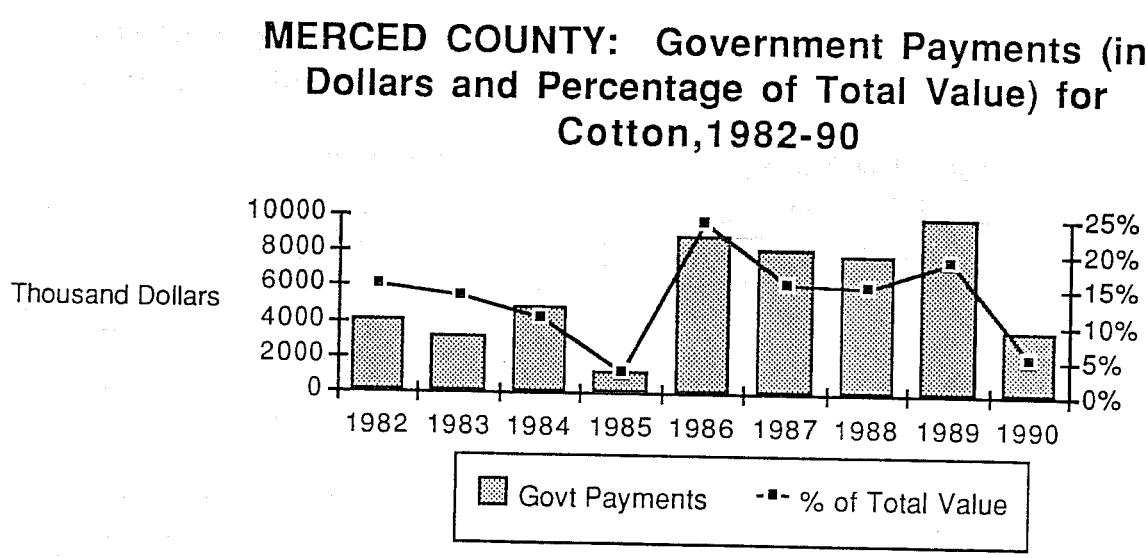
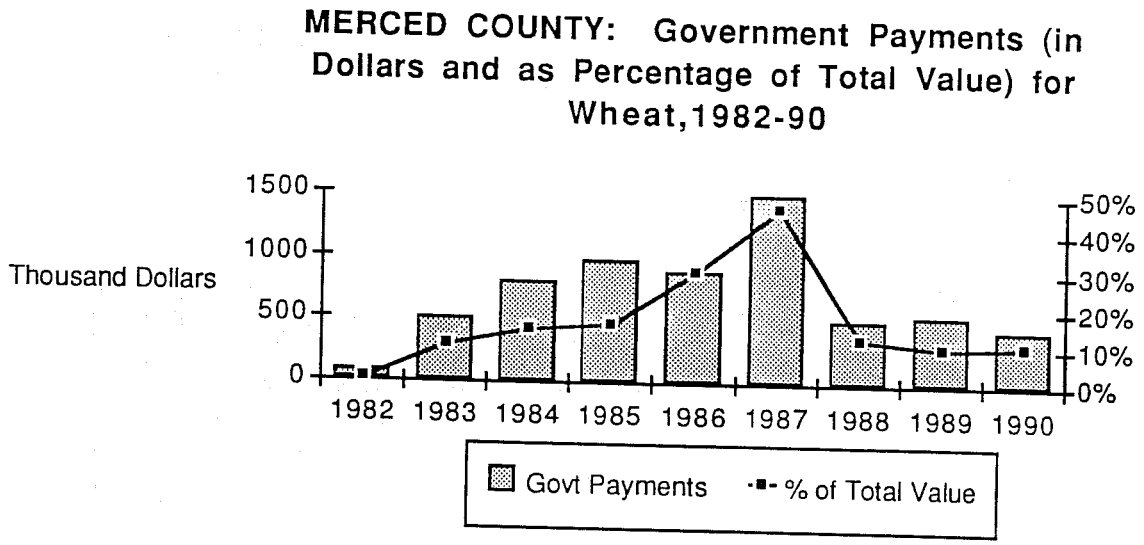


FIGURE 6

Source: Merced County Agricultural Commissioner's annual reports.



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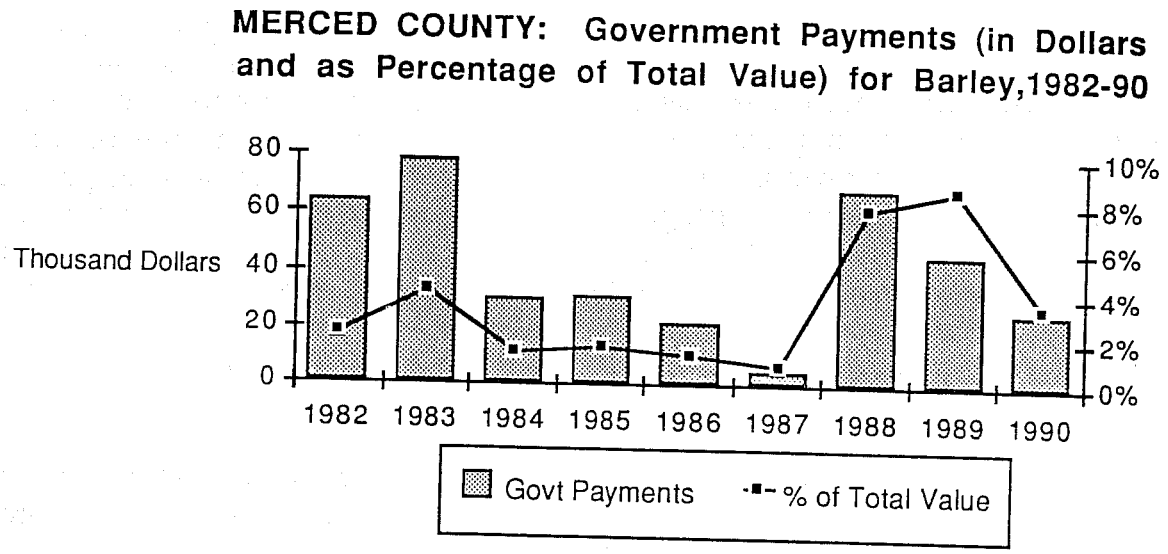
Source: Merced County Agricultural Commissioner's annual reports.



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Source: Merced County Agricultural Commissioner's annual reports.

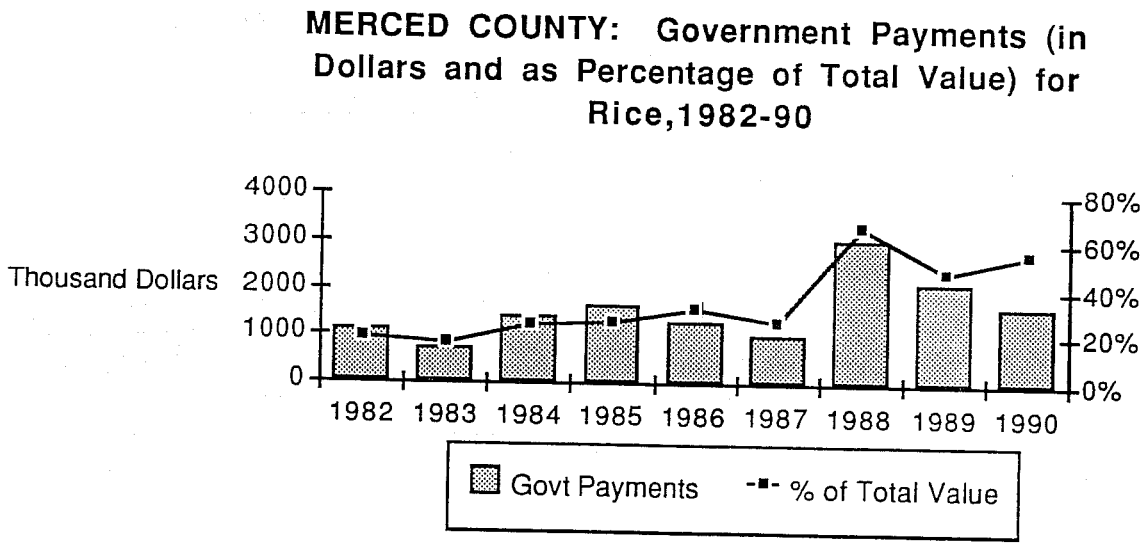

FIGURE 9

Source: Merced County Agricultural Commissioner's annual reports.

In looking at crop prices and government commodity programs, it is important to understand some basic mechanisms and interrelationships. First of all, one could expect that, if a commodity price was sufficiently high or rising particularly fast, it could negate any movement toward water conservation or acreage reduction with respect to that specific crop, even if it was very water intensive. Second, because government payments depend on price, we should see behavior that is the obverse of price movement. Lower government payments are indicators of improving price and lower participation in government programs may be associated with larger crop acreage—as long as water is available. In addition, if crop acreages are increasing, there is less need for crop set-asides. So, the combination of price movements with government commodity programs, while stabilizing farm income, may also set a bound on movement in and out certain crops—an important consideration when one is trying to determine future water use and irrigation changes.

For the period 1981-1990, cotton showed the greatest variability in per unit value with peaks in 1983 and 1990 and a trough in 1985. Looking at the chart of government payments, we also see that the amount of government payments varied in absolute level (between $1.2 million and $9.9 million) and as a percentage of total value (between 3% and 24%). Melons, tomatoes, and sugarbeets were generally quite stable whereas grains such as barley, wheat, and alfalfa demonstrated more variability. What all these crops have in common is that the unit values rose in the first drought year of 1987, the opposite of cotton values for the same year. Government payments for wheat and barley showed fluctuations in both value and percentage during the period, although wheat showed an upward trend in payments and percentage from 1982 to 1987 and a downward trend afterwards. Since the 1987 drainage study (which used the

price data of 1986), we see that prices have generally been rising for cotton, rice, and alfalfa—all high water-demanding crops—while prices for barley, wheat, melons, tomatoes, and sugarbeets have shown no consistent upward or downward trend.

In addition to the government payments paid via traditional commodity programs, other programs such as the Payment-in-Kind (PIK) program also can play an important role in determining cropping patterns and water use. In the case of the PIK program—which was a one-time measure aimed at drastically reducing government food inventories—acreage was removed from the production of certain crops and farmers are given coupons for equivalent amounts of the commodities. In 1983, the PIK program succeeded in taking 40% of PIK cotton acreage, 36% of PIK wheat acreage, and 46% of PIK rice acreage out of production. In spite of the reduction in cropped acreage, there was no reduction in the amount of water delivered. As a result, there was more water applied per hectare which resulted in less output per unit volume of applied water—thus lowering irrigation efficiencies. Because most water districts and farmers pay a flat fee for their water rather than by the individual unit value (much as we pay for most things in a market setting), they are delivered the same amount of water regardless of how the water is distributed among the crops.

In addition to environmental and market constraints, the response to the drought situation is also constrained by existing institutions. Water delivery and use for agriculture can be dealt with at three different levels: the state and federal water authorities, the water district, and the farmer. It would be fair to say that, in California, the state and federal water supply agencies have traditionally been more concerned with macro-supply policies, e.g., distribution of water deliveries through the dam and aqueduct system and addressing overall quality and drainage problems. Likewise, it has generally been up to local districts—which are run by the farm-level water users—to deal with micro-management issues such as conservation and irrigation technology choice. Although these state and federal agencies now have legislative mandates to actively promote conservation among water users, the lack of strict guidelines and follow-ups by these authorities have resulted in slow and uneven progress.[2] The result of the mix of institutional responsibilities is that there are no consistent incentives for conservation throughout the water supply system. Of course, sorting out institutional issues such as these are inherently complex and, thus, are open to broad interpretation. Nonetheless, the above characterizations do fit the present reality.

Since water districts are organized as no-profit agencies governed by boards elected by water-users (generally farmers), they are motivated by cost considerations and are responsive to their members. Adoption of conservation measures, whether technology- or management-based, are subject to what makes economic sense—if water costs are low and the supply is assured, then there is little economic sense in making

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[2]For example, the state has provided funding for investments in irrigation technology and canal improvements at the district-level (Assembly Bill 36.16 and Proposition 65), but the administrative demands these funds make on the districts have made them unattractive.

costly investments. When a change in conditions, for example, an increase in water scracity due to a drought reduces the availability and increases the effective price to farmers, then water districts are more likely to make the capital and management investments that will increase profitability. In general, those districts that have dealt best with the drainage problem are those with the smallest per acre surface water availability. Such districts have the political authority (farmer agreement) and economic motivation to address their problems.

At the farm level, changing irrigation technologies are often seen as the way to address the drainage situation. However, research has shown that, because of high fixed and variable costs of new technologies, an economic environment of high water prices and high crop prices is necessary.[3] These changes must also show permanence over time so that the technology changes are allowed to occur over time (since existing irrigation technologies on the farm must be allowed to depreciate).

In the next four sections we review the experience of the four water districts. We begin each district story with a look at estimated irrigation efficiencies over the past few years. Data on irrigation efficiencies for the four districts discussed in this study were taken from a report by Charles M. Burt, Peter Canessa, and John Parrish (hereon referred to as the Burt report)[4]. Because of the scarcity of on-farm data, their irrigation measures are district-based. In addition to irrigation efficiencies, we look at changes in district policies, farming practices (which include cropping patterns and irrigation management and technology), and drainage releases that have occurred in the districts.

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[3]See, for instance, Dinar and Zilberman, "Effects of Input Quality and Environmental Conditions on Selection of Irrigation Technologies," in *The Economics and Management of Water and Drainage in Agriculture*, Dinar and Zilberman, eds., 1991; also see, Caswell, Lichtenberg, and Zilberman, "The Effects of Pricing Policies on Water Conservation and Drainage," *American Journal of Agricultural Economics* (November, 1990).

[4] Charles M. Burt, Peter Canessa, and John Parrish, *Irrigation Efficiencies in Parts of the Selenium Drainage Area of the West Side of the San Joaquin Valley, with a Focus on Water District Irrigation Efficiencies* (draft), April, 1991.

The Broadview Story

Irrigation Efficiencies

The Burt report indicates (see Figure 10) that district-based irrigation efficiencies (using two-year moving averages) declined from 1981-82 to 1983-84 with steady increases beginning with 1984-85 through 1988-89. The nature of these measures are such that they impute the contribution of groundwater and give very sketchy estimates of pumped groundwater [Although, in the case of Broadview, groundwater plays a minor role in contributing to irrigation.] This would indicate that the efficiencies reported are probably not very robust as indicators of conservation.

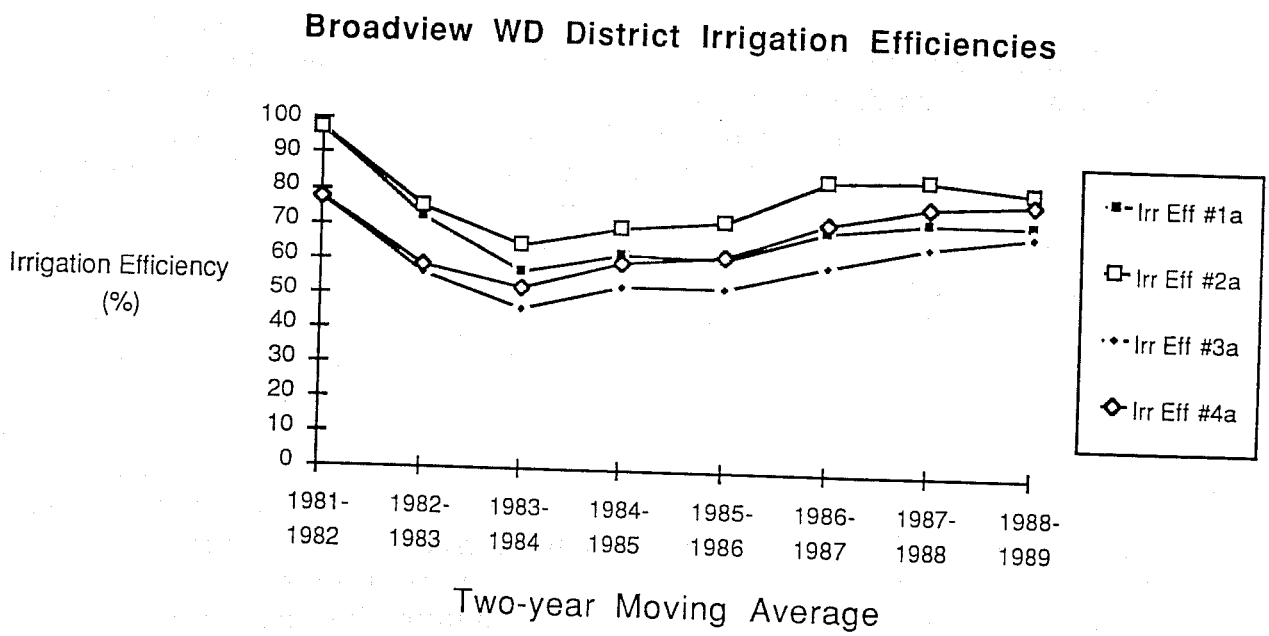

FIGURE 10

Source: Charles M. Burt, Peter Canessa, and John Parrish, *Irrigation Efficiencies in Parts of the Selenium Drainage Area of the West Side of the San Joaquin Valley, with a Focus on Water District Irrigation Efficiencies* (draft), April, 1991.

With the rainfall and CVP deliveries in Figures 1 and 2 in mind, we see that the decline in local rainfall beginning in 1984 did not seem to affect the upward trend of irrigation efficiencies in Broadview that began in 1983-84. The dip in irrigation efficiencies around 1983-84 reflects the fact that 1983 was a PIK year in which an unusually large amount of acreage was taken out of production creating much more fallow land. This resulted in lower total water requirements coupled with the same amount of delivered (applied) water creating low irrigation efficiencies. Since the time of our earlier report (which used data up to 1986), efficiencies have tapered off. It

should also be noted that the efficiencies do not cover the period after 1990 during which the drought began to show greater impact.

Changes in Crop Acreages and Crop Water Requirements

In terms of acres, the principal crops in Broadview are cotton, wheat, barley, and seed alfalfa, with cotton generally accounting for about half the total acreage (see Figures 11 and 12). Of these crops, cotton and seed alfalfa have very high evapotranspiration levels—about twice those of wheat and barley. Post-1986 levels of cotton acreage are generally below those of the pre-1987 levels, but they do show a trend of increasing acreage beginning in 1987 (possibly reflecting the general increase in prices) with a slight dip in 1990 until falling substantially in 1991 due to cutbacks in water deliveries. Seed alfalfa's drought period acreage is generally above pre-1987 levels until 1990 and 1991 when consecutive substantial acreage declines occurred. The less water-demanding crops, wheat and barley, show a little more variation. Wheat shows lower acreage levels after 1987 with a spurt in 1990 in spite of rising unit values from 1987 through 1989. Barley's acreage is lower from 1987 to 1989 than the period prior 1987 but acreage increased significantly in 1990, all in the context of declining unit values since 1988. But, again, with substantial cuts in water deliveries in 1991, wheat acreage was reduced by 66% and barley production ceased. With the first water cutbacks in 1990 and 1991, we see a consolidation of acreage into cotton, tomatoes, and seed alfalfa combined with acreage in very water demanding crops such as barley, soybeans, and wheat being reduced or completely removed, all with an increase in fallowing.

Since crop acreage does not fully represent water requirements of crops, new graphs (Figures 13 through 16) representing total water requirements (based on acreage and evapotranspiration requirements) were created using data from the Burt report referenced earlier. The total applied water requirement (for crop growth) were calculated for each crop. This was done by multiplying the net water requirement per acre[5] by the number of acres to the crop. These graphs indicate that some crops, like tomatoes, sugarbeets, and melons, while not having many acres allocated to them, do have high total water requirements.

[5]This equals the unadjusted ETc plus net leaching (to maintain salt balance) less effective precipitation (reflecting that level of precipitation which is actually used by the plant) less the net external groundwater contribution (reflecting a high water table due to migration of groundwater from **outside** the district).

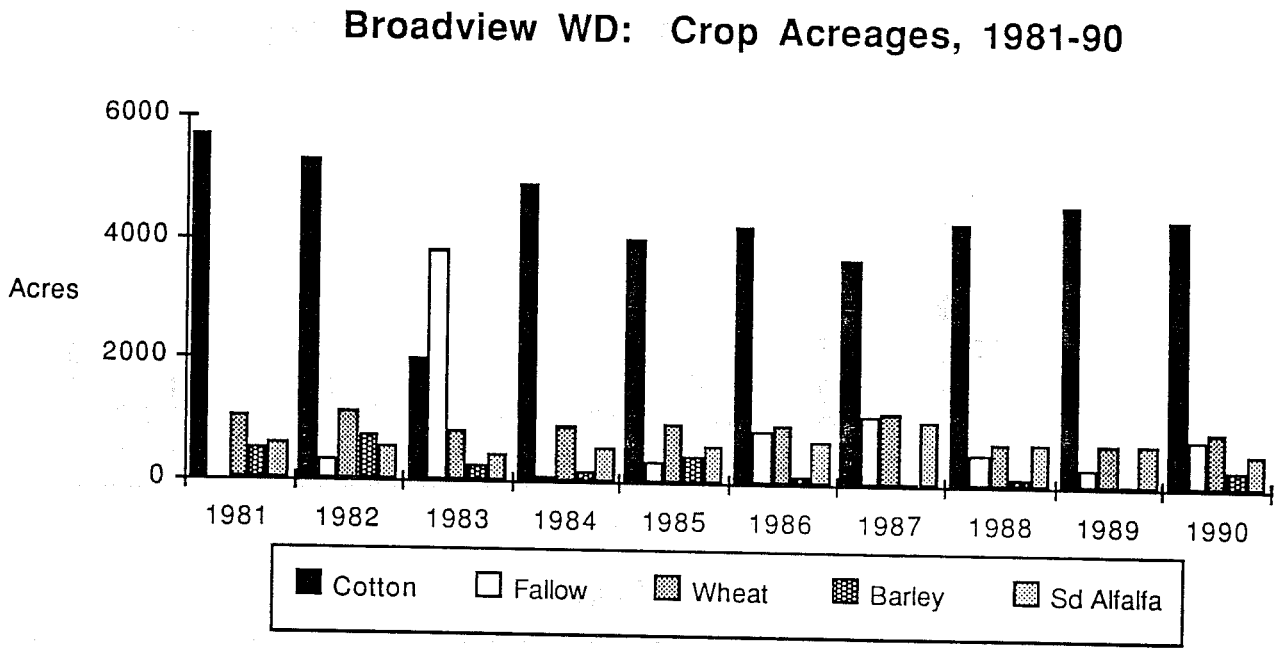

FIGURE 11

Source: Broadview Water District Drainage Operation Plans.

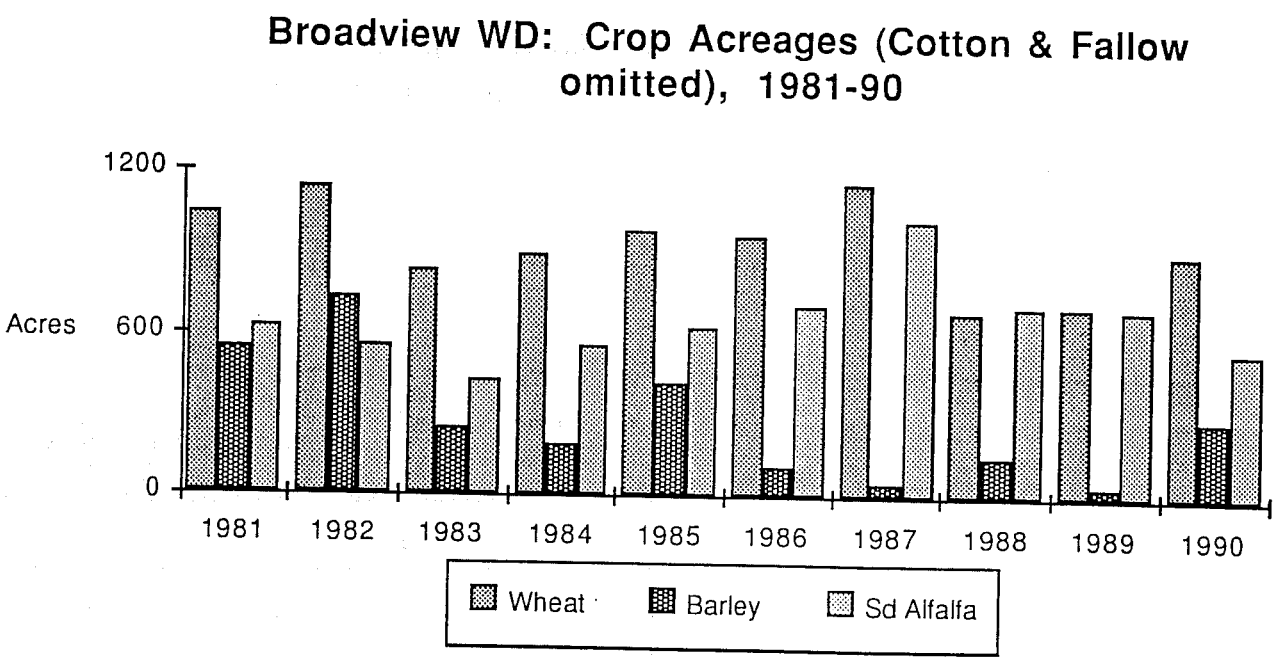

FIGURE 12

Source: Broadview Water District Drainage Operation Plans.

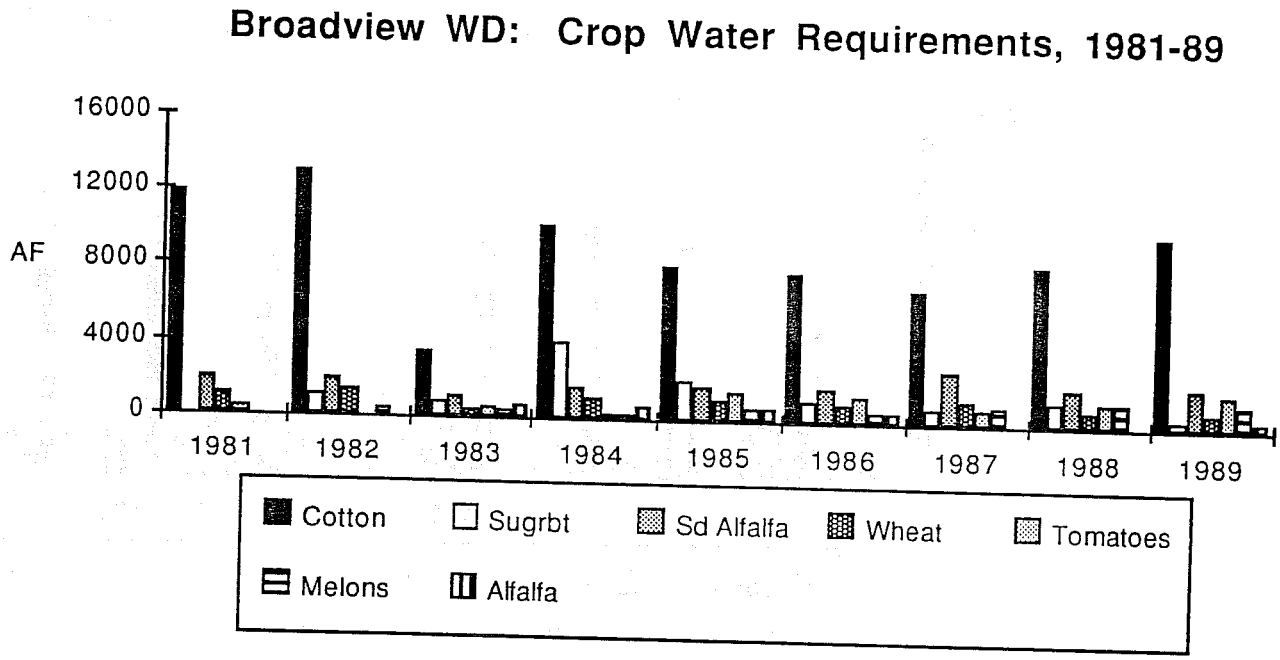

FIGURE 13

Source: Burt, Canessa, and Parrish, *op. cit.*

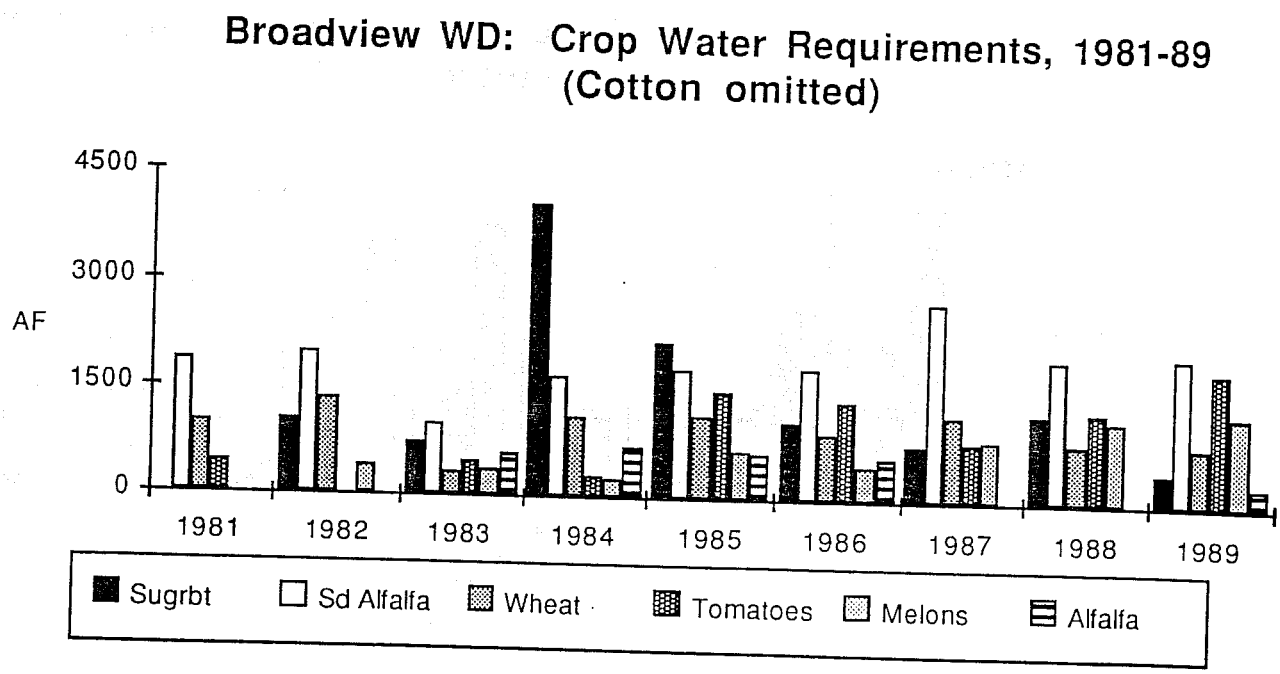

FIGURE 14

Source: Burt, Canessa, and Parrish, *op. cit.*

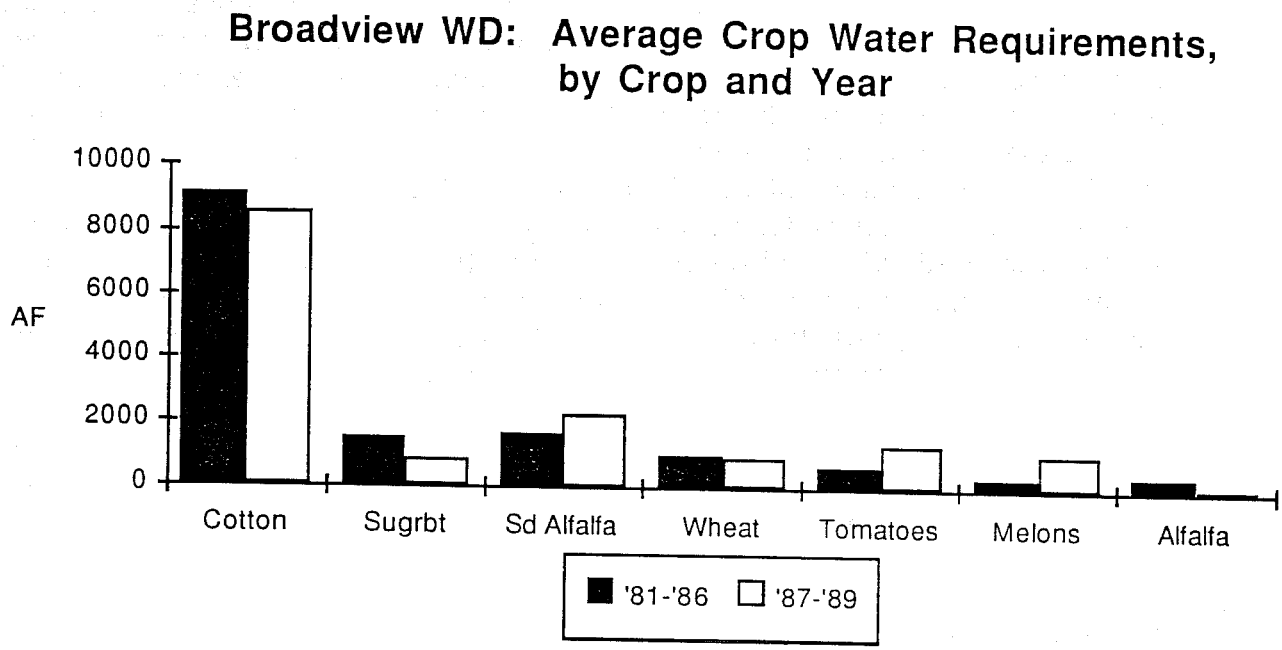

FIGURE 15

Source: Burt, Canessa, and Parrish, *op. cit.*

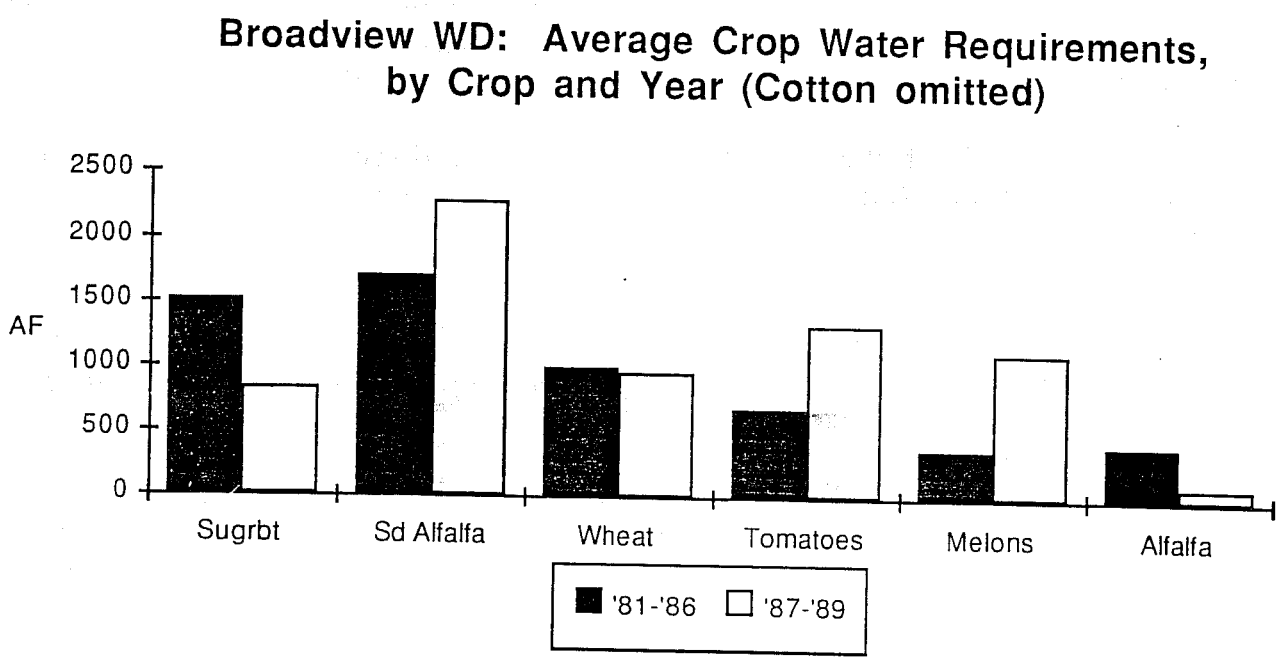

FIGURE 16

Source: Burt, Canessa, and Parrish, *op. cit.*

Because of its high evapotranspiration and high acreage, **cotton** is by far the largest user of water. The trend during the drought (and since the last study) is an increasing one beginning from 1987, although they are still below the pre-drought levels (excluding the 1983 outlier). **Seed alfalfa,** on the other hand, generally shows higher total water demands during the drought period than prior to the drought—this reflects the increased acreage to seed alfalfa. [It has been noted by Harley Davis (Land and Water Use Analyst of the Central Valley Regional Water Quality Control Board) that seed alfalfa uses water very efficiently in actual production and that deliveries to seed alfalfa production will often be less than the theoretical crop requirement.] Of the remaining crops, many of which appear highly variable, **tomatoes** and **melons** manifest higher water demands during the drought than prior to the drought. A reason for the increased tomato acreage and water usage can be traced to its sensitivity to salt. Prior to 1983, the district had to blend drainage water with contract water for some of its irrigation water. Such a blend is higher in salt than the pure contract water and is harmful to tomato production. The creation of a new outlet in 1983 allowed increased CVP deliveries which engendered a significant increase in tomato production.

Water Deliveries and Drainage

Without specific data, little can be said about the accuracy of the irrigation efficiencies discussed earlier. On the other hand, we can draw some conclusions about efficiency in the use of water by examining the data on water deliveries and drainage. As mentioned earlier, the first significant drop in local rainfall occurred in 1984 followed by the broader drought beginning in 1987. The increase in deliveries in 1984 (Figure 17) reflects the new drain outlet that Broadview received in 1983 which allowed an increase in CVP deliveries. Deliveries decreased from 1984 and even increased in 1988—after the onset of the drought—but fell substantially in 1990 and 1991.

Looking at the average monthly water deliveries for the pre-drought and drought periods (Figures 18 and 19), it is apparent that there was a shift in water deliveries. July through December of the drought period showed decreased delivery of water, both absolutely and proportionally.

A better indication of the water situation would be to investigate the drainage levels during the drought period for increase in conservation and efficiency. Looking at the annual levels of total drainage (Figure 20), we see that the total drainage volume (both surface and subsurface) has decreased significantly since 1987 with another significant decrease in the first year of water delivery cutbacks in 1990 and again in 1991. To a lesser degree this is the case (Figures 21 and 22) when only looking at the subsurface tile drainage until two consecutive years of water delivery cutbacks significantly reduced it.

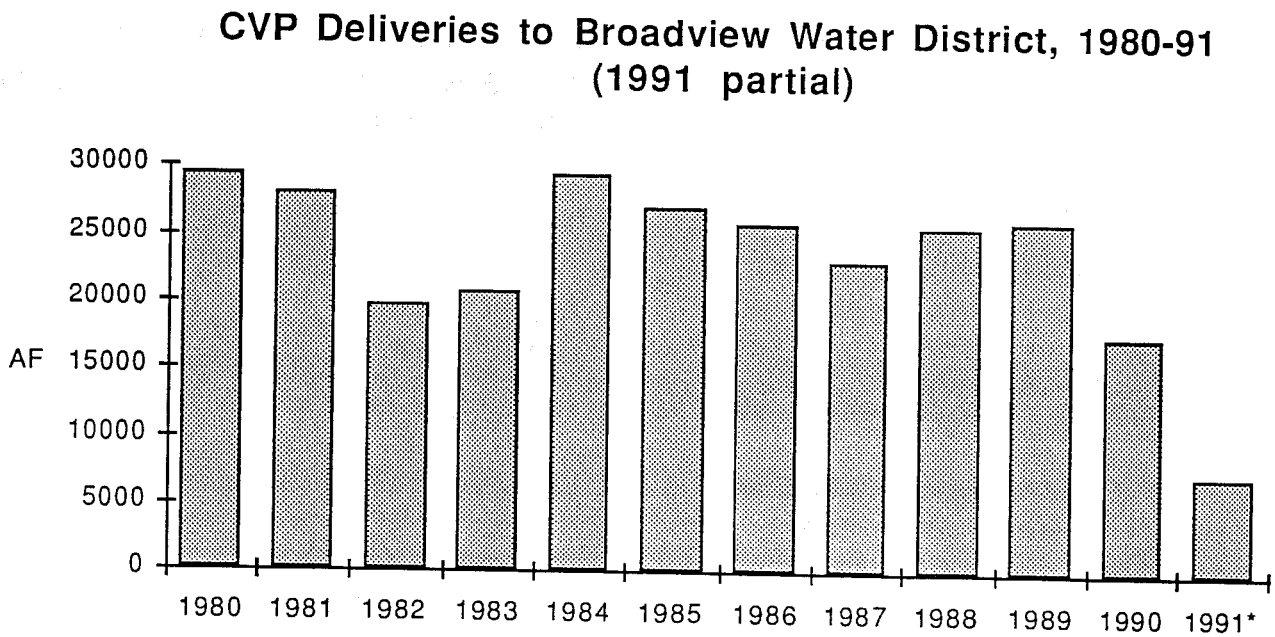

FIGURE 17

Source: Broadview Water District Drainage Operation Plans.

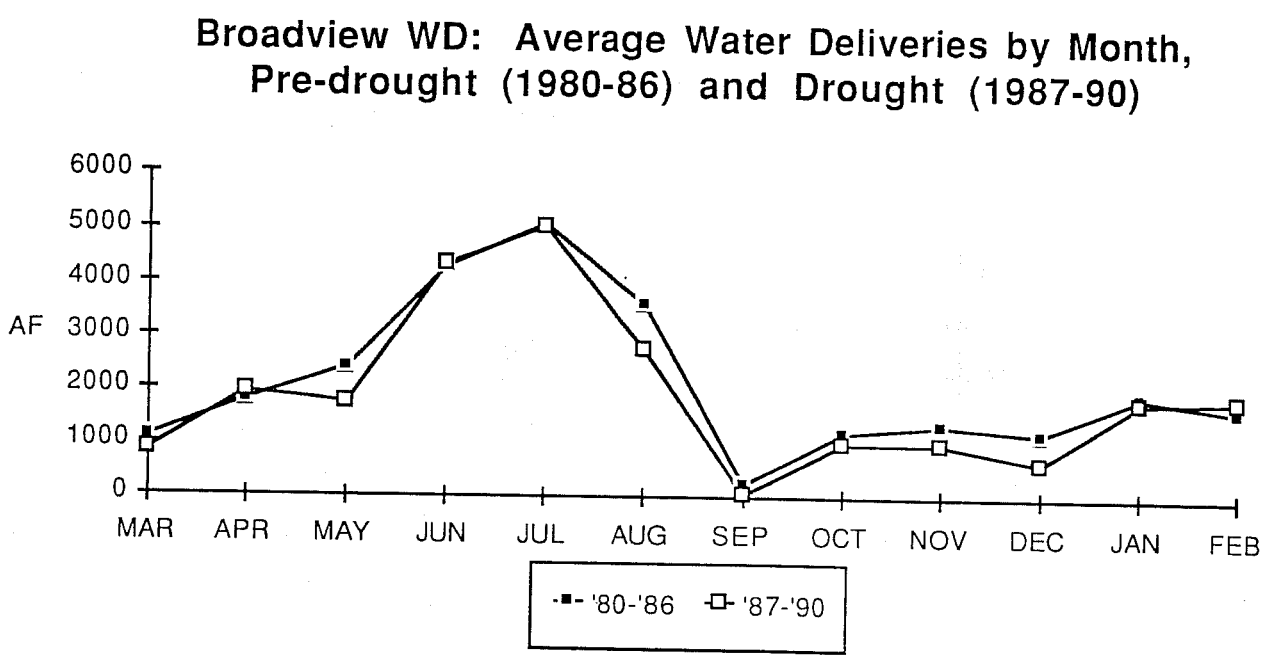

FIGURE 18

Source: Broadview Water District Drainage Operation Plans.

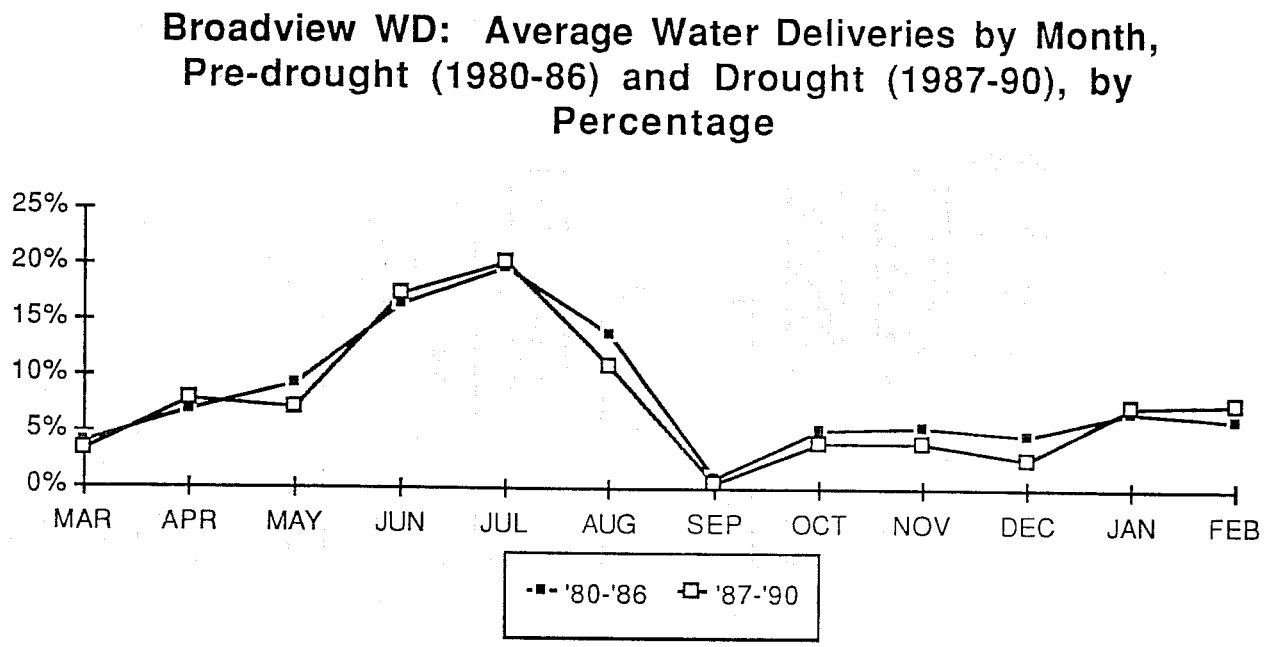

FIGURE 19

Source: Broadview Water District Drainage Operation Plans.

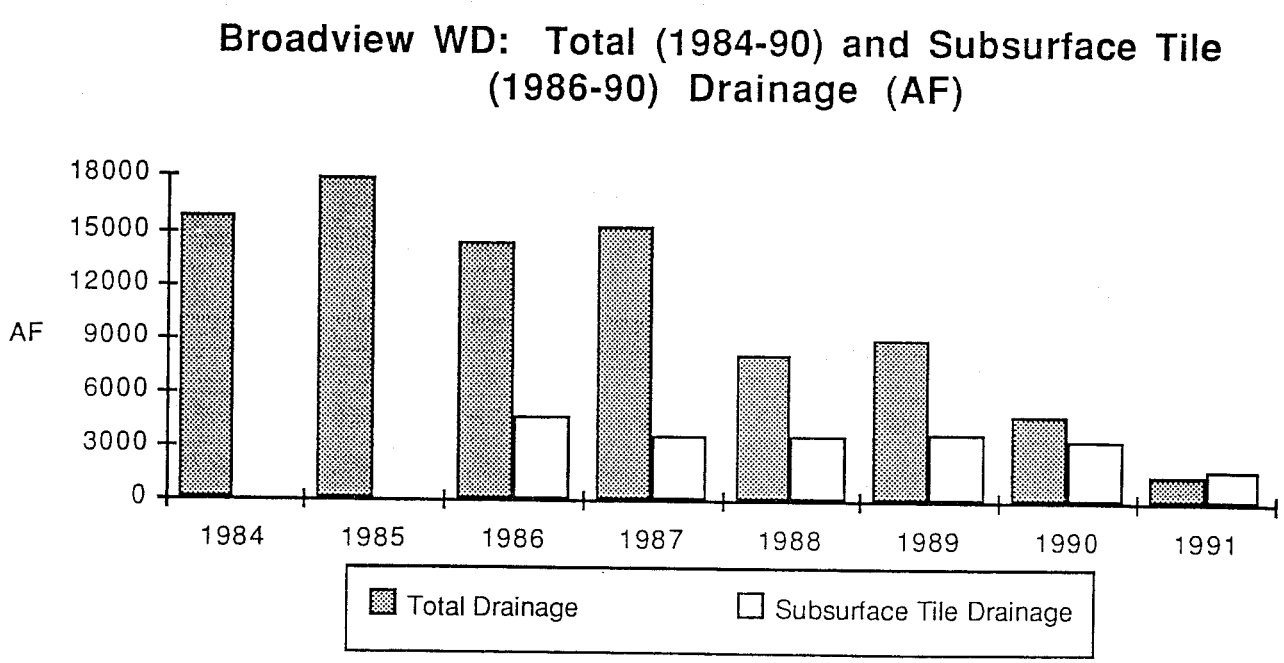

FIGURE 20

Source: Broadview Water District Drainage Operation Plans.

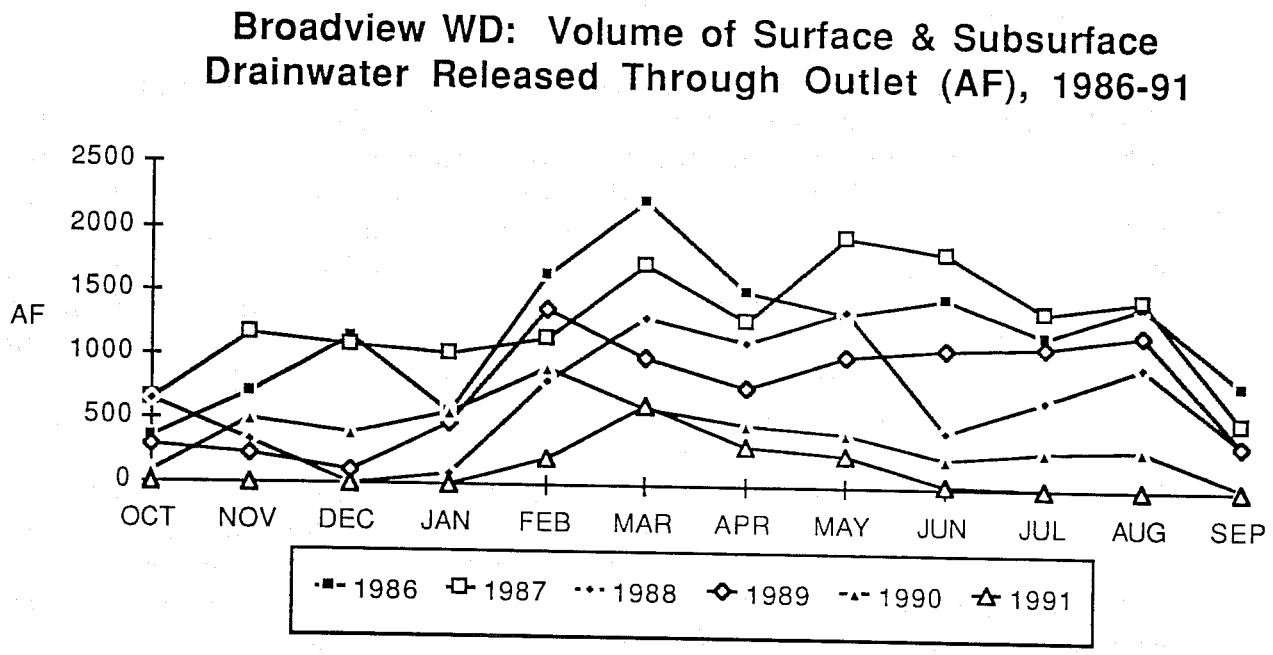

FIGURE 21

Source: Broadview Water District Drainage Operation Plans.

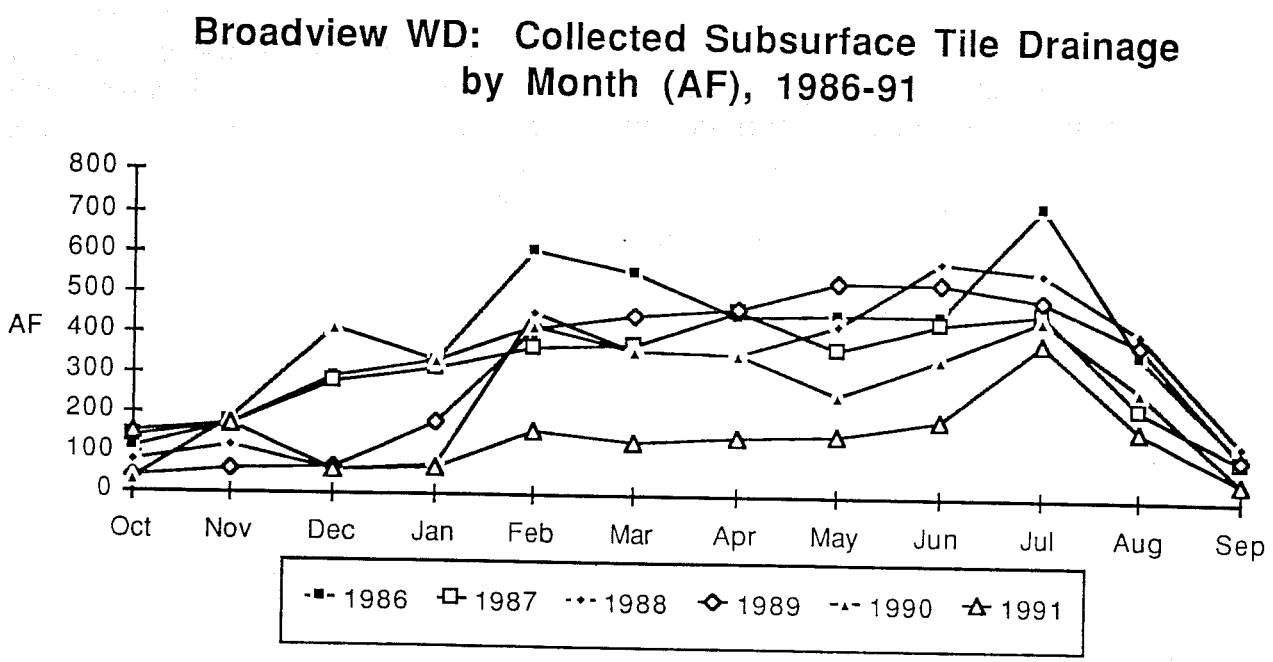

FIGURE 22

Source: Broadview Water District Drainage Operation Plans.

Looking at the month-by-month breakdowns of the two categories, there appears to be general smoothing of drainage patterns.

A number of changes in behavior in Broadview would seem to explain much of the changes outlined above, according to the district's Drainage Operation Plans (DOPs), other district documents, and personal communication. At the district level a tiered water pricing program was instituted in 1988. This program created two price tiers of $16 per acre foot and $40 per acre foot. The amount of water available for the first block of each crop covered was set equal to 90% of the average district application rate for each crop for the period 1986 through 1988. The crops (with the tier cut-off in acre feet per acre) include cotton (2.9 AF/A), tomatoes (2.9), melons (1.9), wheat (2.1), and barley (1.7). In 1989 the program succeeded in reducing average water deliveries to three crops by 10%. There was less success than expected mainly because, by the time the second tier price went into effect, farmers were already locked into a certain level of water use for their final irrigation. After 1989, average irrigation depths fell below the tiers, although much of the reason may be laid to the fact that less water was available. Cotton and melons showed significant and consecutive falls. By 1991, when irrigation water was quite scarce, all crops were below the tiers. In 1991, of 47 fields in the district, only 7 exceeded the tiering levels. Because of the program's effectiveness, the district is considering extending the program to the pre-irrigation of cotton.

In addition, a more flexible policy of water turn-ons and shut-offs was initiated so that farmers had a little more control over the timing of water deliveries. One constraint is that the flexible policies involve more staff resources which are strained as the drought continues. The district has also hired a water conservation coordinator to develop education and training programs for growers which may also have contributed to the reduction in drainage. Broadview has also been recycling its drainage water to the point where it comprised about 18% of its total irrigation water in 1988 and 1989. In 1991 the district allowed grower-to-grower transfers and also saw increased inter-district water transfers, but with continued water scarcity, Broadview's water prices are rising to $90/AF for CVP water and up to $200/AF for water from other sources. Finally, Broadview meters all water delivery, keeps track of irrigation water delivered to specific crops and has a regular system of sampling irrigation water quality. For the longer term, Broadview is undertaking the monitoring and management of shallow groundwater for crop watering and trying to distinguish qualities of groundwater at varying depths.

Farm Practices

Since 1988, there has been a strong shift towards shortened (1/4 mile) furrows as a means of increasing irrigation efficiency. According to the DOPs for 1988 through 1990, 90% of irrigated cotton has less than 1/4-mile furrows, 100% of tomato and melon irrigation had runs less than 1/4-mile (many were 1/6-mile), and 87% of grain fields had runs of a 1/4-mile or less. In addition, 28% of the cotton fields are irrigated in alternate furrows from some water applications, most of the cotton irrigation set times were reduced to 12, hours and over 70% of the tomato fields were irrigated with

sprinklers for the first two irrigations. Pre-irrigation of cotton has also been reduced by farmers since 1987, going from 1.09 AF/acre to 0.99 AF/acre in 1991.

Another important development is the $1.5 million district loan program for the purchase of sprinkler and gated pipe irrigation systems that will be leased to water users. Sprinkler irrigation is presently used on all tomato fields and 1 of 2 wheat fields. The increased use of sprinkler systems is considered an irreversible technology change and should thus lead to a permanent improvement in technology.

As mentioned above, recycled drainage water is of increasing importance with 18% of total irrigation water being recycled in nature. Part of the need for recycling grew out the fact that contract irrigation needs might not have been met otherwise and that, sometimes, the level of drainage was greater than the outlet capacity. The DOPs also mentioned that, if a gravity canal system from the San Luis Canal was implemented that there would be no more district managed recycling and that all farms, as a result, would be required to have on-farm recycling. Unfortunately, broader political difficulties are forcing the postponement of initiating the gravity irrigation system and thus holding up the on-farm recycling requirement.

The manager of the district has said that the primary motivation for many of the changes in on-farm practices and drainage management has been the increasing cost of water rather than concern about drainage issues.

The Firebaugh Canal Story

Irrigation Efficiencies

The Burt report indicates that irrigation efficiencies in the Firebaugh Canal Water District have generally been increasing during the drought period but starting from a relatively low level (Figure 23). The lack of data with respect to water deliveries and drainage make it difficult to explain the movements, although the dip for 1987-88 does coincide with the official start of the drought.

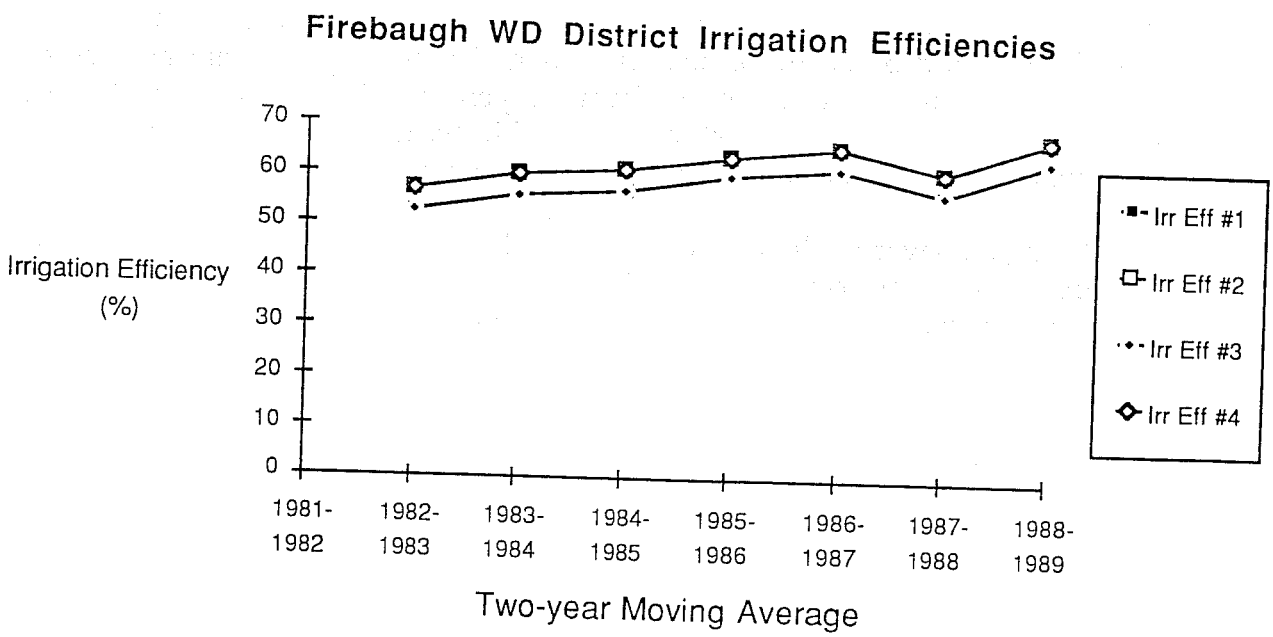

FIGURE 23

Source: Burt, Canessa, and Parrish, *op. cit.*

Changes in Crop Acreages and Crop Water Requirements

Changes in crop acreages, and in subsequent crop water requirements, were apparently influenced to various degrees (depending on the crop) by changes in crop prices (as represented by the unit values of crops discussed in the earlier section). Because acreage decisions are made at the beginning of the agricultural year, the prices received for the previous year's harvests play an important role in allotting acreage among crops—thus we see a lag in acreage response to price. As a result, we will also see crop water requirements lagging behind crop prices.

Independent of the drought, **cotton** production (Figure 24) moved with a one period lag with respect to per unit values of production (Figure 3). Looking at the per unit value declines in 1984 and 1985, there were subsequent cotton acreage reductions in 1985 and 1986, respectively. With the increases in per unit values in 1986 and 1987, there were subsequent acreage increases in 1987 and 1988, respectively. Finally, a unit value decline in 1988 caused an acreage decline in 1989. Although other crops do not all follow the unit value changes, the fact that the value swings were substantial probably made acreage more sensitive to value changes than to the onset of the drought.

The trend in **alfalfa** acreage (Figure 25) and water requirements (Figures 26, 27, and 28) show increases during the entire drought period. Although the direction of acreage changes did not follow the direction of per unit value changes (Figure 4), periods of per unit value declines were followed by less steep increases in acreage.

Wheat acreage (Figure 25) and water application (Figures 26, 27, and 28) showed variability that is not explained by the movements of per unit value (Figure 4). Acreage was generally quite high prior to the drought and low afterwards, although it achieved pre-drought levels in 1989. [Interestingly, in the 1983 PIK year, wheat acreage fell marginally but water application fell substantially.]

There were wide swings in **rice** acreage (Figure 25) and water application (Figures 26, 27, and 28) in the pre-drought period independent of its per unit values (Figure 4), with an acreage peak in the PIK year of 1983 in which growers switched from cotton to rice. The drought period shows significantly lower acreage and water application although 1985 and 1989 showed much lower levels. The 1985 drop seems to have resulted from the 1984 per unit value drop. In both 1985 and 1989, sugarbeets gained additional acreage and water, apparently at the expense of rice.

Sugarbeet acreage (Figure 25) and water requirements (Figures 26, 27, and 28) showed higher levels during the drought period compared to the pre-drought period. This seems counterintuitive since sugarbeets have higher evapotranspiration requirements and since sugarbeet per unit values were quite stable (Figure 5).

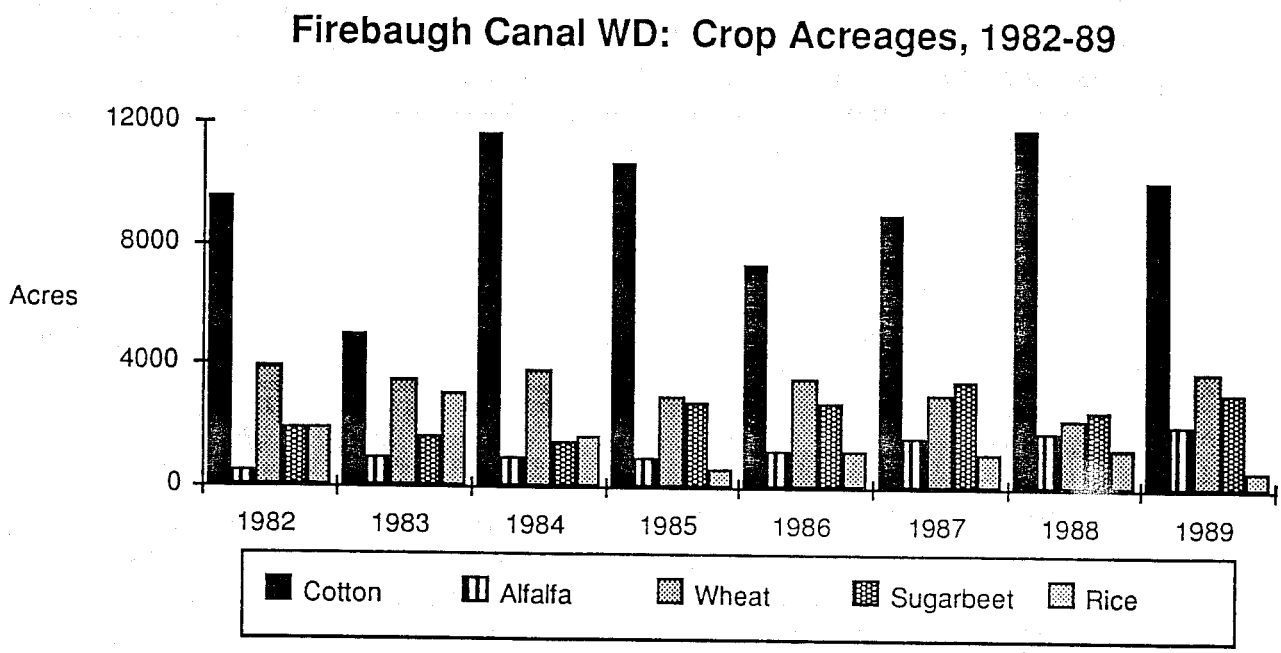

FIGURE 24

Source: Burt, Canessa, and Parrish, *op. cit.*

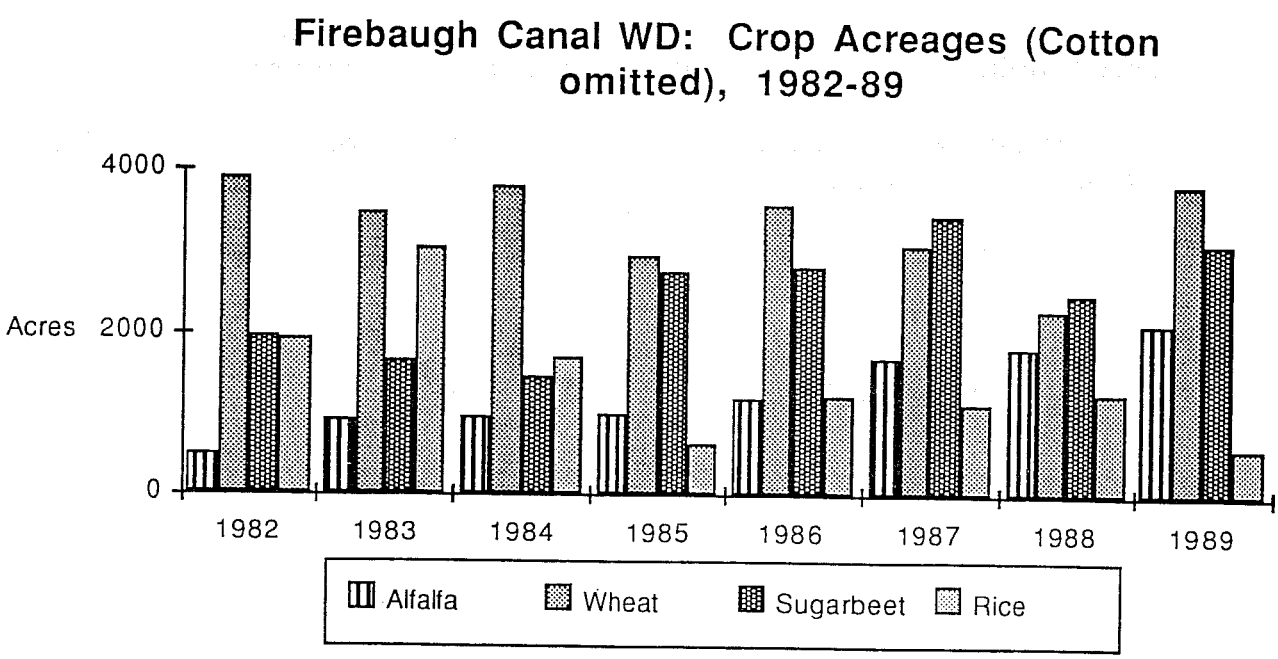

FIGURE 25

Source: Burt, Canessa, and Parrish, *op. cit.*

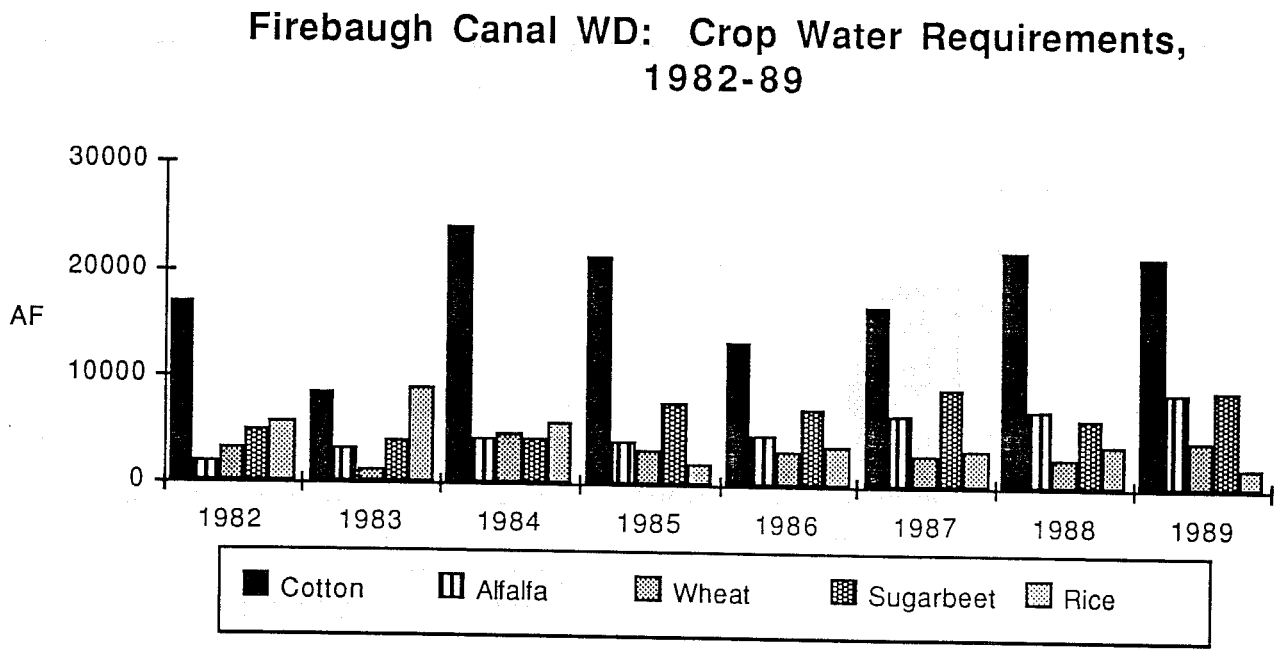

FIGURE 26

Source: Burt, Canessa, and Parrish, *op. cit.*

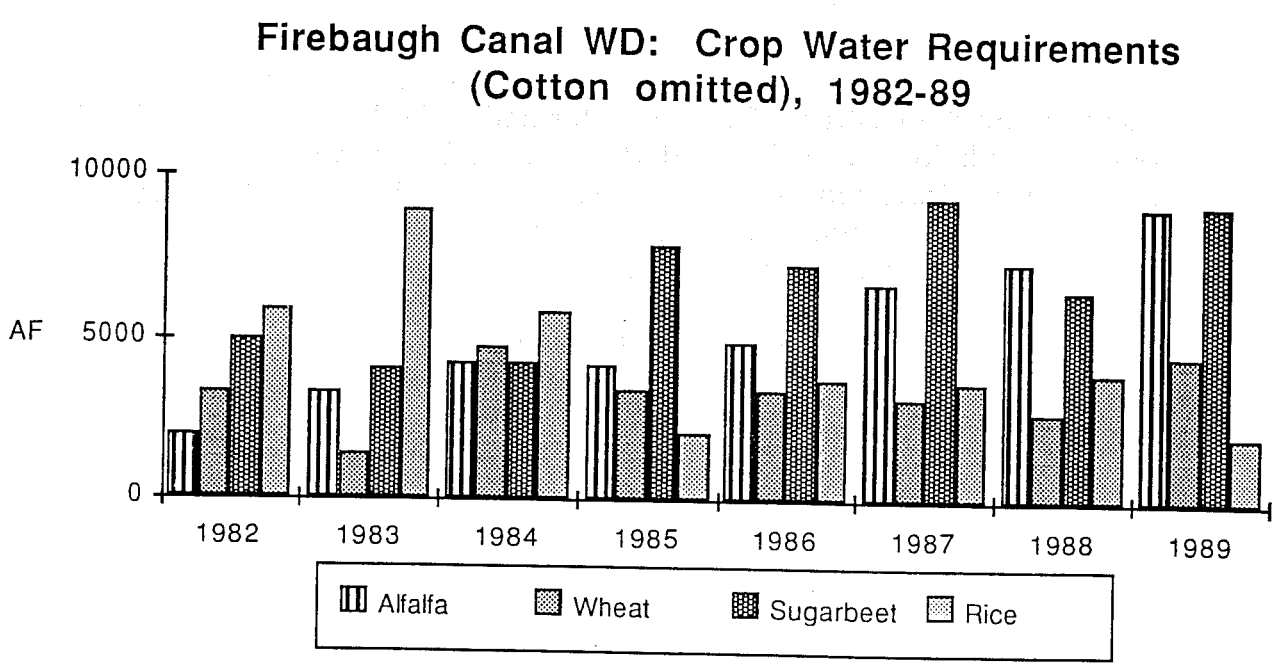

FIGURE 27

Source: Burt, Canessa, and Parrish, *op. cit.*

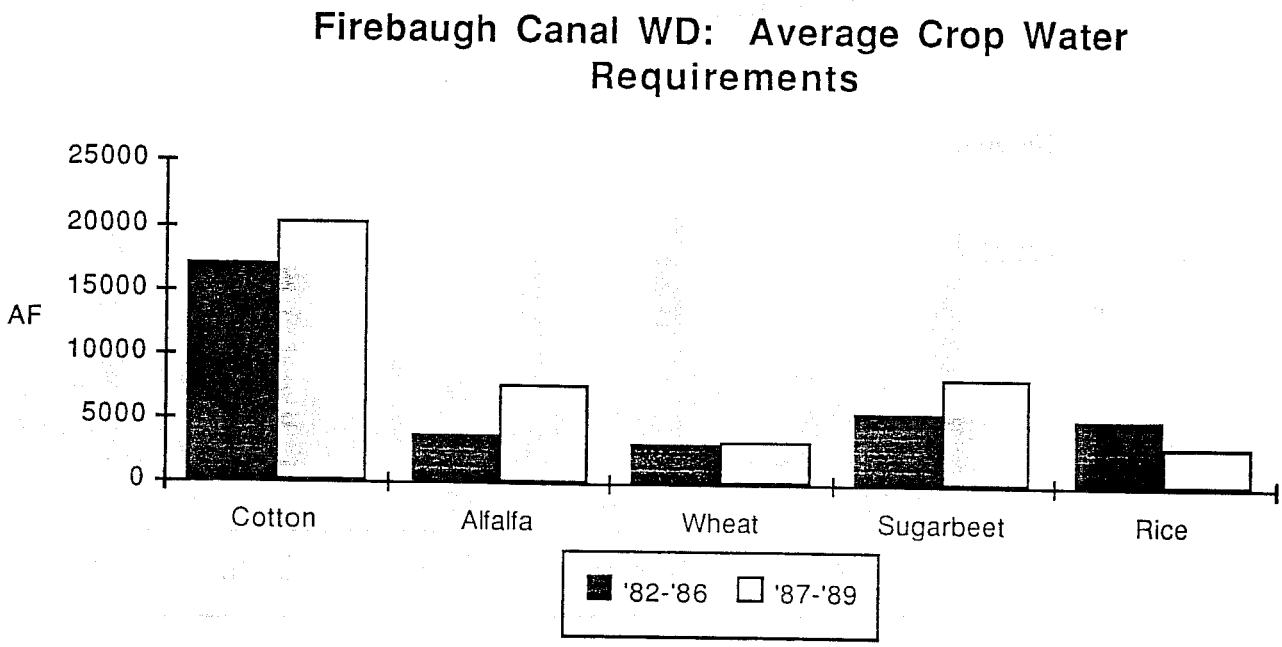

FIGURE 28

Water Deliveries, Drainage, and Crop Practices

Data concerning water delivery and drainage were not available in the DOPs submitted by the District. The only information forthcoming from the DOPs was that water recirculation was being undertaken with five pumps being added in 1991 to the existing eight already in use. Other district actions include the hiring of a conservation coordinator and the intention to require all furrows to be shortened to 1/4-mile and to separate tile water from surface water.

It is important to note that Firebaugh Canal is an exchange contractor and, therefore, receives free project water in exchange for prior rights transferred to the Bureau of Reclamation.

The Pacheco Story

Irrigation Efficiencies

The Burt report indicates that irrigation efficiencies are quite low for Pacheco and the available data show that they have not recovered from their initial fall during the 1985-86 period (Figure 29).

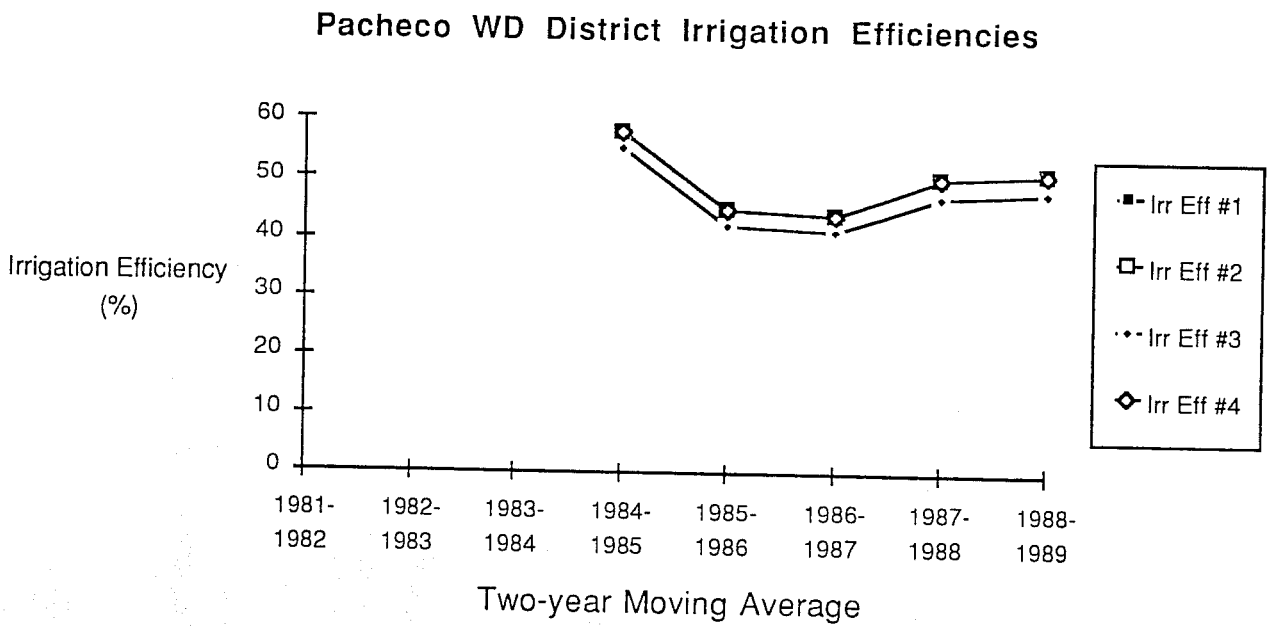

FIGURE 29

Source: Burt, Canessa, and Parrish, *op cit.*

Changes in Crop Acreages and Crop Water Requirements

Like many of the other districts, *cotton* is the dominant crop both in terms of acreage (Figure 30) and water demands (Figure 32). Changes in acreage, while relatively small, do follow (with a one-year lag) changes in the per unit value of cotton (Figure 3).

Melons show significant acreage increases (relative to crops other than cotton) both immediately prior to the drought period and shortly after its onset, which was followed by a noticeable drop in 1989 (Figure 31). Because per unit values of melons were quite stable from the pre-drought period through the existing drought (Figure 5), the increase in melon acreage could be seen as a water-conserving response to the drought.

In spite of its high evapotranspiration levels, **alfalfa** show rather stable acreage (Figure 31) and water application levels (Figure 33) (with the exception of an unexplained doubling of acreage and water in 1987) throughout the drought period.

The changes in per unit values (Figure 4) were rather small during this period and do not seem to explain why such a water-intensive crop would maintain its acreage. Possible reasons could be long-term supply contracts or involvement with dairy operations that require supplies of alfalfa.

Data on water usage by crop provided in the 1992 DOP show that some substantial per acre reductions were achieved. Water usage per acre for cotton dropped from 3.74 in 1990 to 3.07 in 1991 whereas that of melons fell from 2.41 to 2.13 and that of canning tomatoes fell from 2.94 to 2.90.

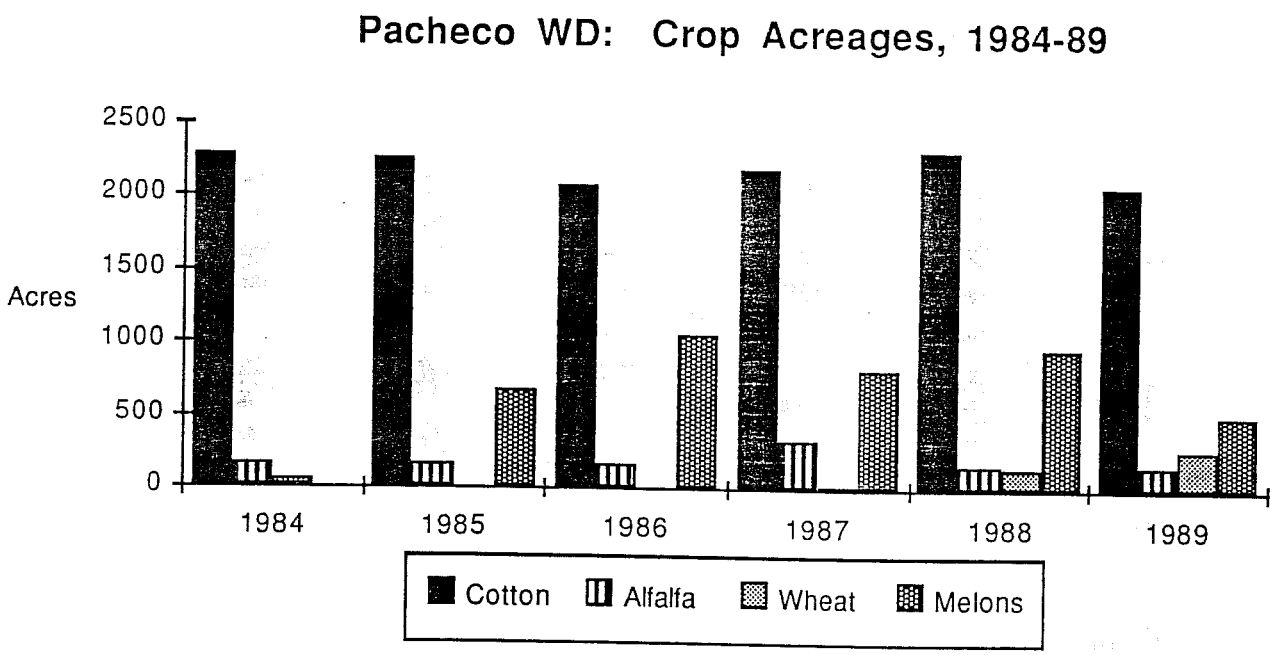

FIGURE 30

Source: Burt, Canessa, and Parrish, *op cit.*

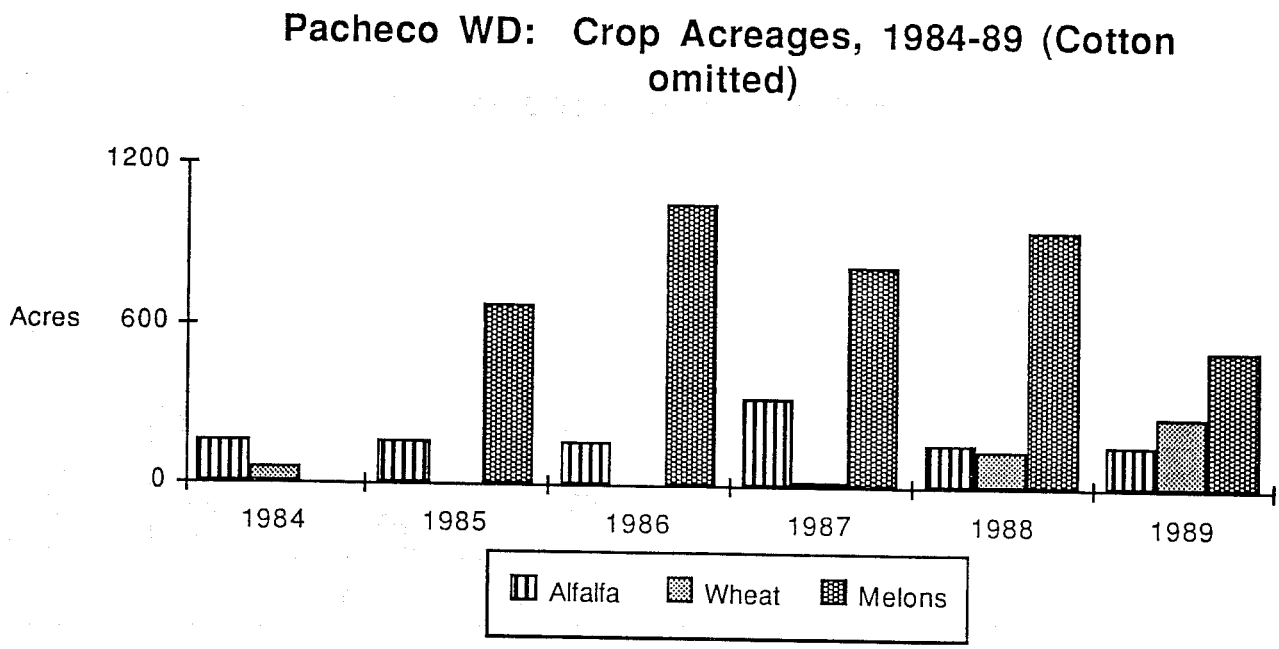

FIGURE 31

Source: Burt, Canessa, and Parrish, *op cit.*

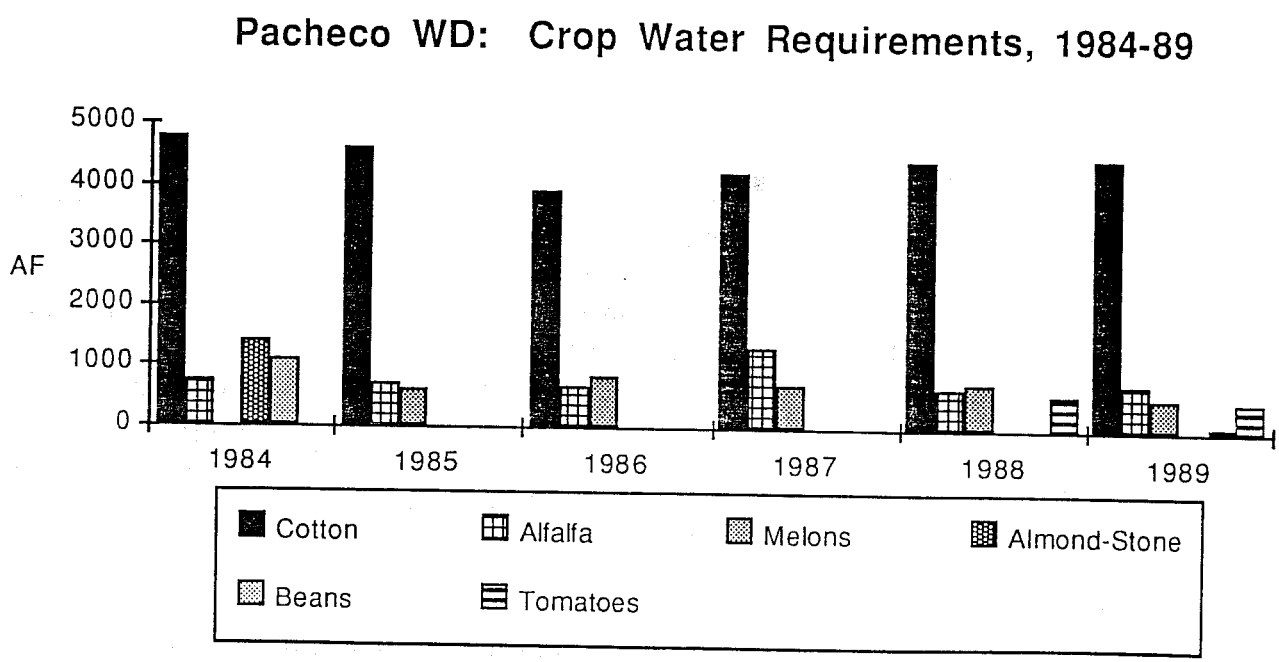

FIGURE 32

Source: Burt, Canessa, and Parrish, *op cit.*

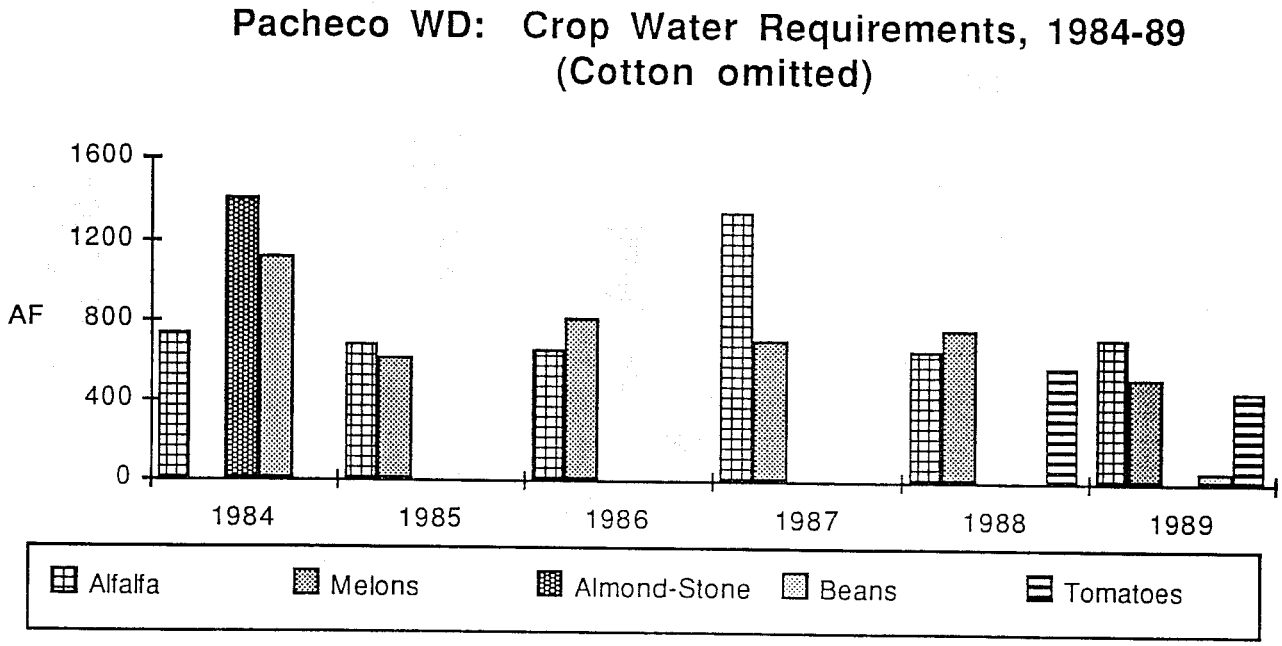

FIGURE 33

Source: Burt, Canessa, and Parrish, *op cit.*

Drainage

The available drainage data do not allow for analysis of how drainage might have changed from the pre-drought to drought periods, but it does show that drainage discharge has been decreasing considerably since the beginning of the drought (see Figure 34). The distribution of monthly drainage discharge, both in absolute and percentage terms, does not seem to indicate any trend (Figures 35 and 36). According to the DOPs, the steep decline in drainage achieved in 1988 was due to mixing drainage water with surface water and reusing it for irrigation. In 1990, approximately 1500 AF were recycled whereas in 1991 it grew to approximately 2050 AF. According to the 1992 DOP, the district is considering a project which will allow the recycling of a greater percentage of drainage water. The system will recirculate the drainage water to the headworks of the supply water delivery system so that the maximum amount of drainage water can be recycled. To achieve more recirculation, a mixing pond is under consideration. In addition, tailwater ditches were given new linings in 1990 to reduce leakage. Tiered water pricing was implemented in 1988 and helped the district achieve drainage reductions—mostly due to improvement of simple management measures such as better supervision of field irrigators, more accurate irrigation set times, and better irrigation scheduling. Although few specific data on the impact of tiered water

pricing are presented in the DOPs, the 1992 DOP indicates that the tier pricing program might be discontinued since the expected water costs for 1992 will be very high and that it would serve little purpose to increase costs above an already high level. Finally, the district is considering initiating efficient waterholding by farmers to further improve irrigation flexibility.

Information concerning on-farm irrigation management and technology changes was not available. One important motivation for expected improvement of irrigation efficiencies, according to the 1992 DOP, is the expectation of a $10/AF increase in the cost of drainage services alone.

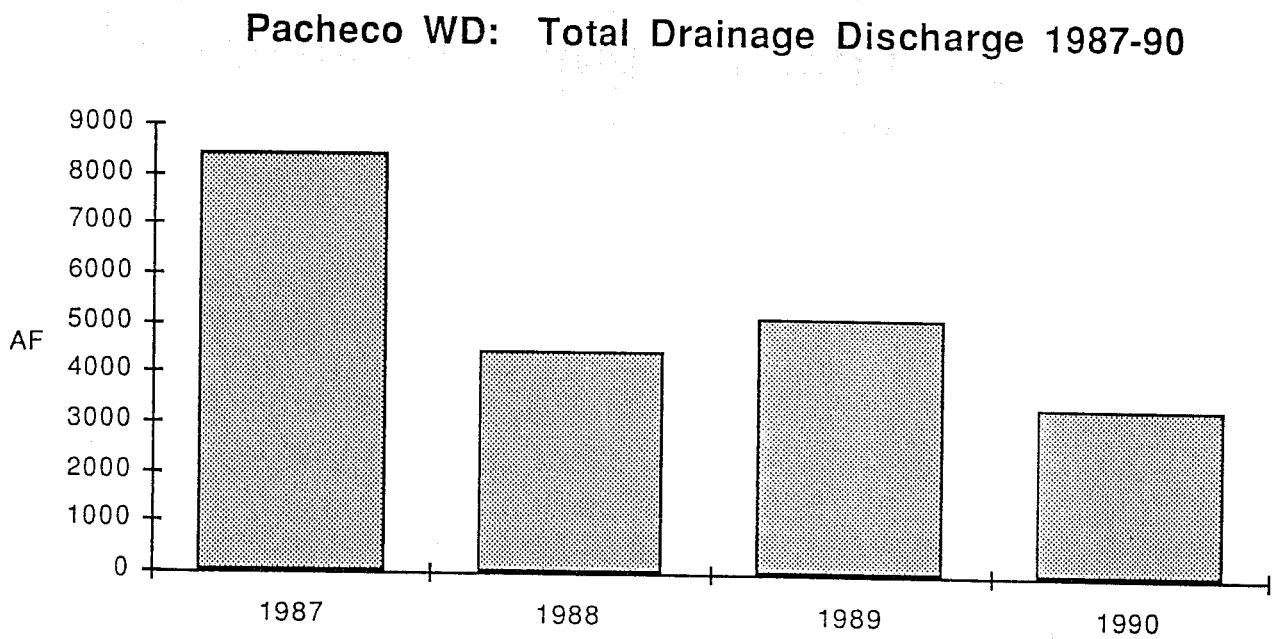

FIGURE 34

Source: 1992 Pacheco Drainage Operation Plan.

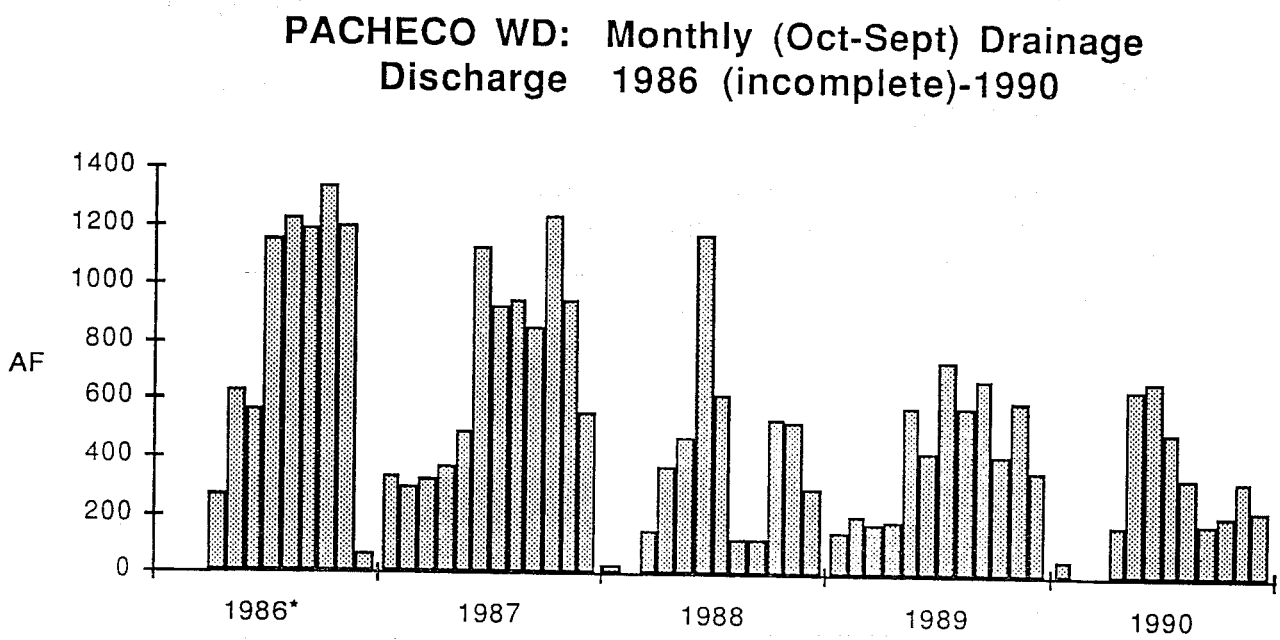

FIGURE 35

Source: 1992 Pacheco Drainage Operation Plan.

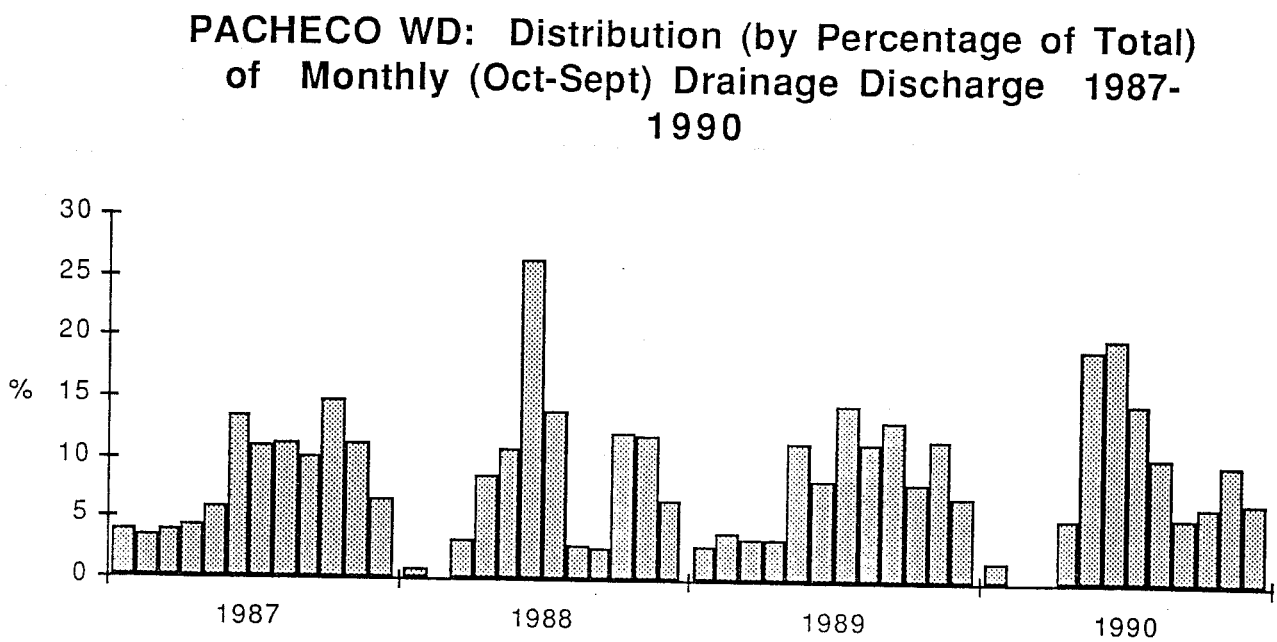

FIGURE 36

Source: 1992 Pacheco Drainage Operation Plan.

The Panoche Story

Irrigation Efficiencies

The Burt report indicates that irrigation efficiencies dipped between the 1984-85 and 1986-87 periods and subsequently rose again (Figure 37).

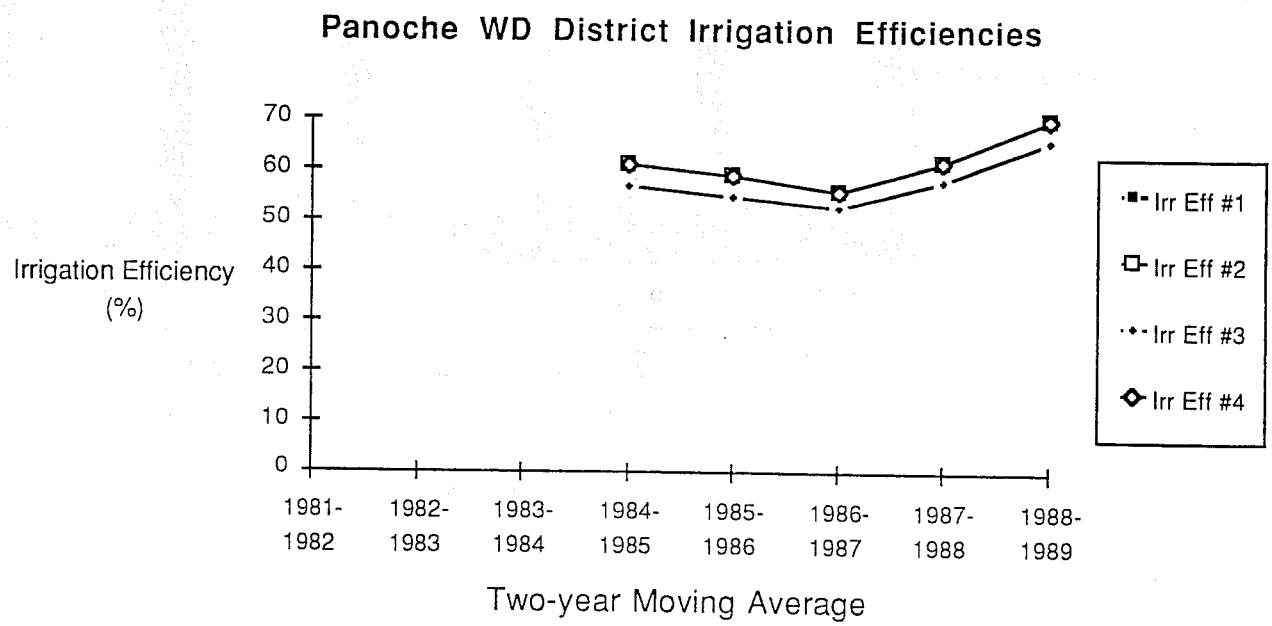

FIGURE 37

Source: Burt, Canessa, and Parrish, *op. cit.*

Changes in Crop Acreages and Crop Water Requirements

Cotton is the dominant crop in the district both in terms of acreage (Figure 38) and water demands (Figure 40). It appears that the drought had little affect on cotton acreage since acreage levels remained relatively stable except for an increase in 1988. The stability also did not seem to reflect changes in per unit values in cotton (Figure 3).

The acreage (Figure 39) and water demands (Figure 41) of **melons** showed relative variability, decreasing from highs in 1984 and 1985 to a low in the initial drought year of 1987 and showing increases through 1989, possibly reflecting the more water-conserving nature of melons but not reflecting per unit value changes since those were quite stable throughout the period (Figure 5).

Tomatoes showed a similar pattern in acreage changes (Figure 39) with a trough in 1987 but followed by a doubling in acreage and water demands (Figure 41) in 1988 with a much smaller increase in 1989, roughly reflecting the trend in per unit values of melons with a one-year lag (Figure 5).

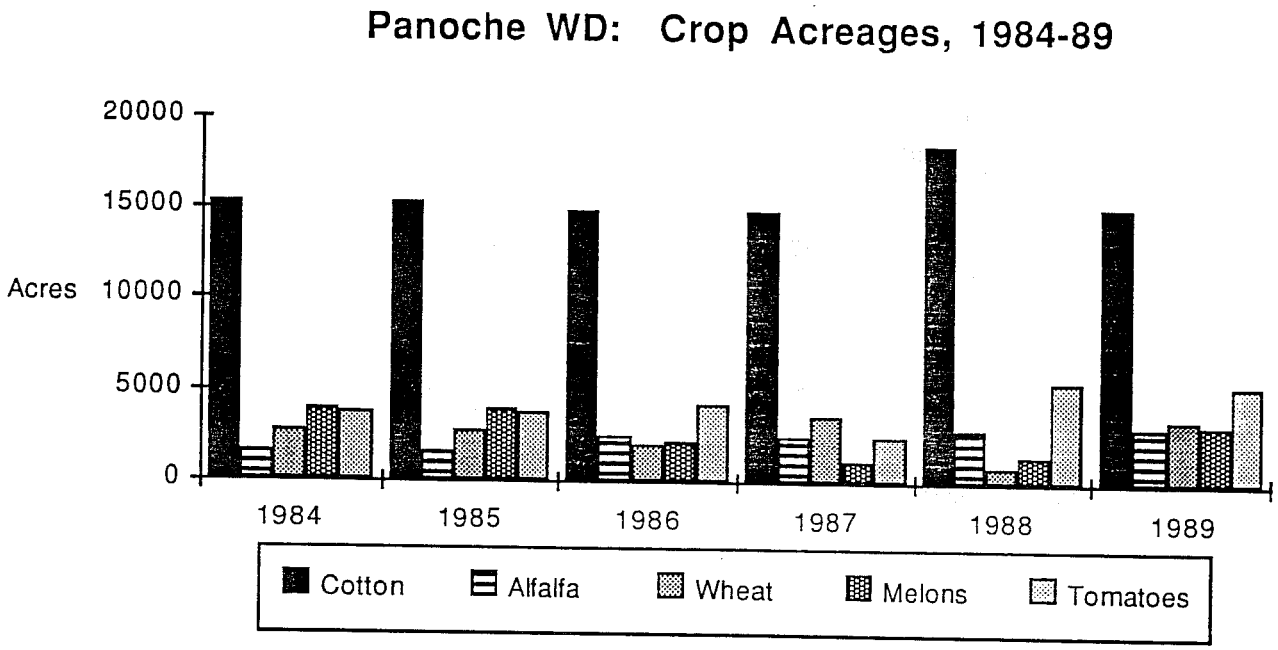

FIGURE 38

Source: Burt, Canessa, and Parrish, *op. cit.*

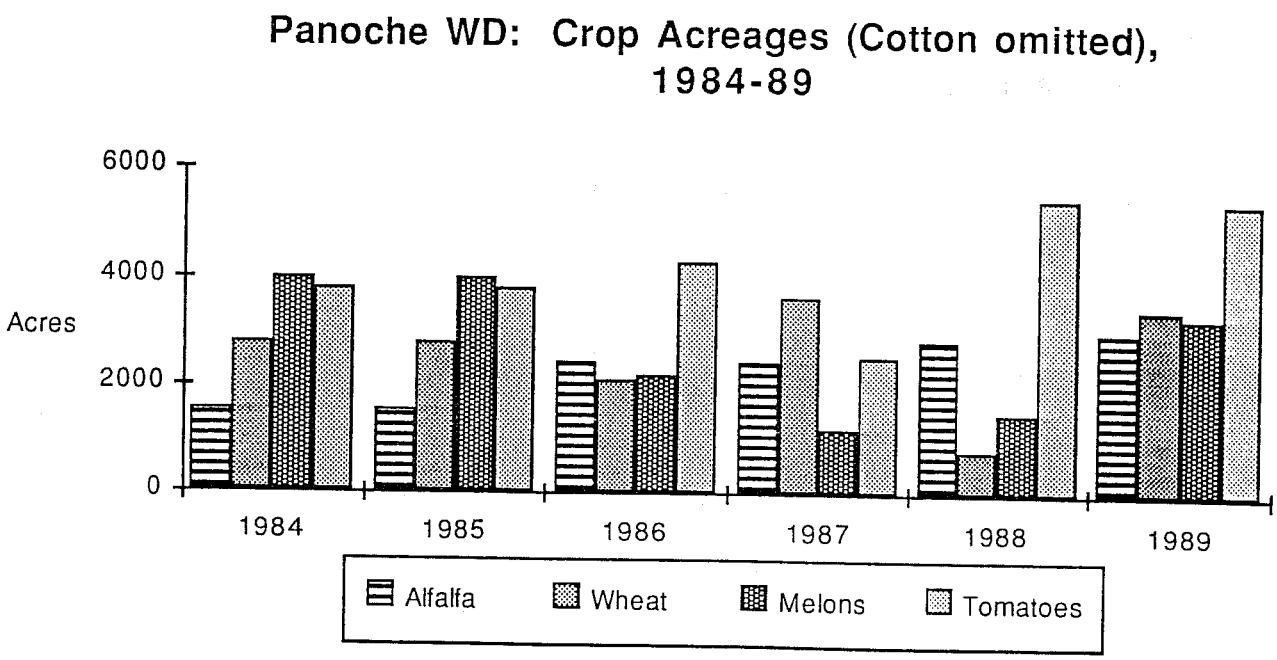

FIGURE 39

Source: Burt, Canessa, and Parrish, *op. cit.*

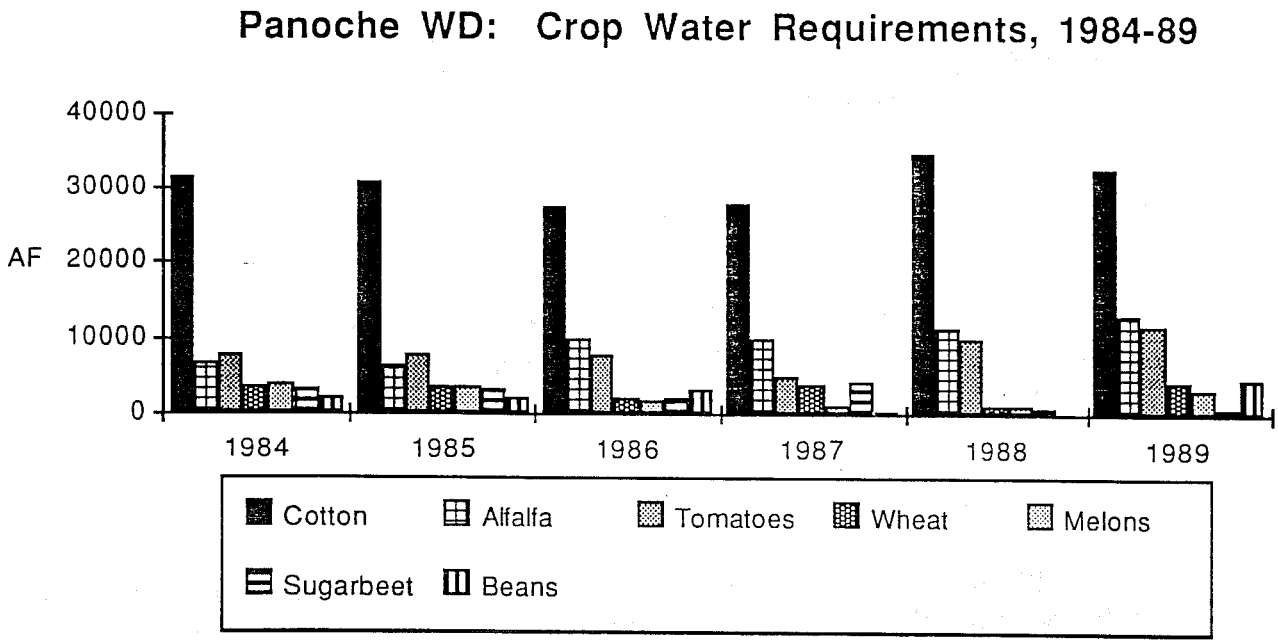

FIGURE 40

Source: Burt, Canessa, and Parrish, *op. cit.*

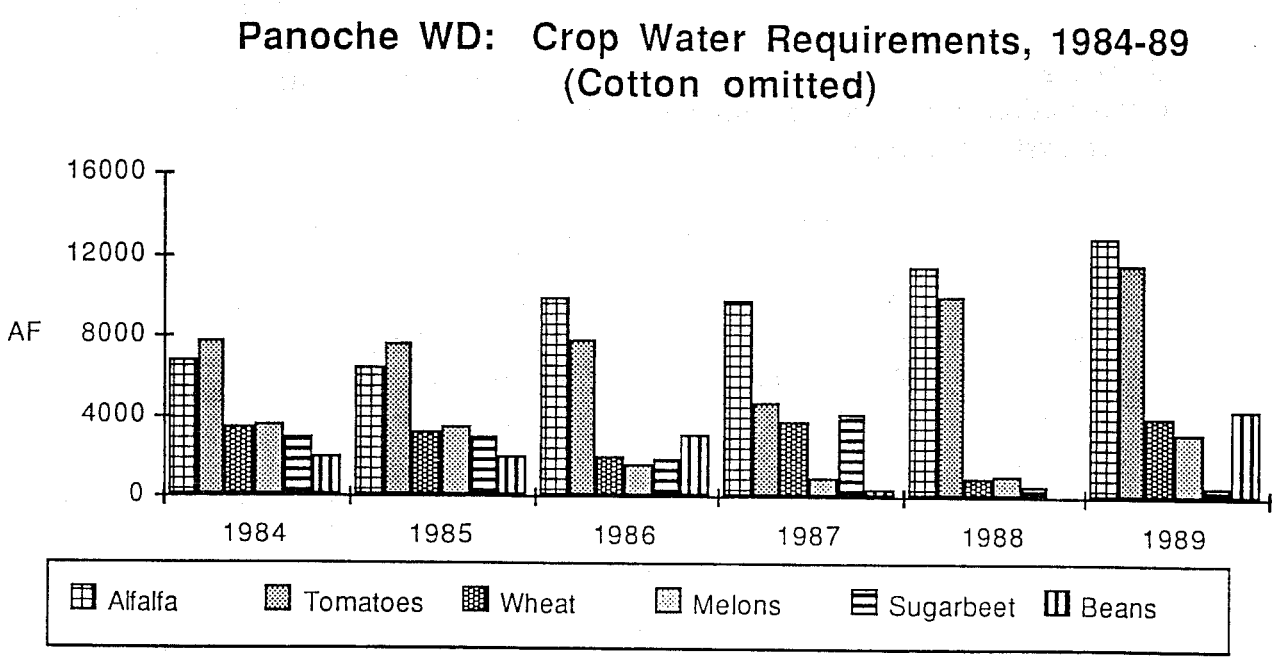

FIGURE 41

Source: Burt, Canessa, and Parrish, *op. cit.*

The most variable crop in the district was **wheat**. During the drought period, its acreage (Figure 39) did not move in the same direction in any two consecutive periods, with drought period highs being larger than the pre-drought level of 1984. These changes do not reflect per unit value changes nor levels of government payments (Figures 41 and 7, respectively).

Alfalfa showed a continuous upward trend in acreage (Figure 39) and water demands (Figure 41) during the entire period of 1984 to 1989, more or less reflecting the gradual increases in per unit values for the same period (Figure 4).

As of early 1992, with the 1991 water allocation down to 25%, only 70% of the district's cropland was in production with priority given to permanent crops and cotton acreage being cut.

Water Delivery and Drainage

Although the DOPs have not directly addressed water delivery issues, the 1992 DOP does note that, beginning in 1990, water in excess of their Bureau of Reclamation contract (2.4 AF/Ac) was not available and that the Board of Directors of the district has adopted a policy to not import surface water above their contract supply unless it is necessary for the survival of permanent crops. This has forced farmers to resort to groundwater pumping in order to make up the water deficit. According to the 1992 DOP, the groundwater pumping should alleviate some of the district's drainage problem because of an interconnection between the deeper aquifers and the shallow perched water table. However, this is at the cost of insufficient leaching and pre-irrigation. In addition to increased water scarcity and the attendant increase, the 25-30% decrease in water use is chalked up to better water application practices, better conservation practices that improve crop yields, and increased installation of tailwater return systems in each field.

Drainage management in the district has been rather successful in terms of reduction of overall drainage levels. The district has put into place two recirculation systems to take drainage water out of the main drainage system and distribute it back into the irrigation system. Looking at the total drainage for the years 1981 through 1990, drought period drainage levels have generally been lower than pre-drought levels and still declining (Figure 42). Comparing average monthly drainage discharge levels of the pre-drought period (1981-1984) with the drought period levels (1985-1990), we can see that the distribution has been shifted down so that less drainage is being released in all months (Figure 42). In addition, the distribution of monthly drainage as a percentage of total drainage released indicates that drainage release is being shifted from the early part of the water year (October through January) to the middle part of the water year (February through April) indicating that less pre-irrigation is occurring (Figure 44).

The district's DOPs say little as to why such changes might be occurring, but they do indicate that they will be installing (or have installed by now) new turnouts for water delivery and a new recirculation facility to reduce discharges by another 2600 AF.

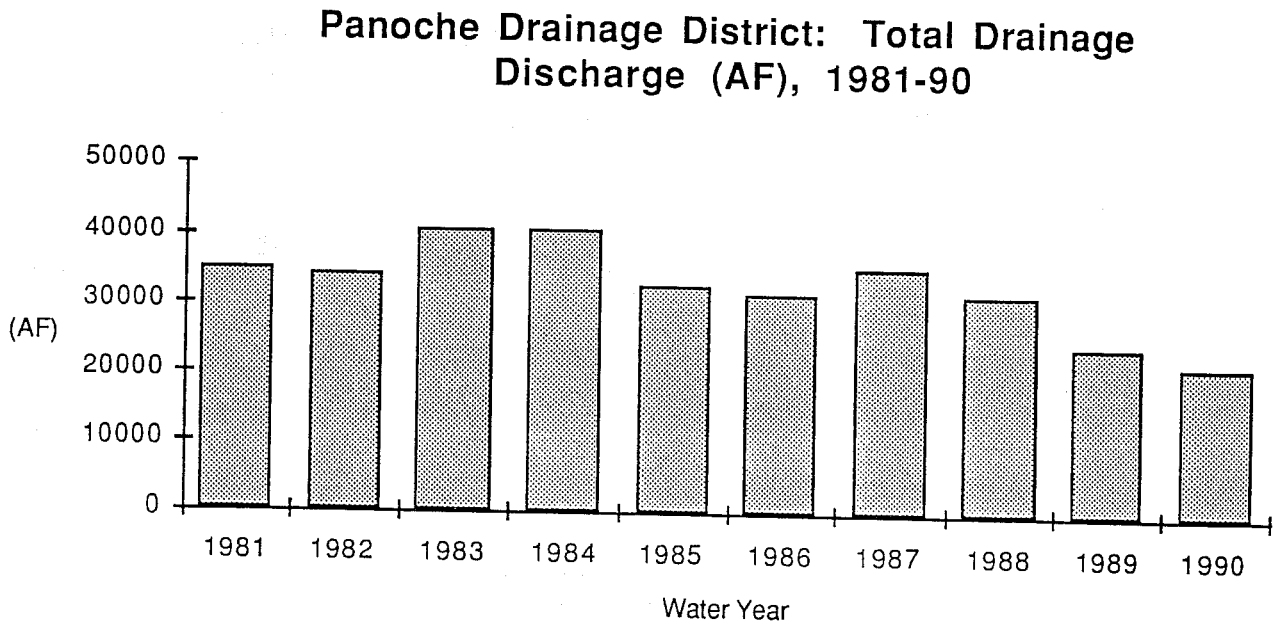

FIGURE 42

Source: 1992 Panoche Drainage Operation Plan.

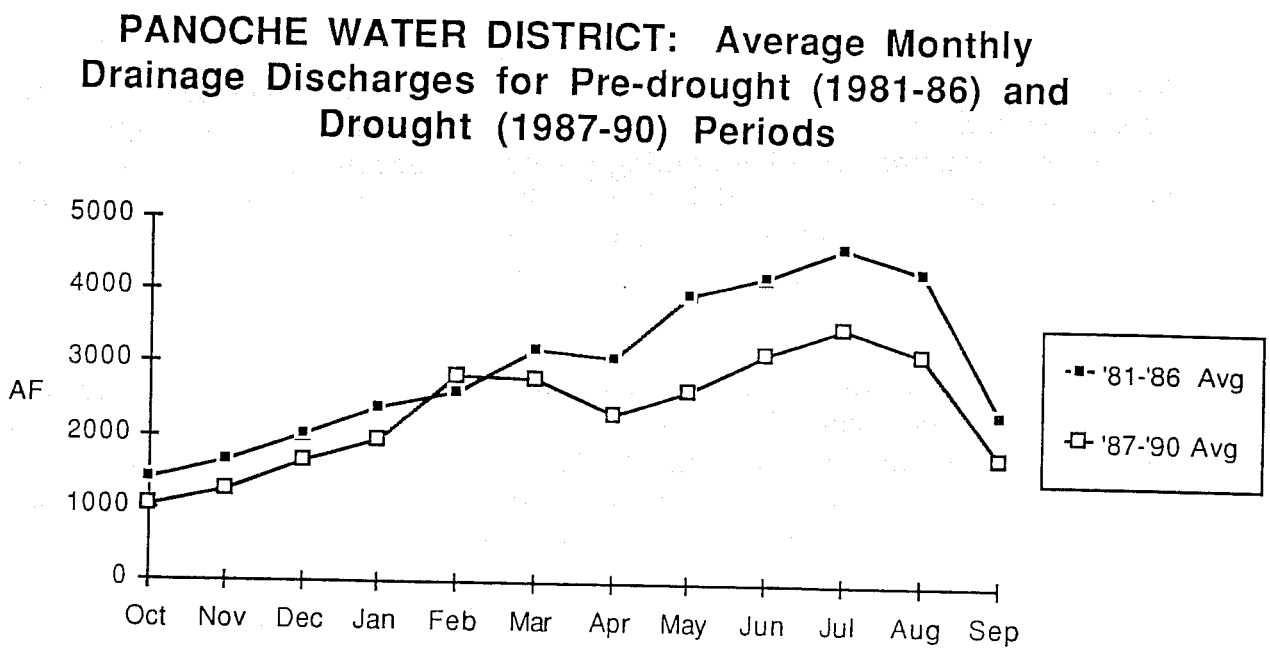

FIGURE 43

Source: 1992 Panoche Drainage Operation Plan.

PANOCHE WD: Distribution (by Percentage of Total) of Average Monthly Drainage Discharge for Pre-Drought (1981-86) and Drought (1987-90) Periods

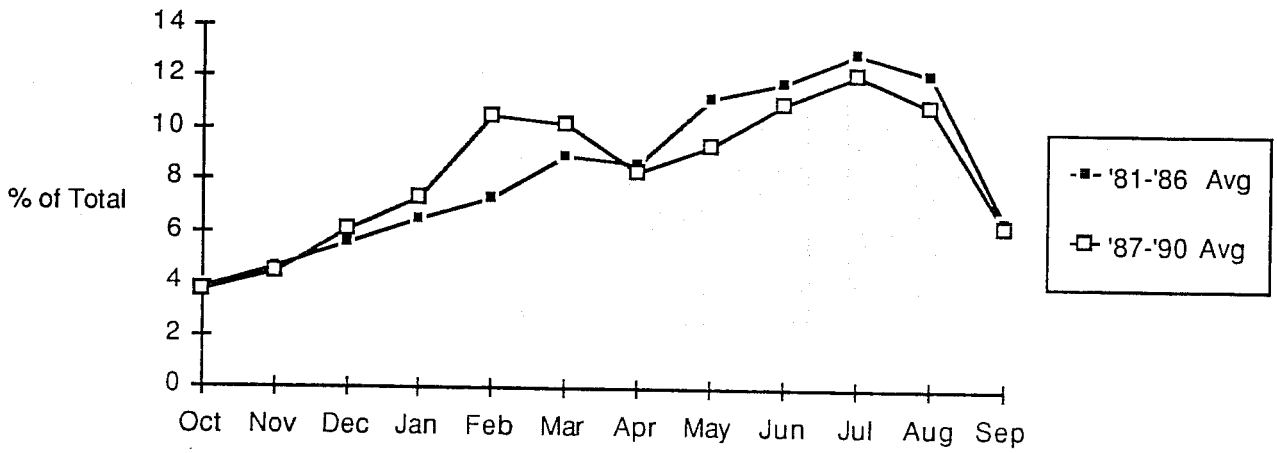

FIGURE 44

Source: 1992 Panoche Drainage Operation Plan.

In terms of district management improvements, a conservation coordinator has been hired, and there is an intent to quantify drainage discharge from fields—both subsurface inflows and outflows. Longer term measures include implementing water scheduling measures, creating holding ponds for recirculation, and allowing farmers to hold over water for more efficient use. Work presently being undertaken includes trying to distinguish between drainage water produced by local irrigation and that increment originating from upslope areas and testing the use of deep-well pumping to regulate the shallow water-table.

With respect to on-farm changes, the DOPs say little. They indicate that the water conservation coordinator has been active and that some farms have hired irrigation consultants. Beyond this, the 1992 DOP says only that farms need to increase the efficiency of return-water capabilities since the district has a policy that tailwater cannot be discharged to the drainage system. Farmers currently do much pre-irrigation with sprinklers, and subsequent irrigations use sprinkler and furrow irrigation. Also, row lengths have been reduced, and there has been an increase in the drip irrigation of tomatoes.

PART III: ECONOMIC AND FINANCIAL CONDITIONS

General Economic Indicators

An important consideration in evaluating the farm-level response to the drought and its implication for drainage issues is the financial well-being of farms in the drainage area. The hypothesis is that farms which are financially secure are more likely to invest in irrigation changes and make management changes in order to meet any drainage requirements. Unfortunately, data concerning on-farm lending in the drainage area are not currently available. Nonetheless, aggregate farm sector data for the United States and California do show that, compared to the financial environment of agriculture in 1986, the present environment is more robust, even with the ongoing drought. This section will review some of the broader data that are currently available.

The U.S. Farm Sector

A Federal Reserve Bulletin article in 1987 reflecting the information available through part of 1986 indicated that the farm sector in the United States was beginning to rebound financially from the farm crisis of the early 1980s.[6] As a result of high investment in land, machinery, and land development in the 1970s, and the subsequent fall in asset prices in the mid-1980s, there was a high degree of restructuring of financial obligations and liquidation of assets by many farm operators. While this caused severe hardship in the farm sector, it also resulted in the shift of assets and debt into more financially secure hands and thus improved the potential condition of the sector in the future. During the crisis, there was a negative total return to farming but there was also the expectation that, once asset prices stabilized, more people would move back into farming with the positive projected income and more conservative investment practices. This more conservative behavior is reflected in the greater reluctance to use debt to finance operating expenses and purchases of machinery and livestock.[7] This reaction was also motivated by the relatively high real cost of borrowing that existed in 1986.

Using more recent data[8], we can also see an improvement in the financial situation of the U.S. agricultural sector. First of all, interest rates as represented by the yield on 6-month Treasury Bills (Figure 45) have been declining since the early 1980s, thus reducing the cost of borrowing to farmers. Assuming that the farm crisis shook out the financially insecure farmers and reinforced greater financial discipline in the sector, then lower interest rates would indicate that necessary investments will be undertaken. The same figure shows that the index of output per unit of total input has

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[6]Emanuel Melichar, "Turning the Corner on Troubled Farm Debt," *Federal Reserve Bulletin*, July, 1987.

[7]*Ibid.*, p. 527.

[8]The data are drawn from the *1992 Economic Report of the President.*

also been increasing since the period of the crisis. This would indirectly indicate that investments are productive rather than speculative in nature. Another indicator of investment is the change in total assets of the U.S. farm sector (Figure 46). While these data do not distinguish among land, machinery, and other assets, knowing that land prices are much lower and much less speculation is occurring would indicate that the changes reflect a healthier sector.

Productivity of U.S. Agriculture and Yield on U.S. 6-Month Treasury Bills, 1980-1991

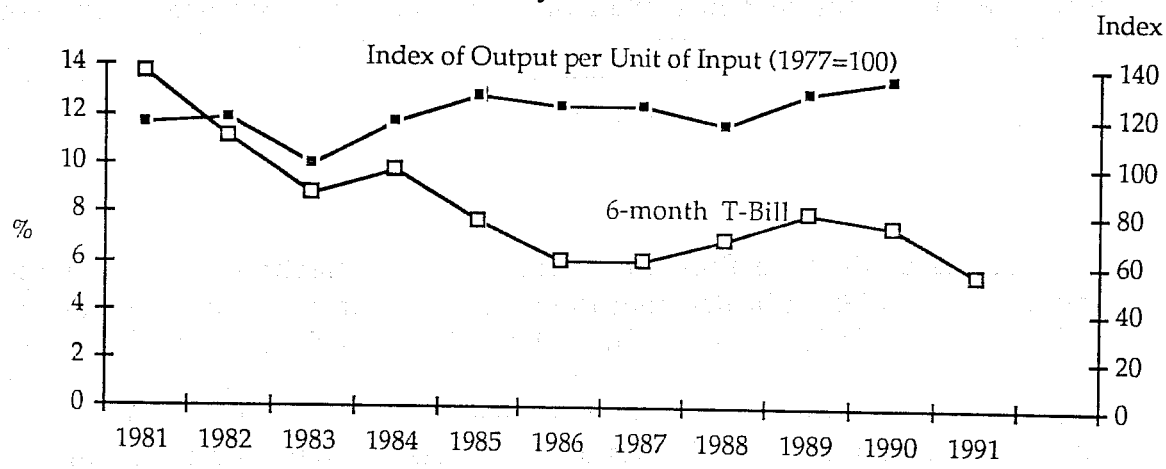

FIGURE 45

Change in Total Assets of U.S. Farm Sector, 1981-1991

(Change measured in millions of dollars)

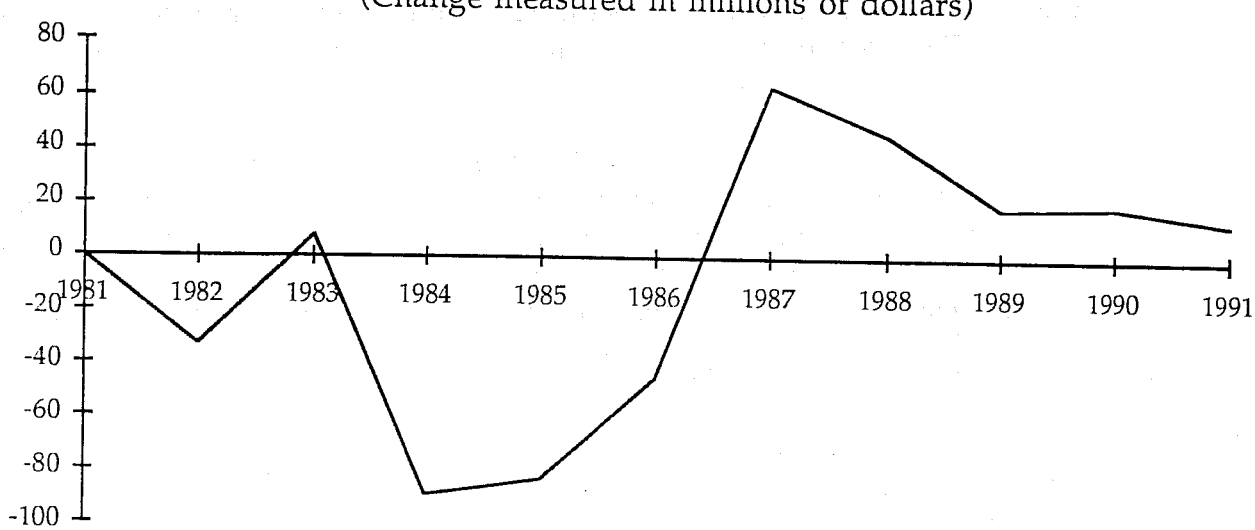

FIGURE 46

Indicators more specific to the past crisis in the farm sector are shown the following tables and figure. The clearest manifestation of the farm crisis occurred through bank lending to farmers. The level of foreclosures and debt restructuring alluded to earlier should now be much lower than before if the sector is indeed more viable financially. Table 1 compares farmland transfer estimates between two periods, 1979-1981 and 1986-1990.

Table 1: Farmland Transfer Estimates, 1979-1981 and 1986-1990

	Voluntary sales*	Forced sales**
1979	81.9	18.1
1980	81.9	18.1
1981	81.1	18.9
1986	57.0	43.0
1987	54.0	46.0
1988	60.0	40.0
1989	66.0	34.0
1990	70.0	30.0

*Voluntary Sales: Voluntary and estate sales.
**Forced Sales: Foreclosures, bankruptcies, tax sales, family transfers, and other sales and transfers.

Source: USDA/ERS, *Farm Financial Stress, Farm Exits, and Public Sector Assistance to the Farm Sector in the 1980's*, 1991.

This table indicates that the forced sales (defined as foreclosures, bankruptcies, tax sales, family transfers, and other sales and transfers) as a percentage of all estimated farmland transfers are dropping during the post-crisis period after 1986. Note that the 1979-1981 period has very low percentages of forced sales and reflects the more speculative character of the period; it would probably be fair to say that these low percentages are not what might be considered "normal".

Aside from forced sales (a measure of farm exit), another measure of financial adjustment is farm bankruptcy that allows restructuring of debt. The Chapter 12 farm bankruptcy provision, enacted in 1986, was designed to rehabilitate family farms in financial jeopardy. The provision made it easier for family farms (defined as those which received at least 50% of gross income from farming and those whose total debt does not exceed $1.5 million)[9] to develop debt-restructuring plans and also simplified and expedited farm cases through the bankruptcy courts. By accelerating restructuring,

[9]USDA/ERS, *Farm Financial Stress, Farm Exits, and Public Sector Assistance to the Farm Sector in the 1980's*, 1991.

the sector was able to find a new financial equilibrium more quickly. Table 2 shows that after the provision was enacted, there was a significant one-year jump in bankruptcies in 1987 that tapered down in the following two years. The Pacific region, which includes California, generally shows an absolutely lower number of bankruptcies but also less of a drop-off in percentage terms after 1987. Nonetheless, the numbers do seem to indirectly reflect the general health of California agriculture.

From the bank side of the crisis, data shows that U.S. farm banks reported that liquidation of farm operations regained some equilibrium after 1986 (Figure 47). The level of "normal attrition" increased at the expense of voluntary liquidation and legal foreclosure.

Finally, from the same data, the article gives a more specific breakdown of indicators of financial stress as reported by U.S. farm bank lenders for the period 1985 to 1989. Table 3 shows that there was a trend of decreasing delinquencies and bankruptcies as well as relatively fewer cutoffs or expected cutoffs of lending. In addition, fewer farmers seemed to be at their maximum borrowing levels.

The net result is that the financial health of agriculture at the national level since the farm crisis is much improved. Increasing productivity, lower interest rates, and restructured debt have all contributed to a certain degree of financial stabilization. It would also be fair to say that lending is now more cautious and based more on the potential performance of the farming operation than on asset (land value) appreciation.

Table 2: Chapter 12 Case Filings by Selected Farm Production Regions

	1986	1987	1988	1989	Total
Corn Belt	103	1,292	447	290	2,132
Northern Plains	148	1,553	358	218	2,277
Mountain	42	546	256	155	999
Pacific	24	363	188	163	738
US Total	600	6,064	2,025	1,433	10,122

Corn Belt: IL, IN, IA, MO, OH
Northern Plains: KS, ND, NE, SD
Mountain: AZ, CO, ID, MT, NV, NM, UT, WY
Pacific: AK, CA, HI, OR, WA

Source: USDA/ERS, *Farm Financial Stress, Farm Exits, and Public Sector Assistance to the Farm Sector in the 1980's*, 1991.

Liquidation Categories for Area Farmers from Survey of U.S. Farm Banks, 1985-1989 (by percentage of total)

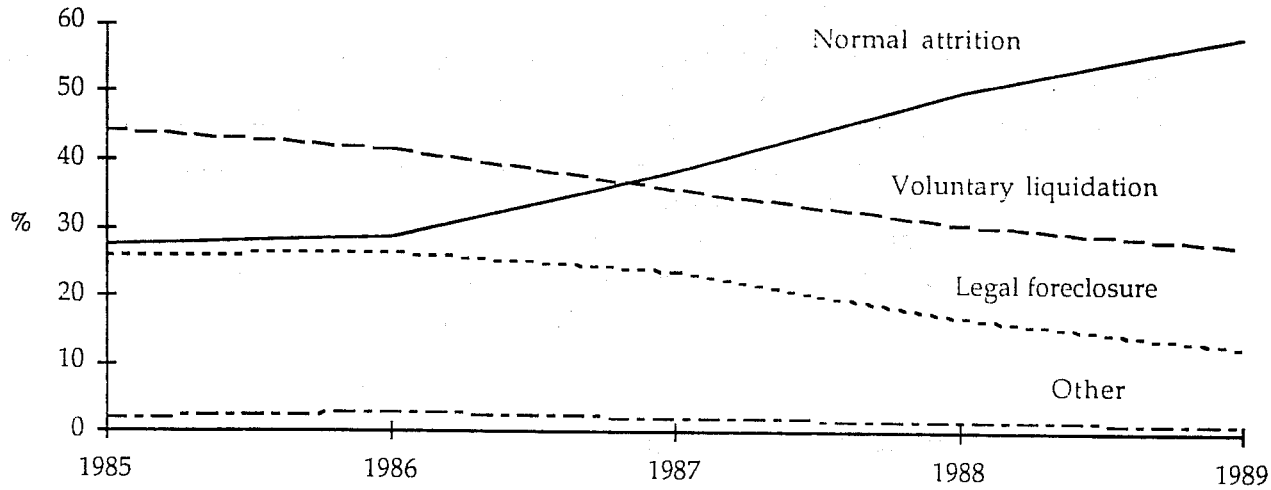

FIGURE 47

Table 3: Indicators of Financial Stress in Agriculture as Reported by Farm Banks, United States, 1985-1989 (in percentage)

	1985	1986	1987	1988	1989
			-(%)-		
Farm loan volume delinquent 30 days or more (in June) *	5.3	6.0	2.7	1.6	1.5
Banks' farm borrowers who had bank financing discontinued (during year ending in June)	4.5	5.6	3.2	1.7	1.3
Farm borrowers bank expect to discontinue (during the year ending in June)	5.7	6.7	2.1	1.5	1.7
Banks' farm borrowers loaned up to practical limit (in June)	36.7	38.8	28.8	22.6	24.6
Banks' farm borrowers who filed for bankruptcy (during the year ending in June)	1.5	2.2	1.4	0.7	0.4

*1989 data for farm loan volume is as of September 30.
Note: 1985 and 1986 were peak stress years.

Source: USDA/ERS, *Farm Financial Stress, Farm Exits, and Public Sector Assistance to the Farm Sector in the 1980's*, 1991.

The California Farm Sector

Although California has been in a drought since 1987, it has only been since 1991 that the agricultural sector has been significantly affected with respect to financial indicators. According to Frank Cannon[10], Vice President and Senior Economist at Bank of America, the financial condition of California agriculture is strong when compared to other sectors of the state's economy—for each year from 1987 to 1990, the key financial indicators of agriculture showed an improvement. It was only in 1991 with the combination of the fifth year of drought and an early freeze that a $1 billion downturn in sales occurred. Cannon states, though, that farm loan performance remained strong; one reason being that debt loads in agriculture are generally low and that the market for most products remain strong. Specific data he gives includes cash receipts, exports, gross farm income, production expenses and net farm income for the period 1988 through 1991 (see Table 4). The highlights of the data are as follows:

- The $1 billion decline in total cash receipts in 1991.
- A lack of decline in exports.
- A decline in gross farm income of $800 million.
- A slight decline in production expenses due to reduced crop acreage, offset by higher water and energy bills.

Table 4: Economic Indicators for California Agriculture 1988-1991

	1988	1989	1990	1991
		-billions of dollars-		
Cash receipts	16.7	17.5	18.9	17.9
Exports	4.0	4.0	4.5	4.5
Gross farm income	17.9	18.9	20.0	19.2
Production expenses	11.8	12.9	14.0	13.4
Net farm income	6.1	6.0	6.0	5.8
		-percentage change-		
Cash receipts	5.7%	4.8%	8.0%	(5.3%)
Exports	20.1%	0.0%	12.5%	0.0%
Gross farm income	14.7%	5.6%	5.8%	(4.0%)
Production expenses	1.7%	9.3%	8.5%	(4.3%)
Net farm income	8.9%	(1.6%)	0.0%	(3.3%)

Source: California Department of Food and Agriculture; estimates and forecasts by Bank of America.

[10]Taken from his position paper submitted for the California Energy Commission workshop, in Sacramento, California on March 28, 1992.

Implications for Drainage

One of the key results of the original 1987 study was that it was important to distinguish between economic and financial impacts of any new drainage quality standards as represented by increase in per acre costs to the farmer. If a significant portion of farmers are in financial trouble, then one would expect that new standards would force many out of operation, leading to either new entrants or consolidation by existing farmers. The land and capital of bankrupt operators would eventually be transferred to other, more secure owners and the net movement of land out of production would be that land of sufficiently poor drainage quality that could not be farmed profitably. This scenario—land changing hands and being retired—was captured in the original study via a model using a distribution of land quality and financial health. The distribution of land solvency and land retirement under per acre cost changes is represented in Figure 51.

Prior to discussing the specifics of the impacts of increasing drainage costs, a quick description of some of the basic economic changes that have occurred since 1987 will be undertaken using some of the same modeling techniques used in the 1987 study. First of all, one of the most significant changes that has occurred relate to prices received by farmers for their output. Six crops were the focus of the 1987 farm financial model: alfalfa, barley, cotton, sugarbeets, tomatoes, and wheat. Comparing the 1987 prices with the 1991 prices as taken from the Fresno County Agricultural Commissioner's 1991 annual report, we can note that:

-alfalfa increased from $87.50/ton to $89/ton;
-barley fell from $184/ton to $106.20/ton;
-cotton increased from $0.69/lb. to $0.77/lb.;
-sugarbeets increased from $50.90/ton to $52.30/ton;
-tomatoes increased from $51.50/ton to $52.30/ton; and,
-wheat fell from $112/ton to $106.60/ton.

As a simplification, we used the same distribution of cropland to crop rotations that was derived in 1987 to measure the impact of the price changes alone. The result of the price change, in comparison with the original results, is shown in Figure 49 (with the 1987 distribution represented by the dark boxes and the 1991 distribution by the light boxes). The figure shows a straightforward shifting out of gross profits indicating that, with the same land under the same crop rotations, more profit is being generated by all land—simply due to price changes.

Cumulative Distribution of Profits over Land in the Drainage Area: 1987 Model (Dark) & 1991 Model (Light)

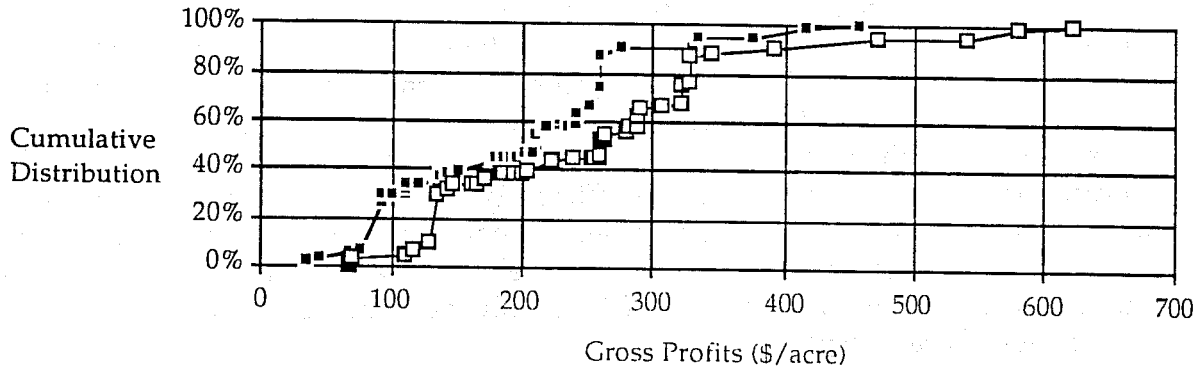

FIGURE 48

Using this same information, we can generate the more informative relationship between land solvency and agricultural production that is represented in Figure 49 (for the 1987 prices) and Figure 50 (for the 1991 prices). In the two figures we can see how, given certain assumptions regarding improvements in the financial health of farms and given the changes in crop prices since 1987, the potential impact of new drainage quality standards has changed since 1987.

1987: % Acreage Solvent and in Production in the Drainage Area after an Increase in Drainage Costs

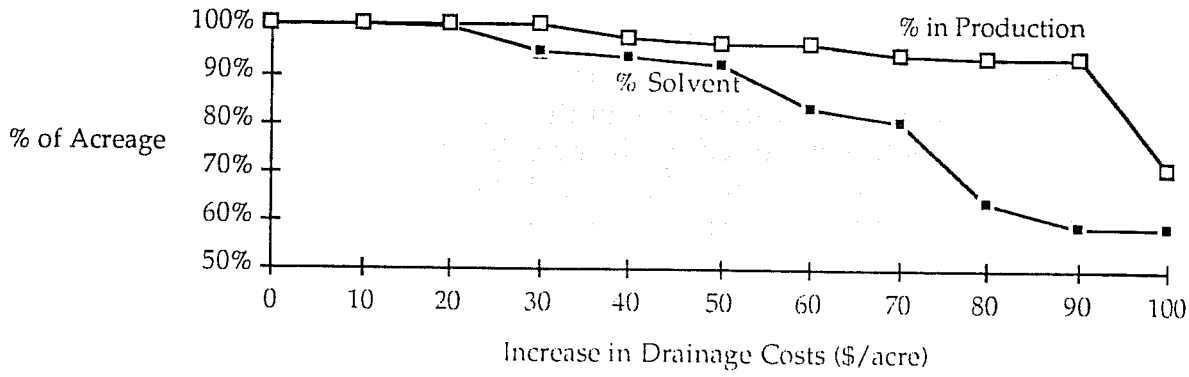

FIGURE 49

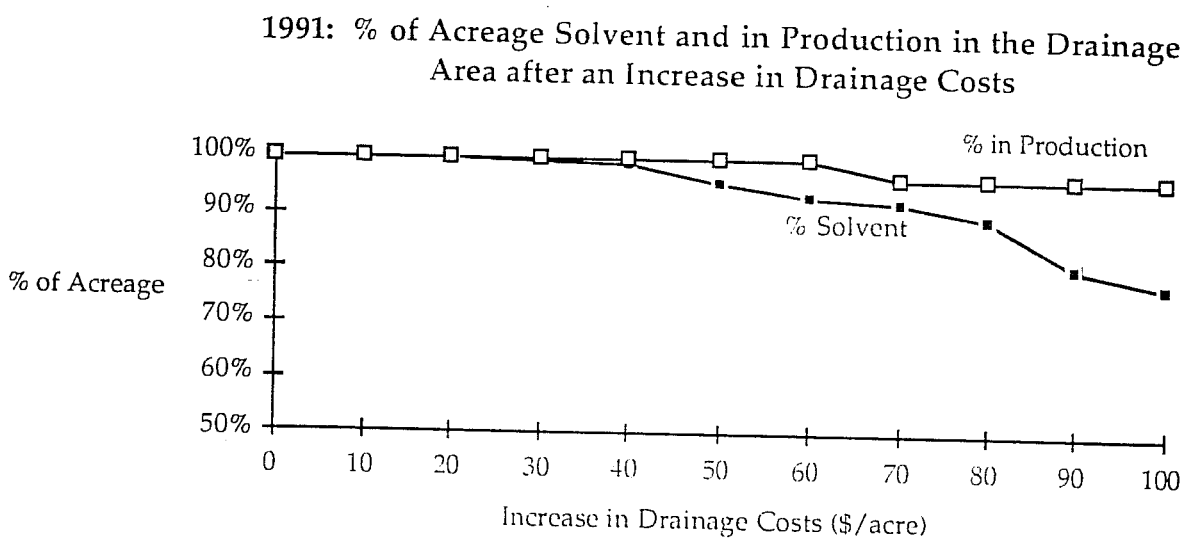

FIGURE 50

In the two figures it should be noted that the vertical distance between the production line and 100% level of the vertical axis represents the land forced into retirement by a cost increase due to stricter drainage standards, and the vertical distance between the solvency line and the production line represents the proportion of land that would change hands.

In order to generate the new solvency distributions, a simplifying assumption was made with regard to the debt/asset ratios of farmers in the drainage area. In the original model the available financial information led to an assumption based on 60% of the farm population having an average debt/asset ratio of 0.2, 30% with a debt/asset ratio of 0.4 and the remaining 10% with a ratio of 0.7. Keeping in mind the significant turnover in farms, the high level of refinancing, and the lower interest rates discussed earlier in this section, we have assumed that the ratios would be halved while keeping the same population distribution.

Turning to Figures 49 and 50, we see that, for increases in drainage costs up to $100/acre that, as a result of the higher prices and the improved financial health of farmers, more land is staying in production and much less land is changing hands as a result of bankruptcy. While the results do emerge from the simplifying assumptions outlined above, they nonetheless reflect the important role of financial and economic conditions when considering drainage regulations that will increase production costs.

For illustrative purposes, the results implicit in Figures 49 and 50 are disaggregated to the four constituent water districts (Figures 51 through 58). The differences among the districts reflect their land quality and crop rotations and the effect that the price changes had on them.

1987/Broadview WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

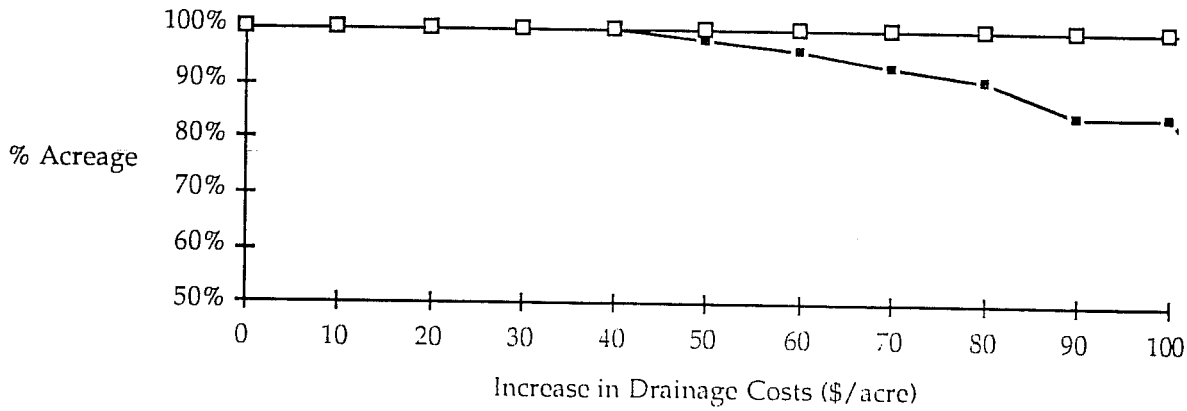

FIGURE 51

1991/Broadview WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

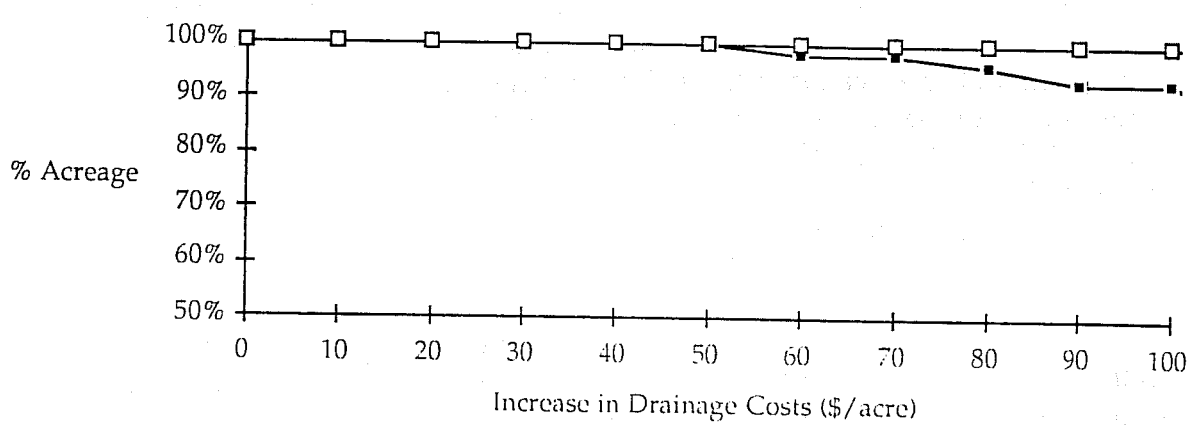

FIGURE 52

1987/Firebaugh Canal WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

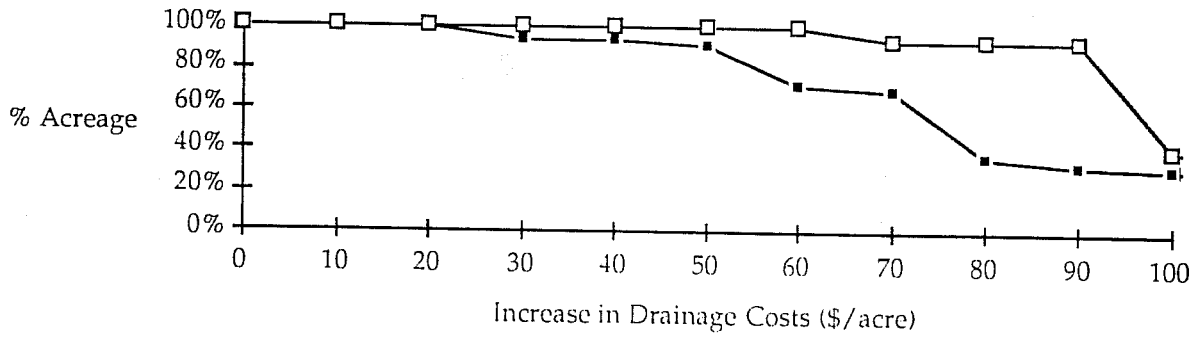

FIGURE 53

1991/Firebaugh Canal WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

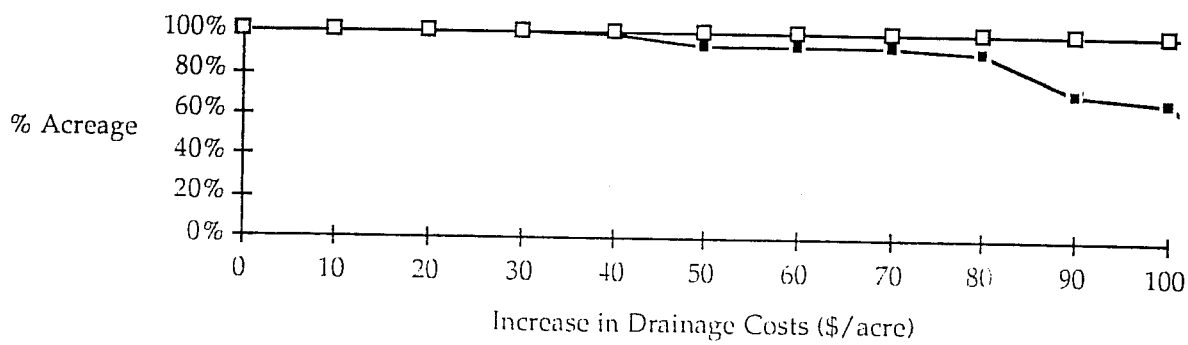

FIGURE 54

1987/Pacheco WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

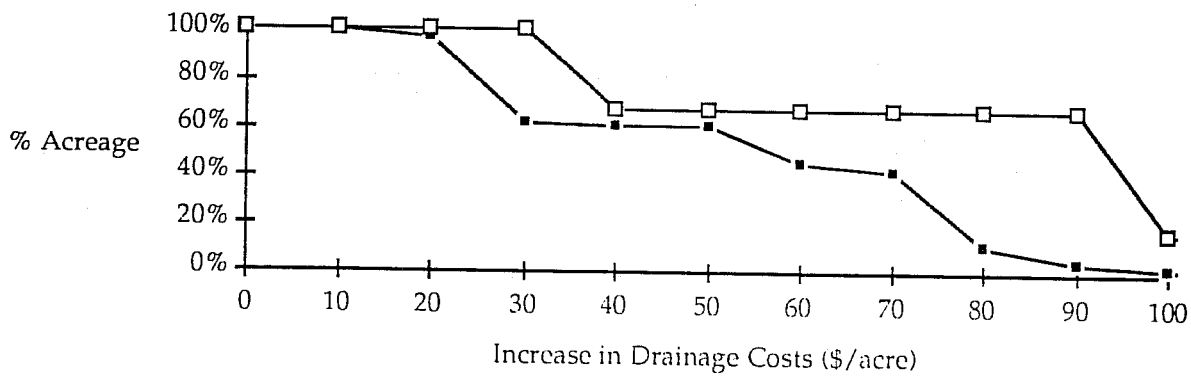

FIGURE 55

1991/Pacheco WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

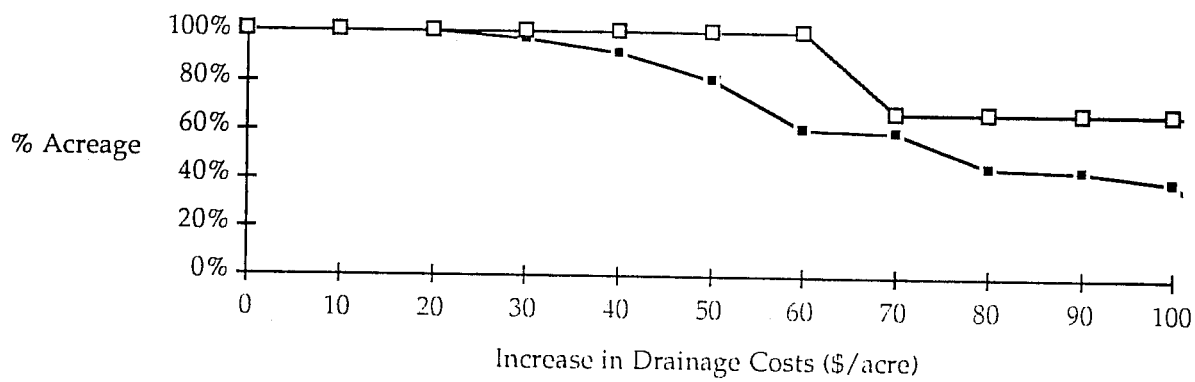

FIGURE 56

1987/Panoche WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

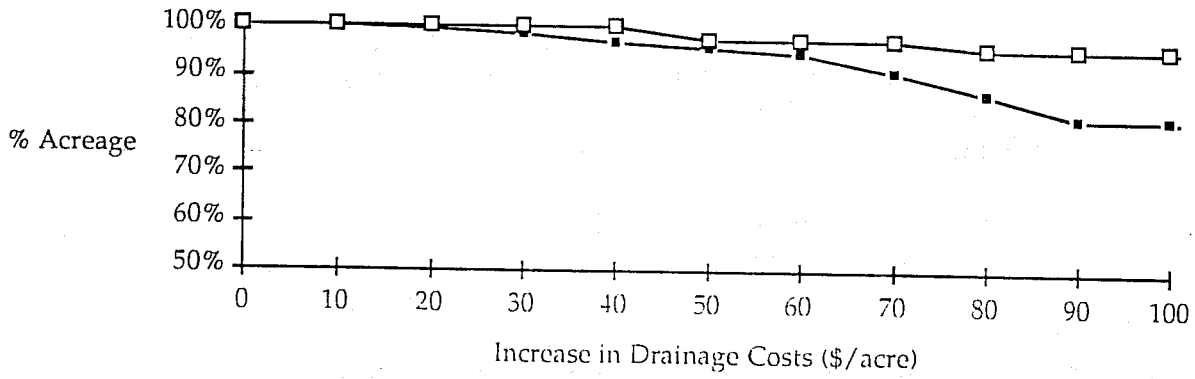

FIGURE 57

1991/Panoche WD: % Acreage Solvent (Dark Boxes) and in Production (Light Boxes) after an Increase in Drainage Costs

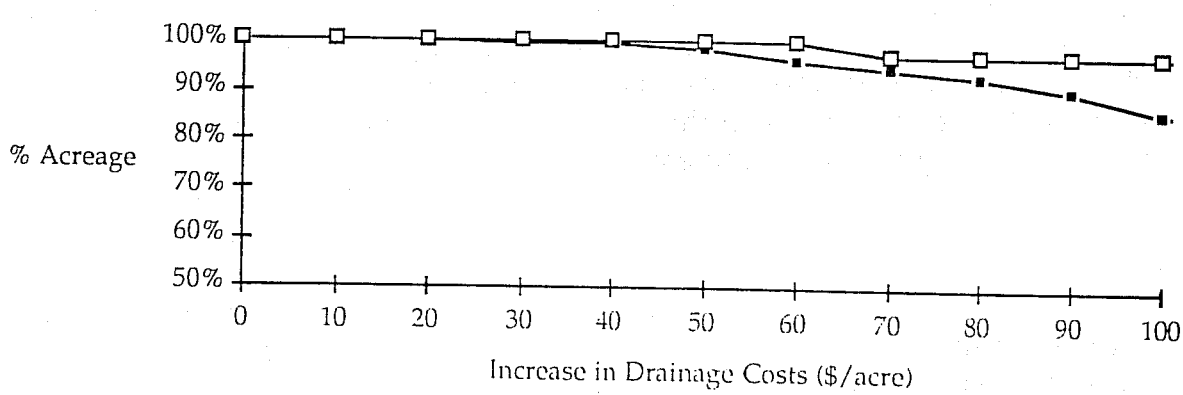

FIGURE 58

PART IV: CONCLUSIONS

Since the initial drainage study was completed in 1987, California agriculture has been subjected to one of the most severe and long-lasting droughts in recent memory. In spite of the significant changes undergone by the sector, the implications of the drought on the original study are not that substantial—the drought has reinforced many of the conclusions and has helped identify some important issues that the Regional Quality Control Board might find valuable for future study and subsequent policy-making.

The immediate impact of the drought came via the cutbacks in water delivery and the subsequent increases in the cost of water to water districts. This led to the adoption of sprinkler and drip irrigation technologies, the increased adoption of more efficient furrow irrigation management methods (such as shortened furrows and alternate furrow irrigation), the alteration of crop mixes and acreage to give priority to high value and water efficient crops, and greater flexibility of water movement on the part of water district managers thus making it easier for farmers to adjust water application to the field conditions at the time of irrigation. In addition, the state has also made water available through the state water bank. As a result, the sector has been able to adjust to the drought so that revenues were not affected until the fifth year of the drought. Although conservation has been successful, questions still remain as to how to address water delivery to wildlife areas and wetlands—areas that once depended on agricultural drainage and now depend on declining water deliveries.[11]

Another consequence of the drought has been to highlight the differing responses by water districts based on the nature of their water rights. Those districts with the junior water rights (those with the least water and highest water costs during the drought period) were the most likely to adjust to water scarcity by changing technologies and behaviors, whereas those with the senior rights (those whose water was cutback less and later than the rest during the drought) were much slower to adjust and even then did so only incrementally. This distinction in response is a possible indicator of how well water markets might perform, i.e., where those who have the highest marginal value for water will generally use it most efficiently. Another potential indicator of water market performance is the performance of tiered water-pricing programs. The success of tier-pricing in local water districts showed how relatively simple differential pricing self-imposed by water districts can induce conserving behavior via the establishment of "norms" of water use for specific crops while generating some revenue for the districts.[12]

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[11]Another drawback to the water conservation has been that management of salt levels in the soil has been deemphasized and that once water is available it will have to be used for leaching.

[12]Since districts cannot make profits, the revenues were sometimes used in conservation loan programs.

Finally, the key result of the original study and of this update is that profits are important to predicting the success of any sort of regulatory program. The data gathered have shown that many irrigation technology and management changes occurred for cost rather than drainage considerations. In addition, the improved financial health of the agricultural sector has also helped to promote the institution of conservation changes that might not have occurred during the less financially secure but water abundant farm crisis period of the early- and mid-1980's.

With the above results in mind, we make the following recommendations as to what areas the Regional Water Quality Control Board may choose to direct further study in order that it might design better agricultural drainage policies. The topics are as follows:

- *Studying the financial impacts of drainage policies*: As discussed above, the financial health of farm operations are critical to the design and timing of drainage policies and the subsequent adoption of technologies and behaviors that will improve drainage quality. A possible approach could be undertaking general financial analyses of the farm sector and developing cash-flow models of farm operations.

- *Studying the impact of conservation on wetlands:* Conservation activities and water cutbacks generated farm-level improvements but further constrained the ability of wetlands and wildlife areas to get assured year-round supplies of water. Possible areas to concentrate on are the study of wetlands production functions that incorporate nontraditional irrigation strategies or cooperation in irrigation with local water districts.

- *Studying price and production uncertainty:* Price and production swings (as examples of economic instability and uncertainty) can potentially negate improvements in water use, especially as they affect the grower's ability to improve water management and drainage quality control. Therefore, drainage policies must address and compensate for the potential swings that can and do occur. Study of price and commodity behavior with respect to surface- and groundwater availability should be addressed.

- *Studying the interdependence of policies:* The influence of water supply policies, commodity programs, drainage regulations and regulations concerning pesticides and other chemicals all interact without there necessarily being any coordination among the relevant agencies. It would be important to study how closely agencies would have to coordinate to achieve a certain level of drainage quality as well as achieving the goals of other agencies with different objectives. A critical element to this examination would be the impact of different water market scenarios on the level and quality of policy coordination as well as on the design and success of individual agencies.

These topics are only suggestions for further study but do address many of the unanswered questions remaining. With the work completed so far, these issues could be addressed in a coherent and integrated manner.

APPENDIX: THE REGIONAL STORY

PREFACE AND OVERVIEW

This study has investigated some of the specifics regarding drainage and drainage-related issues in four water districts. In order to get a better and broader idea of the impact of the drought on drainage issues, we broadened the investigation to include the rest of California to get a more general idea of the changes that the drought has brought about. By doing this, we can fill out some of the missing pieces regarding farmer and water district behavior that did not necessarily come out of the information in the available drainage operation plans. Specifically, we can determine some general patterns of behavior with respect to groundwater use, technology decisions, pricing programs, etc.

The results of the survey (in which approximately 60% of the water districts in the Central Valley responded), show that California responded to the drought in a gradual manner. Appendix Table 1 shows that, as the drought continued and delivered irrigation water became more scarce, water districts began to increase the amount of groundwater pumping and they conserved water by altering their crop acreages, increasing their fallowing and adjusting their irrigation techniques. This delay is probably explained by the fact that existing reservoir stocks allowed farmers to delay having to respond to a lack of rainfall.

A district-level example of lagged acreage and water application is that of the Broadview Water District (Appendix Table 2). Broadview represents the upper bound of adjustment to the drought that has generally been accomplished. [It is important to note in the table that the most significant decreases in both acreage and applied water occurred in 1991.] On the other hand, districts with senior water rights and lower water costs would show much less change since they had no cutbacks in delivery until 1991 (and even then those cutbacks were much less draconian than for the other districts).

The principal changes that were undertaken in response to the drought can be categorized into long-term and short-term changes. The long-term changes included adoption of drip irrigation technologies and the adoption of tier-pricing programs. The adoption of drip technologies have become such that they are becoming the standard method of irrigation for such commodities as tree crops and high-value vegetables. Tier-pricing programs have brought about the institutionalization of lower "norms" of water usage backed up by penalties for extra-normal use. These programs were implemented even in water districts whose water supplies were less vulnerable. A good example of this is the Central California Irrigation District (CCID) which implemented a tier-pricing program and used the proceeds to invest in water-saving irrigation improvements and intends to use the water savings for future expansion of the district. Finally, the fact that interest rates are low (also discussed later) has also promoted the longer-term and irreversible changes by making it easier to invest in district- and farm-level water conservation.

With respect to short-term and reversible changes, changes in crop mixes and land fallowing have been the most significant. Although acreage in water-demanding field crops have declined and fallowing has increased, once prices in the field crops rise and/or the drought is alleviated and water deliveries return to their traditional levels, it is not inconceivable that some farmers could revert to their pre-drought crop mixes.

An important qualifying note to the drought-induced scarcity of water and the resulting water conservation is its effect on rural non-agricultural water users such as wetlands and wildlife areas. Prior to the crisis in the Kesterson Reservoir, agricultural drainage had played an important part in maintaining wildlife areas but with the exclusion of agricultural drainage from those areas combined with water delivery cutbacks, these wildlife areas are quite vulnerable. The Grasslands Water District has reported a steady degradation of their habitat along with outbreaks of avian cholera, all believed to be the result of a lack of water. They are currently looking into the development of an irrigation system that could address their year-round need for water.

Appendix Table 1:
Summary Table of Water Sources and Fallowed Acreage

	Project Water	Non-Project Water	Ground-Water Pumped	Acreage Fallowed
	——Thousands of AF——			Thousands of Acres
Northern San Joaquin				
1987	1112	2086	199	117
1988	1087	1653	324*	117
1989	1128	2048	140	102
1990	962	1908	164	104
1991	846	1613	198	157
Central & Southern San Joaquin				
1987	1818	411	189	109
1988	1787	198	186	119
1989	1954	335	196	148
1990	1372	203	388	129
1991	511	436	677	211
All Other Regions				
1987	258	5482	36	34
1988	289	5879	22	28
1989	300	6047	27	26
1990	307	6126	39	25
1991	249	6071	48	30
TOTAL				
1987	3188	7980	425	259
1988	3163	7730	532*	264
1989	3382	8430	363	276
1990	2641	8238	592	258
1991	1606	8120	923	397

*One water district drastically increased amount of groundwater pumped this year because appropriative source was reduced.

Table 2: Broadview Water District Crop Acreage and Applied Water per Acre of Crop

	1986/88	1989	1990	1991
	—Acres—			
Cotton	4,100	4,649	4,416	3,828
Melons	1,095	1,279	814	198
Wheat	939	708	903	304
Alfalfa Seed	813	694	549	456
Tomatoes	627	840	850	662
	—AF/Acre—			
Cotton	3.20	3.34	2.84	2.40
Melons	2.11	1.93	1.79	1.46
Wheat	2.30	3.02	2.18	1.60
Alfalfa Seed	2.06	1.84	1.88	1.36
Tomatoes	3.22	2.72	3.03	2.69

Source: Broadview Water District 1992 Drainage Operation Plan

THE SURVEYS

The above information was gathered via two surveys conducted in the summer of 1991.[1] The first survey was directed towards California water districts to determine how they reacted to the drought and the second was directed towards irrigation dealers to get an idea as to how new irrigation technologies were adopted in California.

Water Districts Survey

The purpose of this survey was to analyze California's water districts and farmers' responses to the drought during the period 1987-1991. A total of 135 water districts in the state were surveyed through questionnaires, both by telephone and by mail, to gather information about changes in practices by water districts and changes in irrigation, cropping, and groundwater usage by farmers. Additional information about existing water distribution arrangements, water exchange facilities, and any changes therein over the last five years was also obtained. The districts surveyed were those which primarily provided services for agriculture in California. The survey was conducted during the summer of 1991.

Over 11 million acres, including 6.5 million irrigable acres, are served by these 135 water districts. The observations were aggregated into 11 water regions, and each water district was assigned to the county in which its headquarters were located. These regions and number of districts responding are as follows:

1. Central Coast	5	7. Mountain	11
2. Sacramento Valley	24	8. Southern California	17
3. San Joaquin Valley	17	9. Riverside	6
4. Fresno	9	10. Imperial	2
5. Kings and Tulare	17	11. San Diego	15
6. Kern	12		
		TOTAL	135

Irrigation Dealers Survey

The water districts provide only a part of the picture of some important phenomena, for example, adoption of low-volume irrigation, modernization, and automation of existing irrigation systems, in particular, groundwater pumping by

[1]David Zilberman, et. al., Lessons from California's Response to the Drought: On Behavior under Uncertainty, Department of Agricultural and Resource Economics, University of California, Berkeley, California, 1992.

farmers. To gain more insight about this issue, dealers who sell irrigation and pumping equipment to farmers and provide guidance and information regarding irrigation management were surveyed. Forty-five dealers whose names were obtained from the Irrigation Association of the United States were surveyed, and 28 complete responses were received.

Each dealer surveyed was asked about trends in sales of different types of irrigation technology, pumps, and automation. They were also asked to provide us with information about the services they offered their clients (do they sell only hardware or do they also provide advice). Finally, they were asked about their assessment of land shares of different irrigation technologies in their region of operation.

The dealers who were sampled are widely distributed throughout the state. The geographical distribution of our sample, by counties, is as follows[2]:

Riverside	3	Los Angeles	1	Napa	2
Butte	1	Monterey	1	Colusa	1
Mendocino	1	Stanislaus	1	Tulare	4
Santa Barbara	2	Merced	1	Yolo	1
Sutter	1	Fresno	2	Kern	1
San Joaquin	2	Sonoma	2	San Diego	1

The majority of the dealers included in the survey were those generating 50 percent or more of their total revenue from agriculture. Answers provided by dealers show that, even though they all generate their revenues primarily from the sales of irrigation equipment, they are also involved in several other irrigation-related activities as well. Approximately 50 percent of those sampled provide design of agricultural irrigation systems as a service to their customers. Furthermore, over 60 percent of the dealers responding to our questionnaire provide installation of equipment and/or related activities. The majority of dealers who responded did not engage in marketing activities (only three do). Among other activities, although of diminishing importance, are rental of equipment and irrigation- related consulting services.

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[2]As will be seen later, not all dealers responded to all questions included in the survey. Reasons for this vary, some of them do not sell or rent pumps, or they sell irrigation equipment for one crop only, are some of the reasons stated by the dealers.

SURVEY RESULTS

Water Deliveries

Although 1987 was the official start of the drought, water deliveries to agriculture below contracted levels did not occur until 1990. This was due mainly to the storage capacities of reservoirs in the various California watersheds. Because the low 1987 rainfall does not show up until the 1988 storage year, the dip in reservoir levels is not manifested until 1988 (see Appendix Figure 1). [Since the figure represents storage levels of the two largest CVP dams as of December 31 of each year, which would be before the winter rains, the important aspect to note is the change from year to year rather than the actual reservoir level in any single year.] Although the decline in reservoir levels after 1987 is significant, it was not until 1989 and 1990 that similar declines occurred in CVP diversions (see Appendix Figure 2) and in district-level deliveries. The decline in water deliveries by 1990 is evident in Appendix Table 3.[3] Annual CVP water deliveries to water districts responding to the survey which had junior water rights were over 2 million AF annually from 1987 through 1989, but declined to 1.69 million AF in 1990 and to 1.07 million AF in 1991. These junior water rights holders were the first to experience substantial cutbacks in deliveries and had to adjust accordingly. Westlands Water District, as a CVP contract holder, received its average entitlement of approximately 1.2 million AF in 1987, 1988, and 1989, but only received 0.92 million AF in 1990 and 0.34 million AF in 1991. Water districts holding senior rights (such as riparian and appropriative rights), have also experienced cutbacks in water deliveries, but nowhere near the degree experienced by the junior water rights holders. The Imperial region has appropriative rights to Colorado River water and has thus maintained a stable level of approximately 5 million AF throughout the period of the drought.

Declining reservoir levels are also implicit in water deliveries by the State Water Project (SWP). SWP water deliveries hovered at or over 400 thousand AF from 1987 through 1990, but declined drastically in 1991 to only 89 thousand AF. Kings and Tulare, Kern, and Southern California all had drastic cutbacks of SWP water deliveries in 1991.

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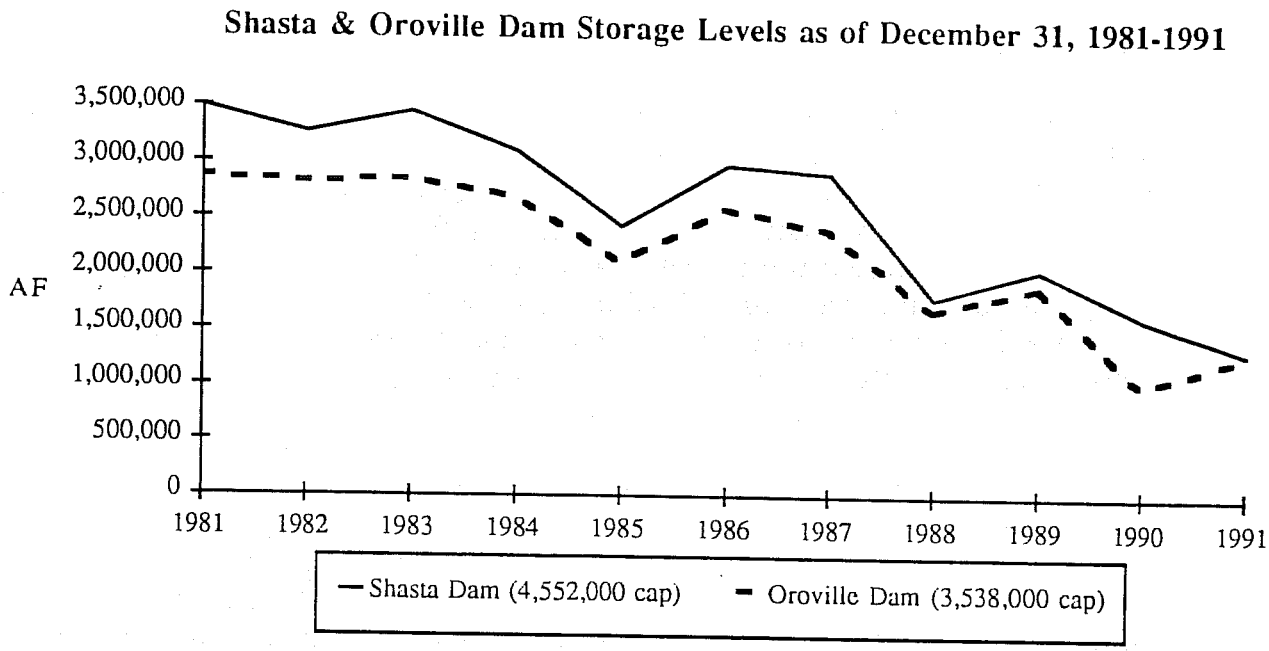
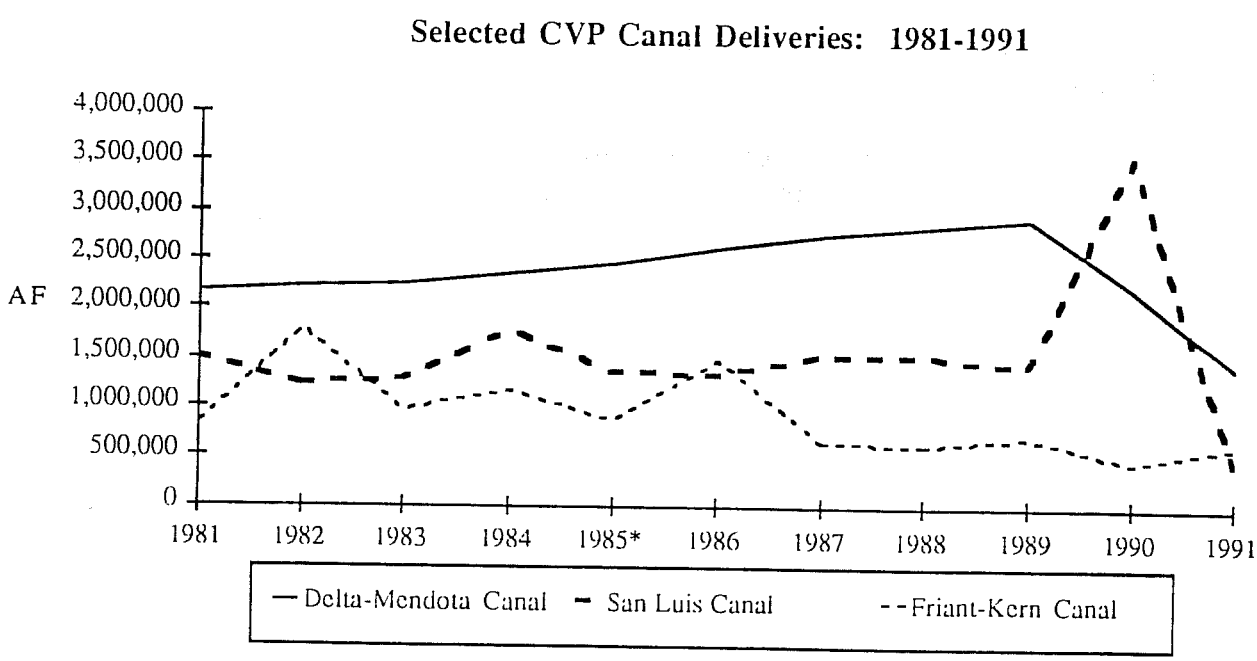
[3]For a breakdown of counties in the regions of Appendix Table 3, see the end of this appendix.



Appendix Figure 1



Appendix Figure 2

TABLE 3: Water Deliveries by Source
(in parentheses are no. of districts responding)

		1987 (Acre Feet)	1988 (Acre Feet)	1989 (Acre Feet)	1990 (Acre Feet)	1991 (Acre Feet)
All Districts	CVP	2,120,674(51)	2,098,986(51)	2,171,763(51)	1,691,700(51)	1,072,418(51)
	CVP Exchange	570,910(29)	576,490(30)	557,010(30)	543,060(30)	444,529(30)
	SWP	496,260(35)	487,107(35)	653,457(35)	406,415(36)	89,060(36)
	Riparian	114,109(28)	104,669(28)	139,422(29)	98,668(29)	148,150(29)
	Appropriative A	5,019,207(41)	4,702,058(41)	5,301,460(41)	5,084,864(41)	4,876,070(39)
	Appropriative B	2,672,010(28)	2,891,018(28)	2,948,408(28)	2,982,735(28)	2,974,957(27)
	Other	174,478(24)	32,045(23)	40,515(24)	71,477(25)	121,070(26)
Central Coast	CVP	124,037(2)	142,133(2)	139,203(2)	145,082(2)	108,450(2)
	CVP Exchange	0(1)	0(1)	0(1)	0(1)	0(1)
	SWP	0(1)	0(1)	0(1)	0(1)	0(1)
	Riparian	0(1)	0(1)	0(1)	0(1)	0(1)
	Appropriative A	68,769(3)	76,291(3)	71,154(3)	73,829(3)	64,000(3)
	Appropriative B	0(1)	0(1)	0(1)	0(1)	0(1)
	Other	0(1)	0(1)	0(1)	0(1)	0(1)
Sacramento Valley	CVP	380,153(13)	363,314(13)	385,790(13)	305,808(13)	250,792(13)
	CVP Exchange	0(7)	0(7)	0(7)	0(7)	0(7)
	SWP	0(7)	0(7)	0(7)	0(7)	0(7)
	Riparian	0(5)	0(5)	0(5)	0(5)	0(5)
	Appropriative A	1,464,926(9)	1,368,775(9)	1,493,667(9)	1,411,244(9)	1,209,288(8)
	Appropriative B	0(6)	0(6)	0(6)	0(6)	0(6)
	Other	151,000(7)	0(6)	0(6)	0(6)	0(6)

TABLE 3: Water Deliveries by Source
(in parentheses are no. of districts responding)

		1987 (Acre Feet)	1988 (Acre Feet)	1989 (Acre Feet)	1990 (Acre Feet)	1991 (Acre Feet)
Mountain	CVP	18,693(6)	16,719(6)	18,263(6)	13,358(6)	13,500(6)
	CVP Exchange	0(4)	0(4)	0(4)	0(4)	0(4)
	SWP	0(4)	0(4)	0(4)	0(4)	0(4)
	Riparian	33,000(4)	33,000(4)	33,000(4)	33,000(4)	33,000(4)
	Appropriative A	172,940(5)	183,086(4)	181,867(4)	178,183(5)	118,800(4)
	Appropriative B	0(4)	0(4)	0(4)	0(4)	0(4)
	Other	9,916(3)	8,874(3)	12,385(3)	10,743(3)	9,326(3)
San Joaquin Valley	CVP	199,509(6)	187,203(6)	205,873(6)	133,823(6)	165,900(6)
	CVP Exchange	532,400(3)	536,810(4)	536,810(4)	522,860(4)	428,829(4)
	SWP	0(2)	0(2)	0(2)	0(2)	0(2)
	Riparian	24,125(3)	30,703(3)	27,792(3)	40,445(3)	34,000(3)
	Appropriative A	445,976(3)	253,499(3)	526,848(3)	456,535(3)	369,895(3)
	Appropriative B	0(2)	0(2)	0(2)	0(2)	0(2)
	Other	0(2)	0(2)	0(2)	0(2)	0(2)
Fresno	CVP	1,242,610(4)	1,246,985(4)	1,246,881(4)	963,146(4)	356,025(4)
	CVP Exchange	20,200(2)	20,200(2)	20,200(2)	20,200(2)	15,700(2)
	SWP	0(2)	0(2)	0(2)	0(2)	0(2)
	Riparian	9,700(3)	9,700(3)	9,700(3)	9,700(3)	7,600(3)
	Appropriative A	221,810(4)	90,382(4)	144,222(4)	82,752(4)	141,300(4)
	Appropriative B	0(2)	0(2)	0(2)	0(2)	0(2)
	Other	0(2)	0(2)	0(2)	0(2)	0(2)

TABLE 3: Water Deliveries by Source
(in parentheses are no. of districts responding)

		1987 (Acre Feet)	1988 (Acre Feet)	1989 (Acre Feet)	1990 (Acre Feet)	1991 (Acre Feet)
Kings and Tulare	CVP	81,465(7)	72,400(7)	90,475(7)	65,110(7)	91,700(7)
	CVP Exchange	18,310(1)	19,480(1)	0(1)	0(1)	0(1)
	SWP	50,738(2)	51,760(2)	55,939(2)	38,157(2)	0(2)
	Riparian	284(1)	266(1)	162(1)	523(1)	0(1)
	Appropriative A	132,523(3)	66,593(3)	112,666(3)	58,468(3)	126,800(3)
	Appropriative B	(0)	(0)	(0)	(0)	(0)
	Other	(0)	(0)	(0)	(0)	15,732(1)
Kern	CVP	36,400(2)	31,200(2)	39,200(2)	27,200(2)	40,000(2)
	CVP Exchange	0(1)	0(1)	0(1)	0(1)	0(1)
	SWP	368,041(6)	344,600(6)	501,249(6)	257,704(7)	7,993(7)
	Riparian	47,000(2)	31,000(2)	68,000(2)	15,000(2)	72,000(2)
	Appropriative A	0(1)	0(1)	0(1)	0(1)	0(1)
	Appropriative B	0(1)	0(1)	0(1)	0(1)	0(1)
	Other	0(1)	0(1)	0(1)	37,000(2)	73,000(2)
Southern California	CVP	30,619(4)	30,614(4)	37,338(4)	30,544(4)	39,200(4)
	CVP Exchange	0(3)	0(3)	0(3)	0(3)	0(3)
	SWP	21,599(5)	20,460(5)	25,188(5)	24,987(5)	9,737(5)
	Riparian	0(2)	0(2)	768(3)	0(3)	1,550(3)
	Appropriative A	1,787(3)	1,599(3)	1,801(3)	1,778(3)	31,257(3)
	Appropriative B	330(3)	698(3)	634(3)	891(3)	310(3)
	Other	0(2)	0(2)	1,080(3)	1,145(3)	0(3)

TABLE 2: Water Deliveries by Source
(in parentheses are no. of districts responding)

		1987 (Acre Feet)	1988 (Acre Feet)	1989 (Acre Feet)	1990 (Acre Feet)	1991 (Acre Feet)
Riverside	CVP	0(1)	0(1)	0(1)	0(1)	0(1)
	CVP Exchange	0(1)	0(1)	0(1)	0(1)	0(1)
	SWP	0(1)	0(1)	0(1)	0(1)	0(1)
	Riparian	0(1)	0(1)	0(1)	0(1)	0(1)
	Appropriative A	34,955(2)	23,699(2)	28,567(2)	33,727(2)	24,847(2)
	Appropriative B	4,790(2)	5,267(2)	5,345(2)	7,197(2)	0(1)
	Other	7,564(1)	17,755(1)	22,895(1)	21,989(1)	21,012(1)
Imperial	CVP	(0)	(0)	(0)	(0)	(0)
	CVP Exchange	(0)	(0)	(0)	(0)	(0)
	SWP	(0)	(0)	(0)	(0)	(0)
	Riparian	(0)	(0)	(0)	(0)	(0)
	Appropriative A	2,457,444(2)	2,628,626(2)	2,719,656(2)	2,773,311(2)	2,773,912(2)
	Appropriative B	2,666,891(1)	2,885,053(1)	2,942,429(1)	2,974,647(1)	2,974,647(1)
	Other	(0)	(0)	(0)	(0)	(0)
San Diego	CVP	7,188(6)	8,418(6)	8,740(6)	7,630(6)	6,851(6)
	CVP Exchange	0(6)	0(6)	0(6)	0(6)	0(6)
	SWP	55,882(5)	70,287(5)	71,081(5)	85,567(5)	71,330(5)
	Riparian	0(6)	0(6)	0(6)	0(6)	0(6)
	Appropriative A	18,077(6)	9,508(6)	21,012(6)	15,036(6)	15,970(6)
	Appropriative B	0(6)	0(6)	0(6)	0(6)	0(6)
	Other	5,998(5)	5,416(5)	4,155(5)	600(5)	2,000(5)

Groundwater Pumping

The declines in reservoir levels and subsequent cutbacks in water deliveries have forced water districts and farmers served by the water projects to maintain their own water consumption via increased pumping of groundwater. Once cutbacks in water delivery were implemented, the data show that groundwater pumping increased dramatically. Districts responded by pumping additional groundwater from district-owned wells as did farmers who pumped from their private wells.

Statewide, 26 percent of all districts pumped additional groundwater due to the drought (see Appendix Table 4). In the San Joaquin Valley and in Southern California, at least 50 percent of the responding districts pumped additional groundwater from district-owned wells. Additional groundwater totaling 19.76 thousand AF was pumped by 13 districts in the San Joaquin Valley. However, within districts, the response varied considerably. In 1991 some districts showed a dramatic increase in groundwater pumping. (One water district increased annual groundwater pumping from 2,000 AF to 20,000 AF per year and, as a result, are experiencing a declining water table.) In contrast, in one district in Southern California, less groundwater was pumped in response to the drought because the district resorted to severe water delivery rationing, and successfully reduced water usage by 30 percent from the 1986-1990 average. In the Mountain, Fresno, and Kings and Tulare regions, only 12-14 percent of the responding districts pumped additional groundwater, while the Imperial region districts pumped no groundwater whatsoever.

Survey responses also reported the degree to which farmers pumped additional groundwater in response to the drought. According to the surveys, 66 percent of the districts reported that farmers pumped an additional 1.31 million AF of groundwater . All of the San Joaquin water districts reported that farmers pumped additional groundwater. In the Sacramento and Kings and Tulare regions, although a high proportion of districts did not pump additional groundwater, over 80 percent of the regions' districts reported farmers pumping additional water. Seven districts in each of these two regions pumped 0.6 million AF of additional groundwater. In the Fresno region the absolute amounts of groundwater pumped were larger than in other regions, and two districts pumped 100,000 AF of groundwater.

In Table 3, we see that the amount of groundwater pumped increased from 425 thousand AF in 1987 to 923 thousand AF in 1991 for all districts. In Southern California, the number of wells in use doubled and the amount of groundwater pumped increased from 1,252 AF to 17,670 AF for four districts. The San Joaquin Valley had the largest number of wells, and groundwater pumping in the region increased from 1989 to 1991. In sharp contrast, in the Riverside region the number of wells decreased between 1987 and 1991 for one district and the amount of groundwater pumped decreased also.

Looking at a sample of districts serviced by the CVP taken from the survey

(Appendix Table 5), it can be seen that there was an almost 80 percent increase in the volume of groundwater pumped between 1989 and 1990, and a 9 percent increase in the number of wells used between 1989 and 1991. Interestingly, exchange contractors significantly increased pumping in 1989, 1990, and 1991 without a significant addition of wells, whereas junior water rights districts significantly increased pumping in 1989, 1990, and 1991 but did not add a significant number of wells until 1991 (Appendix Table 6).

Looking at a longer series for an individual district with no district-owned pumps, it can be seen that the Westlands Water District (Appendix Table 7) increasingly relied on groundwater pumping by its members. The Friant Unit (Appendix Table 8 and Appendix Figure 3) just to the south of Westlands exhibits similar behavior where cutbacks in water delivery forced increases in groundwater pumping. This is implied by the measured change in groundwater storage. The table also shows that, when the Class 2 water (the water delivered by the CVP after all other priority needs are met) was cut, net groundwater recharges decreased; and when significant water delivery cuts occurred, there were net drawdowns of groundwater. Although the Friant data predate the first significant cutbacks in 1990, it can be extrapolated that even more severe drawdowns occurred when Class 1 water was cut to 50 percent of its allocation. Other indirect indicators of increased groundwater pumping occurred in the Central California Irrigation District (CCID) where, over the course of 1991, the groundwater levels under two towns encompassed by the district (although not part of the district) experienced declines of 45 feet and 50 feet while CCID itself experienced an average decline of 14 feet.

Using information from the survey of irrigation dealers, an index sales of water pump sales in 1990 relative to 1987 was calculated. This data is found in Column VI of Appendix Table 9. Generally, the table shows a high ratio of pump sales in 1990 with respect to 1987 for most of the dealers in the sample. Moreover, those areas most affected by the drought show unusually high pump sales ratios. Among the highest sales ratios are those of Riverside, Sonoma, and Tulare. Both the Riverside and Tulare areas have served farmers who faced substantial cutbacks in their surface water deliveries. Sonoma farmers who rely mainly on groundwater were forced by the drought to dig new and deeper wells.

TABLE 4: Steps Taken by the District in Response to the 1991 Drought

	Pumped Additional Groundwater (Percentages of Districts)	Amount of Groundwater Pumped (Acre Feet)	Lined District Canals (Percentages of Districts)	Canals Lined (Miles)	Offered Assistance to Growers For Irrigation Scheduling (Percentages of Districts)	Installed Pressurized Pipelines (Percentages of Districts)
All Distircts	25	274,165	11	114	45	12
Central Coast	20	2,000	NA	NA	60	20
Sacramento	19	20,000	NA	NA	61	6
Mountain	14	3,000	14	NA	11	25
San Joaquin	54	197,060	23	6	38	15
Fresno	25	5,255	13	1	50	13
Kings & Tulare	12	25,000	19	3	35	7
Kern	22	NA	0	NA	67	0
Southern California	53	20,350	0	NA	29	14
Riverside	17	1,500	33	4	80	17
Imperial	0	NA	100	100	100	0
San Diego	7	NA	0	NA	36	14

	Offered Assistance to Growers For Changes in Irrigation Methods (Percentages of Districts)	Changed Water Allocation Schedule (Percentages of Districts)	Changed Water Pricing Practice (Percentages of Districts)	Reported Increases in Number of Exchanges Among Growers (Percentages of Districts)	Indicated that Increases were due to the drought (Percentages of Districts)
All Distircts	38	53	50	53	73
Central Coast	40	40	0	0	0
Sacramento	72	61	44	75	100
Mountain	33	50	38	0	NA
San Joaquin	31	69	46	50	60
Fresno	13	50	25	83	50
Kings & Tulare	25	25	53	78	100
Kern	11	44	44	33	50
Southern California	43	57	47	0	0
Riverside	33	33	50	0	0
Imperial	100	0	50	0	0
San Diego	36	86	100	0	0

Appendix

TABLE 5: Number of Wells and Acre Feet of Pumped Groundwater Supplied by the District
(in parentheses are no. of districts responding)

	1987		1988		1989		1990		1991	
	Wells	AF pumped	Wells	AF Pumped	Wells	AF Pumped	Wells	AF Pumped	Wells	AF Pumped
All Districts	493(67)	424,758(46)	721(67)	532,267(46)	442(67)	362,719(46)	449(67)	591,833(47)	480(69)	922,749(52)
Central Coast	8(3)	199 (3)	8(3)	302(3)	8(3)	200(3)	8(3)	2,576(3)	8(3)	2,000(3)
Sacramento Valley	21(13)	4,400 (6)	21(13)	4,382(6)	21(13)	7,986(6)	26(13)	13,707(6)	26(14)	21,500(7)
Mountain	2(6)	0(3)	2(6)	0(3)	3(6)	0(3)	3(6)	1,378(4)	3(6)	3,000(4)
San Joaquin Valley	296(9)	194,787(6)	526(9)	319,599(6)	246(9)	131,801(6)	247(9)	150,779(6)	251(9)	176,008(8)
Fresno	54(6)	25,998(5)	54(6)	24,871(5)	54(6)	35,298(5)	55(6)	61,372(5)	60(6)	73,905(5)
Kings and Tulare	46(12)	31,253(11)	46(12)	29,444(11)	46(12)	28,707(11)	46(12)	26,545(11)	46(12)	24,057(11)
Kern	0(5)	0(4)	0(5)	0(4)	0(5)	0(4)	0(5)	0(4)	2(5)	4,000(4)
Southern California	18(6)	1,252(4)	18(6)	185(4)	19(6)	462(4)	19(6)	2,234(4)	37(6)	17,670(4)
Riverside	41(1)	33,735(1)	39(1)	21,367(1)	38(1)	26,131(1)	38(1)	33,242(1)	33(1)	23,104(1)
Imperial	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)
San Diego	7(5)	1,134(1)	7(5)	117(1)	7(5)	134(1)	7(5)	0(1)	14(6)	2,505(3)

Appendix
Table 6: Groundwater Pumping in CVP Sample, 1987-91

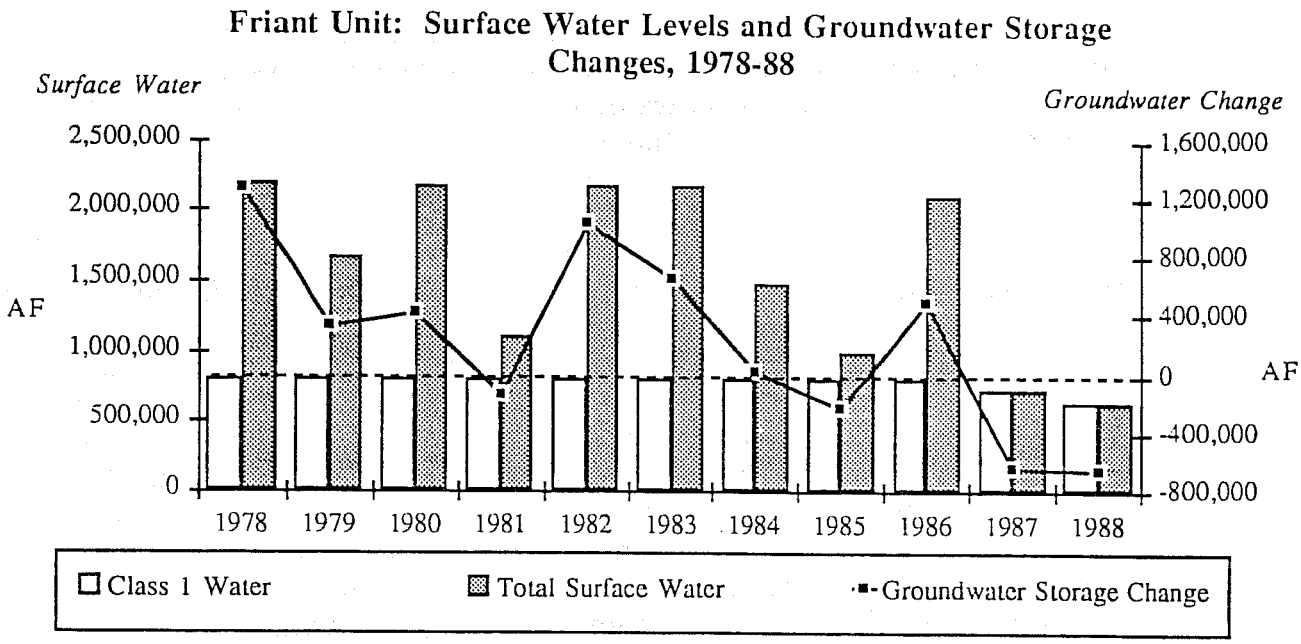
	Exchange Contractors		Non-Exchange Contractors	
	Number of Wells	Groundwater Pumped (AF)	Number of Wells	Groundwater Pumped (AF)
1987	100	43,651	20	1,787
1988	100	58,515	20	1,599
1989	100	59,805	22	5,301
1990	102	108,797	22	7,857
1991	104	135,657	29	24,913

Appendix
Table 7: Westlands WD Water Use

	Project Water		Groundwater		Total Water
	(AF)	%	(AF)	%	(AF)
1980-81	1,244,446	93%	99,000	7%	1,343,446
1981-82	1,236,639	92%	105,000	8%	1,341,630
1982-83	1,090,888	97%	31,000	3%	1,121,888
1983-84	1,473,883	95%	73,000	5%	1,546,883
1984-85	1,315,548	85%	228,000	15%	1,543,548
1985-86	1,194,113	88%	145,000	11%	1,359,708
1986-87	1,309,252	89%	159,000	11%	1,468,252
1987-88	1,270,213	92%	160,000	12%	1,380,917
1988-89	1,157,908	87%	175,000	13%	1,332,908
1989-90	920,681	75%	300,000	25%	1,220,681

Table 8: Friant Unit Contract Water Availability and Groundwater Storage Change

	Class 1 Water (AF)	Class 2 Water (AF)	Total (AF)	Groundwater Storage Change (AF)
1978	800,000	1,388,800	2,188,800	1,274,453
1979	800,000	868,115	1,668,115	343,792
1980	800,000	1,377,212	2,177,212	428,994
1981	800,000	302,987	1,102,987	-125,919
1982	800,000	1,376,288	2,176,288	1,032,360
1983	800,000	1,378,084	2,178,084	656,828
1984	800,000	689,042	1,489,042	23,107
1985	800,000	192,966	992,966	-220,487
1986	800,000	1,301,079	2,101,079	502,953
1987	728,000	0	728,000	-630,714
1988	640,000	0	640,000	-650,000



Appendix Figure 3

Adoption of Modern Irrigation Technologies

With cutbacks in water deliveries, growers have been forced to alter management practices and crop and technology choices in order to deal with the increasing scarcity of water. With respect to technology choice, there are two concurrent approaches being used. The first is more efficient use of the grower's existing technology—such as irrigating alternate furrows and using gated pipes or siphon tubes. The second is adopting new irrigation technologies where they are most cost-effective. The first approach is generally used on the lower-value crops such as cotton, whereas the second approach is used on higher-value crops such as vegetables.

An example is the Broadview Water District where farmers are using sprinklers for pre-irrigation of cotton where the key is to achieve even water application prior to planting. Afterwards, alternate furrow irrigation is used. [It should be noted that sometimes there are constraints to complete adoption of new irrigation technologies—sprinkler or drip irrigation could not be used for later irrigation events in Broadview because of the danger of cracking soils.] In the case of a high-value crop such as processing tomatoes, Broadview growers have adopted the use of sprinklers for the first <u>two</u> irrigation events. On the other hand, growers in exchange districts such as CCID have generally been less inclined to adopt new production methods or

technologies, probably due to their greater security of surface water supply. An exception to this disinclination is their increased willingness to install tailwater return systems and sprinkler systems for high-value crops under a very advantageous conservation loan program run by the district. At a broader level, the water districts survey reports that water districts are offering to assist growers in changing irrigation methods. Appendix Table 4 shows that 72 percent of water districts in the Sacramento Valley offered such assistance. One water district in the Sacramento Valley offers a price rebate to participators in water conservation programs.

Analyzing the adoption of new irrigation technologies at a statewide and regional level, the survey results show that over 35 percent of farmers in all the responding districts installed new sprinklers on 59,000 acres of land, while 33 percent installed new drip irrigation on 21,000 acres. Farmers in the Central Coast were more likely to adopt sprinklers and drip as compared to other regions. In the San Joaquin Valley, Mountain, Kings and Tulare, and Imperial regions, farmers were more likely to adopt sprinklers than drip irrigation systems. The adoption of sprinkler irrigation was significant in Kings and Tulare where farmers in seven districts adopted new sprinkler irrigation on 42,000 acres. A substantial adoption of new drip irrigation occurred in Southern California where farmers in two districts installed drip on 14,000 acres of land. Analyzing the shares of different technologies in irrigated acreage in each region, one finds a tendency towards a reduction in the share of border and furrow irrigation and an increase in the share of sprinklers and drip irrigation. For example, in the Kings and Tulare region, the percentage of acreage under border declined from 31 percent in 1987 to 27 percent in 1991, while furrow irrigation declined from 36 percent to 26 percent over the same period. Microsprinkler shares in this region increased dramatically from 33 percent to 86 percent, while the share of drip increased from 9 percent to 25 percent.

Using information gathered from the irrigation dealers survey, dealers were asked to assess their estimates of the extent of use of different types of irrigation equipment for the period 1987-1991 and for those crops on which the irrigation equipment they sell is used. For the purpose of this study, crops were divided in four main groups: (a) citrus, (b) fruits and nuts, (c) grapes, and (d) vegetables. Dealers were asked to assess the use of different irrigation systems as a percentage of total acreage. This data shows that use of drip increased dramatically over the 1987-1991 period. Nevertheless, use of furrow remained above 30 percent of total acreage at the end of the period. Use of sprinkler on vegetables rose significantly. It is important to mention that according to the data collected, vegetables was the only crop group which depicted an increase in sprinkler use.

A drip use ratio (Appendix Table 9, Columns VIII to X) was calculated for selected crops and for selected dealers using 1987 as a base year. Again, note the high ratio values for fruits and nuts and citrus; they indicate a sharp increase in the use of low-volume irrigation technologies during the 1987-1990 period.

Land Allocation

It is hypothesized that the drought would induce a shift in cropping patterns from highly water-intensive but low-value crops towards high-value crops, possibly requiring less applied water per acre. This would reflect a movement towards increasing the return from each unit of the scarce input—water. Thus, one would expect to see a shift in cropping patterns away from the production of low-value crops such as alfalfa, hay, cotton, and rice, which require 4 to 7 AF of water per acre, towards small grains which are drought resistant, or high-value crops such as vegetables which also require less water per acre than the field crops.

The survey results indicate that the hypothesis generally fits the facts. In the Central Coast the main crops were tomatoes, rice, corn, and fruits and nuts. At least one district fallowed pastureland. In the Sacramento region, the main crops were rice, fruits and nuts, grain, alfalfa, wheat, and sugar beets. The crops with reductions in acreage were rice, sugar beets, and alfalfa; crops with increases in acres were grains, orchards, and vegetables. Total acreage affected was 48,000 acres within seven districts; two districts resorted to fallowing land. In the San Joaquin Valley the main crops were fruits and nuts, alfalfa, and cotton. There was a reduction in cotton, corn, alfalfa, and grain, and an increase in tomatoes, safflower, and sugar beets. Switching of crops occurred over 2,000 acres of land in one district, and two districts reported fallowing land. In the Fresno region, one district switched 75 acres from sugar beets, which requires 5 AF of water per acre, to cotton which requires 2 to 3 AF of water per acre.

In the Kings and Tulare region there was a switch from cotton and alfalfa to tomatoes, other vegetables, and fallowed land. At least 45,800 acres in cotton and alfalfa were reduced in this region. Due to the drought, farmers in one water district in this region set aside 25 percent of agricultural land which amounted to 130,000 acres. In the Kern region where the main crops were grapes, vegetables, cotton, and hay, there was a significant fallowing of grain and lettuce land totaling 14,830 acres. One water district leased 1,000 acres from farmers to fallow In the Mountain region at least two districts reported a shift from alfalfa to grain on over 500 acres. In Imperial over 150 acres under alfalfa and hay were shifted to fruits. In San Diego there was one district which reported fallowing land that had been planted in vegetables.

Westlands The Westlands Water District consists of over 600,000 acres in Fresno and Kings counties, with over 600 member-farm operations. The district primarily grows cotton, tomatoes, cantaloupes, and lettuce. Acreage and yield trends show that high-value vegetables are increasingly important relative to field crops. Specifically, since the drought began in 1988, there has been a large increase in acreage devoted to processing tomatoes, garlic, and onions. This is accompanied with general increases in gross value and gross value per acre.

Other high-value crops, such as spring lettuce and cantaloupes, have maintained high-acreage levels and gross values, although without a clear trend toward increased

or decreased acreage. Since 1988, almonds, a crop with a very high water demand, show a decrease in yield and gross value per acre, possibly indicating decreased irrigation for this tree crop. With respect to field crops, cotton remains the dominant crop. Cotton acreage more or less held steady through the mid-1980s but has declined since 1989, again possibly as a response to cotton's high water demand. Wheat acreage has declined since the early 1980s along with significant drops in total yield. It appears that, while cotton remains the dominant crop in Westlands since the drought began, the trend has been to take acreage out of low-value and/or high-water demand crops such as sugar beets and put it into higher-value vegetable crops.

Tehama-Colusa Canal Authority As with the Friant Unit, specific district-level production data for the Tehama-Colusa Canal Authority are unavailable. Therefore, county data for Colusa and Glenn counties are used (since these coincide with water-usage data presented later). In both counties, rice is the principal crop both in terms of acreage and value. In Colusa County, rice production increased from 1987 to 1988 and changed little in 1989, whereas acreage committed to processing tomatoes and wheat increased significantly from 1987 to 1989 (data were unavailable for 1990). While the increase in wheat acreage seems to go against the drought trend, the data show an increase in value per acre that was apparently sufficient to reverse the expected shift. In Glenn County, rice acreage fell significantly from 1989 to 1990, although not to the level of 1987. Alfalfa hay acreage has fallen since 1988, while prune acreage has increased since 1987 in spite of falling value per acre. To summarize, trends are a little unclear for this part of California; the drought may be having an effect but probably in less direct ways.

Surveyed Water Districts The fallowing of land reflects a grower's decision to economize on the use of his available water and allows for better irrigation for the reduced crop acreage. Table 9 shows the changes in fallowed acreage over the 1987-1991. Fallowed acreage increased from 259,300 acres to 397,200 acres, while irrigated acreage in 62 reporting districts decreased slightly from 2.7 million to 2.5 million acres. The Sacramento and Fresno regions first showed a slight increase in irrigated acreage from 1987 to 1989 and then a decrease with corresponding changes in fallowed land. The San Joaquin Valley region showed an increase in irrigated acreage over the period and a decline in fallowed land. This is commensurate with their ability to draw on large amounts of groundwater during this period. In the Imperial region the irrigated acreage increased moderately while fallowed land decreased because they were able to get all the water they needed from the Colorado River and were not significantly affected by the drought. Some of the regions showed a delayed response in acreage changes because water deliveries did not decline much in the first few years of the drought due to the presence of substantial stocks of water.

Appendix

Table 9: General Characteristics of Sample, Irrigation Dealers

I	II	III	IV	V	VI	VII	VIII	IX	X
							Drip use ratios		
id No	County	City	Ag. Rev as % of Total Revenue	Irri. Consult.	pump sales ratio 1990/1987	automated equip. sales ratio (90/87)	Citrus	Fruits and Nuts	Grapes
9	Colusa	Arbuckle	90	YE	1.52	1.19	6.00		
11	Sonoma	Santa Rosa	50	YE	1.06	1.27			1.20
12	Fresno	Selma	98	YE	na	1.46			
13	Riverside	Riverside	69	YE	2.90	3.12	1.25		
14	Santa Barbara	Santa Maria	80	YE	1.27	1.14			
18	Fresno	Fresno	100	YE	na	na			2.00
20	Tulare	Porterville	100	NO	3.27	na			
23	Los Angeles	L.A.	100	YE	1.76	1.27	1.48	1.48	
26	Riverside	Riverside	90	NO	1.32	1.00	1.17	na	
27	Tulare	Woodlake	99	YE	na	3.28	na	na	
29	San Joaquin	Stockton	90	YE	1.00	1.27		2.00	2.00
30	Sonoma	Sebastopol	65	YE	3.21	3.33			
31	Tulare	Delano	99	YE	na	0.00	1.05	3.00	1.17
35	Napa	Santa Elena	100	YE	na	1.14			na
37	Stanislaus	Oakdale	75	NO	1.44	1.28		na/11	
38	Santa Barbara	Santa Maria	95	YE	1.41	1.19			1.36
41	San Joaquin	Lodi	95	YE	na	na		3.00	1.25
44	San Diego	Santee	20	YE	na	1.27		1.29/1.29	
49	Monterrey	Salinas	100	YE	1.00	1.27		1.05	
52	Napa	Napa	50	YE	na	na			1.10
54	Sutter	Yuba City	60	NO	na	1.05		na/3.00/3.00	
56	Bute	Durham-Chico	90	YE	1.56	1.42		2/4,0/3.0	
57	Tulare	Visalia	99	NO	na	na	1.50		
58	Kern	Shafter	98	YE	1.70	na			
59	Merced	Dos Palos	98	YE	1.32	1.15		na	
61	Mendocino	Ukiah	70	YE	1.36	1.19			na
62	Riverside	Riverside	40	NO	3.02	2.90	1.12	1.00	
63	Yolo	Woodland	90	NO	1.33	1.00			

Irrigation Management on Existing Crops

In addition to the technology changes mentioned earlier, other technology choices are available to reduce water use without necessarily changing crops. In areas where water has been cut back substantially, and where changes in technology may not be feasible because of uncertainty with respect to further cutbacks in water deliveries, some growers are opting to stress crops more and force the roots to go down further to seek available groundwater. This is an extreme measure but feasible for short periods of time. In less extreme circumstances, a common choice for cutting back water use is the combination of shortening furrows to a half- or quarter-mile and installing tailwater return systems. The shortened furrows result in a more even application of water to the soil and, therefore, less waste (since a longer furrow must have more water applied per unit distance to ensure minimum wetting of soil at the end of the furrow). The tailwater return systems allow reuse of irrigation water through mixing with fresh water. In many Central Valley water districts, furrow shortening and tailwater return systems were consistently the first responses to water scarcity since they did not entail drastic technology changes.

The survey responses (see Appendix Table 10) show that farmers are indeed shortening furrow length and improving existing furrow irrigation. Thirty-five percent of all districts responding reported that farmers are improving existing furrow irrigation. In the Imperial, Fresno, Central Coast, Sacramento, and San Joaquin regions, at least 50 percent of the responding districts reported that farmers were undertaking such improvements. Furrows have been shortened on over 13,840 acres throughout the state, with 6,840 acres involved in the San Joaquin region, 5,500 acres in Kings and Tulare counties, and 1,500 acres in the Sacramento Valley. In one water district farmers have cut their furrow length in half and have laser leveled their fields; these farmers are also stretching the interval between irrigations from 10 days to 2 weeks.

Farmers are also lining ditches to increase the efficiency of water delivery to existing crops. In the San Joaquin Valley and the Imperial region, 41 miles of on-farm ditches have been lined. Most of this was done in the San Joaquin Valley where farmers lined 35 miles of ditches; 6 miles of ditches were lined in the Imperial Valley. In addition, 10 of the districts responding reported that farmers are laser leveling fields, irrigating during cooler hours, and monitoring water use carefully. Seven districts reported that farmers are stressing the crop by using less water, spacing out irrigations over longer intervals, and irrigating for shorter durations. Farmers in four districts are using tailwater returns, or are plugging leaks and installing gated pipes or siphon pipes.

Water districts are also helping farmers improve irrigation efficiency for existing cropping patterns by offering to assist growers in adopting irrigation scheduling. Forty-five percent of all responding districts have offered this assistance to growers (Appendix Table 4). Water districts are also trying to improve the efficiency of their deliveries by lining canals and installing pressurized pipelines. Approximately 114 miles of district canals have been lined across the state, with 100 miles lined in the Imperial Valley,

TABLE 10: Steps Taken by Farmers in Response to the 1991 Drought

	Pumped Additional Groundwater (Percentages of Districts)	Groundwater Pumped (Acre Feet)	Lined On-farm Ditches (Percentages of Districts)	Ditches Lined (Miles)	Shortened Furrow Length (Percentages of Districts)	Area Involved in Furrow Shortening (Acres)	Improved Existing Furrow Irrigation (Percentages of Districts)
All Distircts	66	1,892,600	6	41	24	13,840	35
Central Coast	50	NA	33	NA	67	NA	67
Sacramento	83	59,300	7	NA	31	1,500	50
Mountain	33	NA	0	0	13	NA	11
San Joaquin	100	76,600	8	35	50	6,840	50
Fresno	63	675,300	13	NA	50	NA	75
Kings & Tulare	88	623,100	6	NA	25	5,500	35
Kern	67	399,000	0	NA	22	NA	22
Southern California	67	59,300	0	0	0	0	25
Riverside	50	NA	0	0	50	0	17
Imperial	0	0	50	6	0	NA	100
San Diego	29	NA	0	0	0	0	0

	Introduced Sprinkler Irrigation (Percentages of Districts)	Area Involved in Sprinkler Introduction (Acres)	Installed Drip Irrigation (Percentages of Districts)	Area Involved in Drip Installation (Acres)	Switched to Less Water-Consuming Crops (Percentages of Districts)	Area Involved in Switching (Acres)
All Distircts	35	159,150	33	36,140	32	158,915
Central Coast	67	70	67	1,930	33	NA
Sacramento	29	3,100	24	5,000	59	48,060
Mountain	38	100	44	100	25	500
San Joaquin	50	6,740	25	2,850	18	2,000
Fresno	38	102,000	50	15,200	25	15,075
Kings & Tulare	47	42,790	29	1,660	47	78,300
Kern	11	NA	10	NA	44	14,830
Southern California	15	200	25	9,000	17	NA
Riverside	20	250	33	0	0	0
Imperial	50	3,500	0	0	50	150
San Diego	42	400	64	400	21	NA

6 miles lined in the San Joaquin Valley, 4 miles lined in the Riverside region, 3 miles lined in Kings and Tulare, and 1 mile lined in the Fresno region. Pressurized pipelines have been installed in 12 percent of all districts responding with the greatest number of districts undertaking this in the Mountain region.

The data gathered from the irrigation dealer survey indicates that over 70 percent of the responding dealers sell automated irrigation equipment. Using the same criteria as for sales levels of pumps, an index ratio of sales of automated equipment was calculated for the 1987-1990 period (see Appendix Table 9, Column VII). The data demonstrates an upward trend in the index. This trend is probably correlated with the upward trend of sales of pumps. In practice, pumps are sometimes a specific component of automated irrigation equipment. Data obtained indicate that dealers who sell pumps also sell automated irrigation equipments. In general those dealers responding to the survey reported high sales of automated irrigation equipment during the 1987-1990 period. Consistent with the data obtained for pump sales, the data show high automated sales ratios for those areas most affected by the drought. Riverside, Tulare, and Sonoma experienced the highest increase in sales of automated irrigation equipment for the period in study.

Institutional Changes

The principal institutional changes that have occurred due to the drought are tiered water pricing and the creation of the state water bank. Of the two, tiered water pricing is more significant since it requires administrative initiative on the part of the water districts. Tiered water pricing is essentially inverse block pricing in which an initial volume of water, based on some historical level of use, is sold at a given price and water purchased above and beyond the historical level is sold at a significantly higher price. Obviously, the type of water rights held by a district influences the price levels. In the Broadview Water District, the two tier prices are $16/AF and $40/AF and the tier volumes are set by crop. This setup is only possible because the district has field-specific accounting of water. The difference in the tier prices reflects the cost to the district of collecting and discharging the drain water resulting from excess irrigation. The first tier volume was set at 90 percent of the average water applied during the 1986-1988 period. With a year of experience, growers successfully cut back water usage as can be seen in Appendix Table 11.

Tiered pricing in an exchange district such as CCID is somewhat different. The program was not implemented because of severe water shortage, but rather, it was initiated to demonstrate improved beneficial use of water and to protect against movements to remove their water rights. In CCID, there is no crop-specific tiering, simply a Tier 1 price of $5.50/AF for the first 3 AF and $16.50/AF for all additional water. The price difference covers the cost of groundwater pumping. Growers are also allowed to "sell" back any of their unused Tier 1 water to the district. The district management is generally aware of water usage by growers and tries to convince them of the importance of conservation, but there is no desire nor mandate for the district to

undertake formal field monitoring to make tier-pricing more effective.

In the survey, water districts were asked if they changed their water pricing practices in response to the drought. Of all districts responding, 49 percent indicated that they had adjusted their pricing schedules. Many districts instituted some form of tier-pricing based on allowable allocations in relation to a base year. For example, one water district in the Mountain Region charges $18/AF for 50 percent of the 1989 allocation and $29/AF for any water delivered above this. Some districts, in the San Diego region, have four tiers of increasing prices corresponding to 85 percent of base, 86 percent to 90 percent of base, 91 percent to 95 percent of base, and above 96 percent of base. Overall, at least 15 of the districts responding have instituted some form of surcharges based on level of use or tier-pricing.

Appendix Table 4 shows what percentage of districts in each region changed their pricing practices in response to the drought. Many districts reported price increases; some prices even quadrupled. A water district in the San Diego region reported changing prices three times in 1991 alone. In the Sacramento Valley region four districts reported price increases ranging from 16 percent to 100 percent because of the drought. Prices increased four times, ultimately to $200/AF, in a water district that had to obtain emergency water from the state's water bank.

The other institutional change of note is the creation of the state water bank which provides a means for transferring water from those districts with water surpluses to those with shortfalls. Last year the seller price was $125/AF and the buyer price was $175/AF at the Delta; 825,000 AF were purchased and 435,000 AF were sold. Metropolitan water districts purchased 370,000 AF (85 percent of the total) and the remaining 82,000 (15 percent) went to agriculture.

The survey of water districts shows nine districts either sold water to or purchased water from the water bank in response to the drought. Water districts in the Sacramento Valley, San Joaquin Valley, Mountain region, and Fresno, Kern, Kings, and Tulare counties sold water to the water bank. Districts in Kern and Kings and Tulare counties reported purchasing water from the state water bank.

Water districts have also been changing water allocation schedules to growers. Water allocation schedules have been changed in 53 percent of all districts. Eighty-five percent of districts in the San Diego region reported changes, 69 percent in the San Joaquin Valley, 61 percent in the Sacramento Valley, 57 percent in Fresno, 53 percent in Southern California, and 50 percent in the Mountain region. Many districts instituted some form of mandatory or voluntary cutbacks in allocations. For example, in a water district in the Kings and Tulare region, water allocations to growers were cut from 2.1 AF per acre to 1 AF per acre in 1990; the Westlands Water District instituted rationing in response to the 1991 drought. A Central Coast water district instituted mandatory water rationing in April, 1991, but it was made voluntary the following July.

Fifty-two percent of all districts responding reported that there have been significant increases in the number of water exchanges[4] among growers during the last few years; 72 percent of them believe it is related to the drought. These exchanges especially increased in the Kings and Tulare, Fresno, Sacramento, and San Joaquin regions (see Appendix Table 4). These exchanges may have taken place because farmers have switched to less water-consuming crops and then they have water to share with neighboring farmers who find themselves short. In one water district, growers who have installed drip irrigation use groundwater and consequently may transfer their surface water entitlement to others once a year with the district's approval. Most of these water exchanges take place towards the end of the season when the farmer no longer needs his or her water and wants to use the entitlement before supply is shut off.

Appendix

Table 11: Broadview Water District Tiering Levels, Prices and Results, 1989-91

	1986-88 Average	Tiering Level	1989	1990	1991
			(Feet)		
Cotton	3.20	2.9	3.34	2.84	2.40
Tomatoes	3.22	2.9	2.72	3.03	2.69
Melons	2.11	1.9	1.93	1.79	1.46
Wheat	2.30	1.9	3.02	2.18	1.60
Sugarbeets	4.58	3.9	3.73	2.54	*
Alfalfa Seed	2.06	1.9	1.84	1.88	1.36
Rice	5.65	5.1	5.40	*	*

[4]Exchanges being the trading of a portion of one farmer's allotment of water to another farmer within the same district, although there are occasional instances of transfers between farmers of different districts.

Breakdown of geographic aggregations into counties for Appendix Table 3

Central Coast
Contra Costa
Monterey
San Benito

Sacramento Valley
Butte
Colusa
Yolo
Sacramento
Glenn
Sacramento
Solano
Sutter

San Joaquin Valley
Merced
Madera
Stanislaus
San Joaquin

Fresno
Fresno

Kings and Tulare
Kings
Tulare

Kern
Kern

Mountain
Shasta
El Dorado
Nevada
Placer
Siskiyou
Shasta

Southern California
Ventura
Orange
Santa Barbara
Los Angeles

Riverside
Riverside

Imperial
Imperial

San Diego
San Diego