ECONOMIC ARRANGEMENTS TO IMPROVE DRY-YEAR SUPPLY RELIABILITY IN THE LOWER COLORADO RIVER BASIN

by

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ABSTRACT

The precarious balance between water supply and demand in the Lower Colorado River Basin leaves water users in the Basin vulnerable to dry-year supply variability. Particularly during drought, temporary water transactions can facilitate an efficient reallocation of water from low-value uses to uses with a relatively higher marginal value. This research is an analytical and empirical investigation into temporary, market-based water transfers to stimulate an efficient reallocation of water during drought. Temporary water leases across the western U.S. between 1987 and 2005 are analyzed using two-stage least squares (2SLS) techniques to compare and explain the determinants of the price of the West's water leases. Dry hydrologic conditions are shown to increase the price of leased water in virtually all state and regional models analyzed. Also, water leased for agricultural use is found to be less expensive than water leased for municipal or environmental purposes in most models. To inform drought-responsive lease arrangements, this research demonstrates the residual or farm budget approach to estimate net returns over variable costs for select field crops in Yuma and La Paz counties in Arizona. Estimates range from -$50.00/AF of water applied for upland cotton produced in Yuma County to a high of $67.37/AF of water applied for alfalfa in La Paz County. As a point of comparison, NROVC for head lettuce are estimated at $1,425.20/AF of water applied. Such estimates can be useful in negotiations over compensation payments for voluntary irrigation forbearance programs.

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CHAPTER 1

1.1 INTRODUCTION: THE LOWER COLORADO RIVER BASIN IN CONTEXT

The Lower Colorado River Basin is the focus of this research. This is a region characterized, in many ways, by the supply and demand for water. The Lower Basin States of Arizona, California, and Nevada have historically relied on man-made infrastructure such as dams, reservoirs, and canals to ensure a reliable water supply. However, as Lower Basin water demands swell due to factors such as rapid population growth and environmental needs, this historic approach is proving inadequate. Consequently, drought-induced supply variability carries with it the potential for considerable economic consequences. As an alternative to the historical supply-augmentation approach, water markets are now being utilized, to various degrees, as a mechanism to stimulate the efficient reallocation of water during drought.

The Colorado River is the primary source of irrigation and domestic water in Arizona, southern California, and Nevada. The River serves over 20 million people in the Lower Basin, and water demand is projected to steadily increase (Pontius 1997). The following table breaks down the annual allocation of Colorado River water between the Upper and Lower Basins and among the states.

Colorado River Annual Allocations (MAF)	
Upper Basin	
Colorado	3.9
Utah	1.7
Wyoming	1
New Mexico	0.85
Arizona	0.05
Upper Basin Total	7.5
Lower Basin	
California	4.4
Arizona	2.8
Nevada	0.3
Lower Basin Total	7.5
Additional Allocation	
Mexico	1.5
Total	16.5

Table 1.1 Colorado River Allocations

The Lower Basin States have a long history of conflict and compromise over their respective shares of Colorado River water, and pressure among the states has escalated in light of recent drought conditions in the Basin.

While water transactions have occurred in basically every western state in some form, there is wide variability between states in terms of market activity and development, the types of transfers that dominate the market, the price, quantity, and purpose of transactions, etc. Presumably, this is because each state has unique hydrology, water infrastructure, water needs, water rights, and water laws surrounding transfers. In the Lower Colorado River Basin, California, Arizona, and Nevada each have distinct water supply issues and a distinct history of water transfers.

1.1.1 California.

Historically, California has consumptively used approximately half a million acre-feet more than its 4.4 million acre-feet (maf) annual allocation of Colorado River water by making use of other states' unused apportionments (Pulwarty *et al*. 2005). After years of unfruitful negotiations to address California's excess use of Colorado River water, in 2001 the Secretary of the Interior instructed California to reduce its use to within its apportionment, which brought parties back to the negotiating table and eventually led to California's 4.4 Plan. Under the plan, California has until 2017 to reduce its annual diversions from around 5.2 maf to 4.4 maf in non-surplus years. California's plan for meeting this objective is laid out in the Quantification Settlement Agreement, which, among other things, calls for the transfer of senior agricultural water out of irrigation to municipal use.

Hanak (2002) and Howitt and Hanak (2005), provide a summary overview of historic transactions in California's water market. Market transfers now exceed 1.2 maf annually, eight to ten times more than the traded volume in the mid 1980s. Water transferred through water markets now accounts for 3% of the State's water use. The market is dominated by short-term transfers that are negotiated on an annual basis; 80% of market transactions are short-term in nature, though the number of long-term agreements has increased recently. Recent market growth has been dominated by water transfers for environmental purposes.

Agriculture accounts for approximately 92% (or 27 maf) of all consumptive water use in California, and thus it is not surprising that agricultural water districts are the main suppliers (Gollehon and Quimby 2000). In most years, over 90% of water transferred through markets in California originates in agriculture

1.1.2 Arizona

In Arizona, the construction of the Central Arizona Project (CAP) fundamentally changed the nature of Arizona's water supply. In 1968, Arizona was granted approval for the construction of the CAP, a pipeline to deliver 1.5 maf of Colorado River water to municipal, agricultural, and Indian water users in central Arizona. The CAP was constructed in hopes that providing an additional source of surface water would offset unsustainable groundwater overdraft that had been taking place in the State (Pontius 1997). California's eventual support of the construction of the CAP was contingent on Arizona accepting a junior priority status, meaning CAP water users would be the first to experience reduced deliveries in the event of shortage on the Colorado River system. Today, uncertainty surrounding Upper Basin development, shortage sharing criteria, and Indian reserved rights all create anxiety over the CAP's junior priority.

The Arizona Water Banking Authority (AWBA) was established in 1996 in response to California's tendency to use more than its 4.4 maf allocation as well as Arizona's conviction that it needed to rapidly develop (and thus protect) its full Colorado River allocation. The Arizona Water Bank was established with some basic objectives in mind: to protect Arizona against Colorado River shortage or CAP supply disruptions by storing any unused apportionment in underground aquifers; to support the management objectives of the Arizona Groundwater Code; to promote the settlement of Native American water rights claims; and to support California and Nevada in meeting their supply requirements while protecting Arizona's allocation by facilitating interstate water banking in Arizona (Arizona Water Banking Authority). The Arizona water bank also has the potential to facilitate interstate water marketing within the Lower Basin states (Pontius 1997).

1.1.3 Nevada

Nevada's 300,000 AF/year allocation of Colorado River water, which once seemed adequate to support the State's needs, has become a worrisome issue as southern Nevada's urban population continues to explode. Unlike the other Lowe Basin states, Nevada simply does not have a large agricultural base, which eliminates the potential for transferring water out of irrigated agriculture to municipal use within the State. Inter-state temporary water transfers have been virtually nonexistent in Nevada. As a result, Nevada has pursued a number of proposals to increase its Colorado River apportionment, through both agreements with the other Lower Basin states as well as Utah in the Upper Basin, which, until recently, have largely been unsuccessful.

In late 2004 Southern Nevada Water Authority (SNWA) reached an agreement with Arizona to allow Nevada to store unused Colorado River water in Arizona's underground aquifers (Southern Nevada Water Authority 2006). Under the agreement, which is an amendment to a 2001 groundwater banking agreement, Nevada paid $100 million to Arizona in 2005 and starting in 2009 will make 10 annual payments of $23 million. In exchange, Arizona will store up to 1.25 million acre-feet of Colorado River water for Nevada's future use.

From the brief discussion of the supply and demand situation in the Lower Colorado River Basin, it is obvious that managing water supply to minimize exposure to supply variability, particularly during drought, is a critical, impending challenge facing each Lower Basin state. California is trying to live within its Colorado River allocation. Arizona is dealing with the junior priority CAP status. And Nevada is searching for means of augmenting its supply. Temporary, dry-year water transfers represent one viable mechanism available to the states to stimulate the reallocation of water during drought.

1.2 ECONOMIC RATIONAL FOR DRY-YEAR TRANSFERS

In an analysis of the effects of western water markets on rural communities, Gollehon (2000) identifies three reasons why western water transfers will involve irrigation water. First, simply because agriculture accounts for such a substantial proportion of water use in the West, the source of water for transfers will necessarily be concentrated in irrigated agriculture. Second, the low use value of irrigation water in many regions is also identified as motivating transfers. And finally, the relatively stable nature of agricultural water allocations makes transfers out of agriculture more attractive to urban and industrial users.

Western water rights are governed by prior appropriation, or a “first-in-time, first-in-right” system. As such, many irrigators across the West hold senior water rights while municipalities or newer uses such as the environment or recreation have a junior priority status. This implies that in the event of shortage, irrigators with senior water rights will receive their full allocation, while junior rights holder may be shorted. When there is a shortage, this is often an inefficient allocation of water because the value of the water used to irrigate low-value crops is much lower than the value to a municipal water district, for instance. In other words, the value of marginal product (VMP) of applying another unit of water to low-value crop production is lower than the VMP of supplying another unit of water to a municipality (Brozovic *et al.* 2002). Particularly during drought, well-functioning water markets can facilitate the temporary transfer of water from low-value uses to uses with a relatively higher marginal value. By taking advantage of each user's differential value, the water is allocated more efficiently.

1.3 DROUGHT.

1.3.1 Tree-Ring Record of Drought in the Colorado River Basin

Although drought events are related to changes in large-scale atmospheric circulation, climatalogical and hydrologic records currently represent the best understood approach to predicting drought (Meko *et al.* 1995). Because recorded streamflows have a limited period of record, assessments of climate prior to the late 1800s must rely on proxy indicators. Of these proxy indicators, tree-ring analysis is the most favorable because climactic signals and environmental conditions are reflected in tree-ring chronologies. Precipitation and evaportranspiration are key variables in the water balances of trees, making tree-rings indicative of drought. For the period of 1705-1979, analysis of spatial patterns of tree growth show that tree-ring chronologies in the interior western U.S. are especially strong indicators of drought and, for that reason, are used in a study by Meko *et al.* (1995) to describe a worst-case scenario drought on the Colorado River.

Using tree-ring data, streamflow reconstructions of the Colorado River at Lees Ferry from 1520-1961 indicate that the estimated long term mean annual flow on the River was 13.5 maf, substantially less than the 16.2 maf estimate used in the negotiation of the Colorado River Compact (Stockton and Jacoby 1976). The reconstruction also shows several deviations of up to 2 maf from the estimated 20-year mean.

The most severe sustained drought indicated in the Colorado River reconstructions occurred in the late 1500s. The ten lowest 20-year means all overlap in 1590-1600, with the lowest occurring from 1579-1598, which seems to have occurred in the upper main stem area of the Colorado River (Stockton and Jacoby 1976). However, tree-ring evidence suggests the drought stretched far beyond that, in fact to all major runoff producing parts of the basin. According to reconstructions and historic flow data, this drought was more sever and prolonged than any other drought the Colorado River basin has since experienced. The 20-year average flow for the period of 1579-1598 was 10.95 maf, which is 2.55 maf below the long-term reconstructed mean of 13.5 maf.

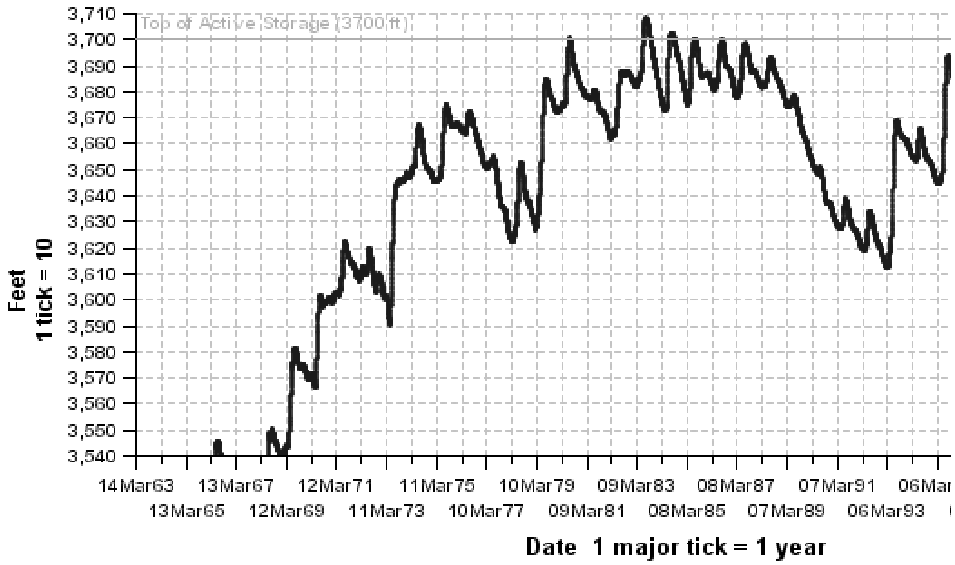
These reconstructions are evidence of the need to be prepared for a drought in the Colorado River Basin potentially more extreme and sustained than any in recorded history

1.3.2 Current/Recent Drought Conditions in the Colorado River Basin

Beginning in October, 1999, the Colorado River experienced 5 years of extreme drought. During this time, below average precipitation led to low runoff and streamflows, all resulting in the rapid drawdown of storage reservoirs Lake Powell in the Upper Basin and Lake Mead in the Lower Basin. At the end of September, 1999, Lake Powell was at 95% of capacity, but between 2000 and 2004, inflows into the reservoir were well below average. And by April, 2005 Lake Powell had reached a low elevation of 3,555 feet or 33% of live storage capacity (Bureau of Reclamation April 2006).

Hydrologic conditions in 2005 were much wetter than the previous years, and inflows into Lake Powell were 105% of average, raising the lake level and increasing the water in storage by 2.77 maf. Water year 2006 also appears to be an average to above average hydrologic year that will help increase storage in Lake Powell, yet it is still premature to assume the drought in the Basin is over. Lake Powell currently (April 4, 2006) stands at 3588.7 feet, or 111.3 feet from full pool and 44% of live capacity (Bureau of Reclamation April 2006). Projections through July 2006 are encouraging; inflow into Lake Powell is forecasted to be 105% of average, and the water level of the Lake should begin to rise in the spring as streamflow increases with snowmelt runoff.

The following table shows the annual elevation of Lake Powell since the completion of its construction in 1962, through the time it took the lake to fill (until approximately 1980), and up through March of 2006. The impacts of the 5 year drought between 1999 and 2004 on the elevation of Lake Powell are self evident.



Source: http://www.usbr.gov/uc/crsp/charts/displaysites.jsp

Figure 1.2 Lake Powell Historic Elevation

1.3.3 Shortage Sharing in the Lower Colorado River Basin

Each year, the Secretary of the Interior evaluates the water supply situation on the Colorado River for the Lower Basin States and declares the year to be surplus, normal, or shortage. While regulations and operating criteria have been defined for normal and surplus conditions, the implications of a shortage declaration have never been explicitly defined (Bureau of Reclamation March 2006a). Increasing pressure on supply, drought, and the corresponding draw down of the Colorado River system's two main storage reservoirs, Lake Powell and Lake Mead, however, have prompted the development of guidelines on how shortage conditions would be declared, managed, and shared among the Basin States.

In June, 2005 the Basin States began the process of developing shortage sharing guidelines for the Lower Basin and coordinated management strategies for lakes Powell and Mead under low reservoir conditions (Bureau of Reclamation March 2006b). Given the potential for severe environmental impacts of the shortage sharing and coordinated management guidelines, the Department of the Interior also began a formal National Environmental Policy Act (NEPA) process. This will include the preparation of an Environmental Impact Statement (EIS) to evaluate probable environmental consequences for a range of alternative operating scenarios.

A "scoping report," released by the Bureau at the end of March, 2006, was the culmination of a 5-month scoping process aimed at soliciting public input into the necessary extent of operations alternatives. Four principles are identified in the report as fundamental requirements for alternative operating scenario proposals (Bureau of Reclamation 2006b). They are:

(1) Develop criterion for declaration of a "shortage" that would initiate shortage sharing among the Lower Basin States below their annual 7.5 million acre-feet allocation of Colorado River water;

(2) Develop coordinated management guidelines for lakes Mead and Powell, particularly under low reservoir conditions;

(3) Develop guidelines for increasing the flexibility of storage and delivery of water in Lake Mead (including non-system, exchanged, and conserved water) to enhance the ability to meet the needs of water users, particularly under low reservoir conditions; and

(4) Incorporate the elements of the new guidelines (1-3 above) into the existing Interim Surplus Guidelines.

These new guidelines will also be interim, persisting only until 2025 so that modifications can be made in line with experience gained and lessons learned during the interim period. The Bureau expects to submit a draft EIS by the end of 2006, a final EIS in November, 2007, and a Record of Decision by the end of that year.

1.3.4 Intentionally Created Surplus.

One component of the Seven Basin States' preliminary proposal for Colorado River interim operation guidelines includes the initiation of an "Intentionally Created Surplus" program (Bureau of Reclamation Feb 2006). The basic idea behind the Intentionally Created Surplus (ICS) program is that Colorado River water users in the Lower Basin would be able to generate ICS credits to be stored in Lake Mead through engaging in extraordinary conservation, thereby helping to avoid shortage in the Lower Basin and maintaining the elevation of both Lake Powell and Lake Mead at levels higher than would otherwise have been possible.

The chief methods of extraordinary conservation would be irrigation forbearance agreements, canal lining, and desalination programs. Lower Basin states would be permitted to create ICS credits through extraordinary conservation only up to specified volumes. California could conserve up to 400,000 AF/year, Nevada would be allowed 125,000 AF/year, and Arizona's maximum ICS credits would be 100,000 AF/year. Each year when annual water orders are placed for the following year, states with ICS credits could request the recovery of those credits in addition to their water order for the year. ISC credits would also be available, upon approval by the Bureau of Reclamation, in the case of extreme weather or water emergency situations

1.4 SUMMARY OF CHAPTERS.

Chapter 2 is a review of literature published on a variety of topics relevant to economic strategies to enhance dry year water supply reliability. These include the economics of drought, various mechanisms used to reallocate water during drought in theory and practice, econometric analysis of market-based water transfers, the economic rational for dry-year option contracts, and finally various methods developed for valuing agricultural water.

Chapter 3 is an overview of the data and methodology used in econometric analysis of temporary water transactions across the western United States. The full dataset consists of 660 temporary water transfers between 1987 and 2005. Analysis is performed at the state, regional, and west-wide levels.

Chapter 4 presents the models and results of econometric analysis of temporary western water transfers. First, a brief summary overview of western leases is given. Then, for each state in the west with over 30 leases over the study period, a brief introduction to the state's water laws is presented prior to exhibiting state-level regression models and results. Next, the data is aggregated to regional (Pacific Northwest and Southwest) and west-wide models. The main objective of the analysis are to assess what factors have a statistically significant impact on the price of leased water, including the original and new use of the water, the number of acre-feet involved in the transaction, the years of the life of the lease, and drought/climactic conditions. The two central hypothesis are: (1) the price of leased water increases as hydrologic conditions become dryer; and (2) the maturity of a lease market will be reflected in the insignificance of the new use of the water. In other words, as markets mature, it is expected that prices will converge on an equilibrium price across all new uses.

Chapter 5 demonstrates the application of the farm budget or residual approach to valuing irrigation water. The exercise is carried out for several crops and one vegetable in Yuma and La Paz counties in Arizona. The culminating calculation is net returns over variable costs, which represents the minimum compensation payment irrigators would need to receive for temporarily fallowing their land to be just as well of had they irrigated.

The final chapter, Chapter 6, recaps the major findings of the research and their significance in enhancing dry year supply reliability in the Lower Colorado River Basin. This chapter also discusses the policy implications of the findings

1.5 SIGNIFICANCE OF RESEARCH

As has been demonstrated by discussion of the precarious balance between water supply and demand in the Lower Colorado River Basin, the economic implications of drought-induced supply variability have the potential to be widespread and acute, affecting many different sectors of the economy. Water management strategies to enhance dry-year supply reliability are essential to minimizing susceptibility to drought-induced shortage. This research looks at temporary dry-year water transfers as a potential mechanism for enhancing supply reliability and contributes to the successful development of such a strategy in two ways.

First, the econometric analyses of temporary water transactions across the West offer a quantitative analysis of the factors that influence the market price of water. Well-functioning water markets can provide incentive for the reallocation of water according to its use value, and an understanding of the determinants of the price of water is essential to a well-functioning water market (Brookshire *et al.* 2004). If water users do not have a clear concept of the marginal value of water, the transactions costs associated with negotiating and carrying out a temporary water transfer can grow quite large. The empirical analysis performed here is a first step towards identifying what factors influence the price of water in different lease markets across the West.

Secondly, the farm budget analysis component of this research, which is used to value irrigation water in western Arizona, can be used as a tool in negotiating dry year forbearance payments. Net returns over variable costs is the *minimum* compensation payment an irrigator would need to receive to make temporary land fallowing an attractive financial option. Thus, this value can be used as a benchmark from which negotiations can begin. This calculation is very straightforward and transparent and is easily modified to reflect changes in input and output prices. The basic framework established would also be easily transferable to other locations and crops and thus could be applied in areas outside the study region in this research.

CHAPTER 2

2.1 THE ECONOMICS OF DROUGHT

The economic impacts of drought are diverse and can reach far beyond an area actually experiencing a physical drought. The U.S. incurs an estimated $6-$8 billion in drought-related costs and losses annually from economics sectors such as agriculture, energy, recreation, municipal and industrial, governmental, and the environment (National Oceanic and Atmospheric Administration 2002).

The effects of drought in agriculture, the largest water user in the U.S. and particularly in the western U.S., can be quite acute. Agricultural costs associated with drought include crop failure, reduced crop productivity and increased susceptibility to disease and insects, wind erosion, and federal spending on drought support for farmers. These direct agricultural impacts also affect ag-related industries such as farm machinery and other agricultural inputs, food processing, financial institutions, etc.

Municipalities and industrial users, who often hold junior water rights, can experience supply shortage during drought, leaving them to face high costs of acquiring supplemental supplies or to incur losses due to the inability to meet demand.

Drought can also have severe implications for energy production. The ability to produce hydropower may be impaired as streamflow and reservoir storage levels decrease, and higher temperatures typically associated with drought simultaneously bring with them increased energy demand. Further, balancing environmental needs with power production, which is always a challenge, becomes even more difficult during drought.

Drought can also have implications for recreation and tourism industries. Opportunities for boating, rafting, fishing, hunting, bird watching, etc. can all be diminished because of drought. And, of course, this has many trickle down effects to other sectors of the economy that rely on business generated by recreation/tourist activity in the area.

2.2 WATER TRANSACTIONS TO MANAGE DROUGHT/DRY-YEARS

Today, traditional supply-side approaches to water resource development, such as reservoir construction, are becoming less and less economically and environmentally viable. Yet rapid population growth, environmental considerations, and drought conditions continue to place additional demand on the West's water supply. These circumstances have prompted efforts to explore newer methods to reallocate water and minimize vulnerability to supply variability. Water transfers via market mechanisms present one opportunity for efficiently reallocating water.

An early analysis by Vaux and Howitt (1984) uses an interregional trade model to evaluate market-driven water exchanges under two different water management strategies in California. Under the first scenario, the only means of supply augmentation is assumed to be development of new supplies. The second scenario analyzes the impact of allowing a limited market-like mechanism to facilitate interregional water trade.

Significant results of the analysis show that under the first scenario of supply-side augmentation, all water prices increase, and urban water prices are particularly affected. Nonetheless, 100,000 acre-feet of new supply created by supply-side development can be justified through 2020.

Under the second, market-like scenario, urban water users are found to be better off as compared to the first scenario in terms of cheaper prices and more available supply. The increase in supply is attributed to incentives for irrigators to use less water, which they will do so voluntarily in response to price incentives. Another interesting conclusion is that when water marketing is introduced, supply-side development is no longer justifiable, implying that some urban supply development that has historically taken place was not cost efficient and if marketing had been allowed likely would not have occurred.

2.2.1 Incorporating Water Transfers into Water Management Strategies

A study by Lund and Israel (1995), described below, provides a conceptual foundation for incorporating water transfers into water management systems.

The agricultural sector in Spain has been engaged in water marketing since the 15th century (Maass and Anderson 1978), and water marketing has occurred for years in the agricultural sector in the western U.S., typically among farmers with mutual irrigation companies. These examples of water transfers are generally limited to a single sector, but economic and environmental conditions today are encouraging transfers between sectors, such as agriculture to urban. Such transfers provide an opportunity to make water supply systems more efficient and flexible (Lund *et al.* 1992).

The economic efficiency of water markets will not match ideal markets due to a number of constraints identified by Lund and Israel as inherent in water markets: poorly defined water rights; high transaction costs associated with transfers; relatively few buyers and/or sellers engaged in the water markets; complicated and/or costly conveyance of the water between buyers and sellers; imperfect communication between buyers and sellers; and third party impacts on the environment and rural economies.

Water transfers can be permanent or temporary in nature. When water rights actually change hands, the transaction is know as a permanent transfer and is a form of supply augmentation. Historically, the majority of permanent transfers have occurred between agriculture users selling to urban buyers. When potential buyers are more concerned with enhancing supply reliability during drought or other shortage situations (e.g. flooding, contamination), temporary leases may be more appropriate.

Temporary water transfers that are generally completed within one year are known as spot market transfers. The price per acre-foot is often established by a bidding process. Water banks are a constrained form of spot market transfers in which users sell water to the water bank at a fixed price (set by the water bank and *intended* to act as the market clearing price, though the pricing structure is not market based) and buy water from the bank at a higher fixed price. The price discrepancy stems from the bank's administrative and technical costs. During drought, water banks can lessen urban suppliers' incentives to rely on more expensive traditional water supply augmentation and water conservation in planning. In the agricultural sector, water banks can change the way water and croplands are managed during drought (Lund and Israel 1995).

Contingent transfers or dry-year options are another form of reallocation that may be particularly desirable to enhance dry-year supply reliability. These temporary transfers, which are contingent on supply shortage, are based on a specific time horizon which is partly determined by the nature or cause of the supply shortage. During drought, dry-year transfer arrangements made between senior and junior water rights holders would be most logical, as the water deliveries to users with senior water rights are the least likely to be effected by drought-induced shortages. Agricultural interests are typically the sellers in such transfers.

The design of water transfers inherently must encompass legal considerations. The legal transferability of water varies from state to state and within states as water law evolves. In instances where a transfer involves changes in the conditions specified by the original rights holder, legal considerations are especially pertinent. Often, legislation is in place to lessen obstructions to transfers during drought or other emergency supply situations. Conversely, long-term, planned transfers tend to encounter significant legal and economic constraints.

Equating the quantity of real water with the quantity of paper water (based on terms of contract) is often a difficult task. On farms, for instance, the amount of water that would become available if land was fallowed or crop patterns changed is often difficult to exactly determine. Seepage, evaporation, and natural accretion also create uncertainty surround the estimate of how much real water is actually available for transfer. If not addressed by developing standards or by involving the government in tying real water to paper water, the amount of paper water is likely to exceed the amount of real water. The result is then excessive withdrawals, to the detriment of downstream users (Lund and Israel 1995).

Along with ensuring wet water, Lund and Israel identify conveyance, storage, and treatment of the transferred water as another significant component of most water transfers. In regions where extensive transfer and storage systems exist, there is a higher likelihood of successful water markets. In less equipped and/or coordinated regions, new conveyance systems and storage facilities may have to be developed.

The price of water can significantly influence the quantity demanded and supplied. Thus, the price of water, whether set by the market, through negotiations, or by a water bank, also has important implications for the number and character of transfers. Arranging for conveyance, storage, and possibly treatment are additional costs inherent in transfers. Other transaction costs can include legal fees, paying for public review or technical studies, and third-party compensation (Lund and Israel 1995).

A 2002 case study of the Central Valley Improvement Act (CVPIA) by Weinberg uses a case study analysis examines the economic implications of applying a variety of water policy tools to address inefficiencies in federal water allocations. The basic framework for the empirical analysis is an estimated revenue function which is then incorporated into a nonlinear programming model.

The CVP in California provides irrigation water for over 2.5 million acres of cropland, producing crops worth over $3 billion annually. For the empirical analysis, Weinberg develops an optimization model using agricultural and urban water use benefit functions to analyze the economic impact of four CVPIA provisions: water markets, tiered water prices, environmental surcharges, and fish and wildlife allocations. While the analysis of water markets is focused on water sales, the basic methodology employed could be applied to water leases. The dataset is a mixed panel with a maximum thirteen year time series of crop and water use for the 142 water districts using CVP water. Other variables include total output, crop prices, and county-level soil and climate variables such as number of frost days, average precipitation, and average slope percentage. Urban water demand functions are based on published measures of demand elasticities in California (Weinberg 2002).

Results suggest that in order for water markets, tiered water prices, and environmental surcharges to successfully initiate more efficient water allocations, the price of water must rise above shadow prices. Further, water markets are found to be necessary to minimize the cost of environmental water allocations. With the implementation of water markets alone, results suggest CVP farmers would sell 342,000 acre-feet if water to urban users at $32/af. The sales would decrease crop revenues by $10 million and create $36 million in urban gross benefits, $11 million of which would be transferred to irrigators for water payments. Thus, farmers' total revenue would increase by $1 million and urban net revenues would increase by $25 million (Weinberg 2002).

The following section provides a more in-depth look at various forms of temporary water transfers identified and described in the literature as promising means of addressing drought-induced supply variability.

2.2.2 Water Markets

A study by Landry and Anderson (1999), which takes a closer look at the development of water markets worldwide, asserts that there is a need for water reallocations to meet growing demand, which will be kept in check by higher water prices. However, reallocation and market pricing of water has been slow to occur because price and allocation decisions have been made in the political arena. As such, interests groups have often successfully prevented meaningful increases in water prices or reallocations. A market system in which prices are determined by the free exchange of water is necessary to bring supply and demand into equilibrium.

States in the western U.S. such as Colorado and California are home to some of the most established water markets in the world. In Colorado, urban areas such and Denver, Fort Collins, and Colorado Springs have had a reliable supply of water because of the growing, active water market. And California has supported ag-to-urban transfers through the establishment of emergency drought water banks, federal water acquisitions for environmental purposes, and a growing options market for short term water transfers (Landry and Anderson 1999).

Other examples of developing western water markets include: an electronic trading board in the Westlands Irrigation District in California where farmers buy and sell water; active water markets in Utah and Nevada in response to rapid urban growth; and an irrigation forbearance program in Oregon aimed at enhancing stream-flows to protect endangered fish. Negotiations and trade in the Lower Colorado River Basin between Arizona, who has cheap surplus water from the Central Arizona Project, and water thirsty California and Nevada represent interstate trades, which is one of the newest forms of water marketing. Water markets are also developing outside of the U.S. in countries such as Mexico, Australia, and Chile. In Chile, for example, dry-year options have been employed to save on buying water rights that are only needed during dry years (Landry and Anderson 1999).

In almost every water market, transfers are subject to the approval of some form of government with the intent of protecting other rights holders. The approval process, however, can be lengthy and costly and, some claim, is limiting market growth. States such as Oregon and Colorado have recognized the bureaucratic hold up and have tried to mitigate the problem by assuring relatively rapid decisions on transfers.

Landry and Anderson conclude with the idea that water markets worldwide present and opportunity to create equitable and efficient water reallocations as well as incentive to conserve. As water becomes more and more scare, these infant markets are likely to expand and dramatically change the way countries face their scarcity problems.

2.2.2.1 Econometric Analysis of Temporary Water Transactions

Brookshire *et al.* (2004) specifically examine the market price for water in the western U.S. through an econometric analysis of Arizona's Central Arizona Project (CAP), Colorado's Colorado Big Thompson Project, and New Mexico's Middle Rio Grande Conservancy District. The study looks at the price history in these three markets in a preliminary effort to explain the determinants of the price of water and trends in western water markets.

Pooling the three markets, the study analyzes the market price of water as a function of the type of buyer (either government, irrigation district, or municipal), population change, per capita income, a drought index, and a dummy variable to indicate the specific market (CAP, Colorado, or New Mexico). Results of this regression indicate that Colorado's market is more mature and efficient relative to the CAP and New Mexico markets, reflected in Colorado's higher prices. Also, government buyers pay less for water than agricultural and municipal water users, a phenomenon explained by the monopsony power of the government sector and the fact that many government purchases are made for federally mandated environmental protection programs. Population change is not significant in the model, though per capita income is positive and highly significant. This suggests that an increase in a population's income corresponds to an increase in the price per acre-foot of water. Finally, the drought index is confirmed as expected; the coefficient is negative and significant, indicating higher water prices as conditions grow dryer.

In another study, Loomis *et al.* (2003) examines the market price of water in the western U.S. but from an environmental use perspective. Here, the hedonic price method is used to explore water market transactions for instream flow. The logarithmic model explains the price per acre-foot of water as a function of attributes such as the new water use (i.e. recreation, endangered species protections, wetland restoration, etc.), average precipitation, and the type of seller and purchaser.

Significant results of the study indicate that government agencies pay less per acre-foot for water than do private organizations, higher than average rainfall levels are correlated with lower water prices, and the price of water for recreational purposes is significantly higher than water purchased for other uses.

2.2.3 Water Banks

Water banks are established in almost every western state, and although there are functional differences among the banks, each share a common goal of transferring water to the use for which it is most needed. In fulfilling this goal, banks can take on the role of broker, clearing-house, or market-maker while simultaneously fulfilling other administrative and technical functions. In a report on western water banks by Clifford *et al.* (2004), a water bank is defined as, "an institutional mechanism that facilitates the legal transfer and market exchange of various types of surface, groundwater, and storage entitlements." Unlike a leasing program, which generally involves a single buyer who temporarily purchases water from multiple sellers for a specific purpose, water banking involves interaction between multiple buyers and sellers to organize entitlement transfers.

The market structure is a critical component of a well-functioning water bank because it determines how participants interact and carry out transactions and also plays a role in price determination and the dissemination of market information. Buyers and sellers rely heavily on price and market information to locate trading partners and to evaluate price signals on the value of water, so adequate price and market information is essential to the development and functioning of a water bank.

The simplest type of bank organization is as a clearing house. Here, buyers and sellers declare their intent to transact. Most commonly, prices are determined through repeated, bilateral negotiations between a single buyer and a single seller. The clearing house structure is limited in that price dispersion could continue to exist in thinly traded markets, and transactions costs may be quite significant.

A fixed price structure, in which the market clearing price is fixed by the bank, is another market configuration employed by water banks. Here, it is assumed the bank has sufficient information to correctly estimate the clearing price and that there is uniformity in quality and reliability of water rights within the market region. Although the fixed price structure creates a sense of fairness and reduces concerns about price gouging and market speculation, a major limitation is the structure's inability to respond to changes in market and climactic conditions. This limitation becomes quite acute during dry years because a lack of incentive to bank water during wet years leads to insufficient supply during drought.

A more flexible, less risky option for the structure of water banks is one allowing buyers and sellers to negotiation options to supply or purchase water. Maximum price and quantity of water to be transferred as well as timing and location of delivery is negotiated as an option contract.

Despite their potential for easing and improving water reallocation by facilitating transfers, there are a few reasons why market activity in banking programs tends to be limited in the western U.S. First, water banking in the West is a relatively new concept, and potential banking participants have limited experience with banking. Also, the number and type of participants is often restricted. Finally, there have been limited outreach and education programs in the initial stages of development of water banks (Clifford *et al.* 2004).

2.2.4 Dry-Year Options

Agriculture represents over 80% of water consumption in the southwestern U.S., much of which yields relatively low economic returns (Griffin 2006). Because the cost of transferring water out of agriculture to other, higher-value uses is generally more feasible and less expensive than developing new water supplies, attention has increasingly been drawn to the potential for market transfers of agricultural water rights.

Instead of ensuring drought protection by the purchase of senior water rights, which may generate significant third-party costs, Michelsen and Young (1993) consider “dry year options” or “water supply option contracts” (WSOC) to meet municipal water demands during drought.

A dry-year option is “a formal contract or agreement between a farmer or group of farmers and an urban water user to transfer water temporarily from agriculture to urban use during occasional critical drought periods such that the urban user secures a source of drought water supply.” Dry year options are temporary transfers of water out of agriculture to higher valued, nonagricultural uses. Dry year options would only be implemented in drought/shortage conditions; agricultural water rights would be maintained, and agricultural water supply during normal supply conditions would no be affected. This approach to addressing dry year shortages is thought to be cost efficient and also minimize third-party economic impacts on agricultural communities.

From the perspective of the urban buyer, the value of a water supply option contract is a function of the cost of an option vs. the cost of the most likely supply alternative. By comparing option contract costs with alternative water supply costs, the present value benefit of an option contract (PVOB) can be determined, with a positive present value benefit implying an option contract is a less costly alternative.

The following are suggested as key provisions for water supply option contracts to identify and protect the rights of buyers and sellers:

1. The exercise price, which is the payment to the farmer for the net value of forgone agricultural production each time the option is exercised, should be negotiated

between the city and individual farmers. The exercise price is variable over time to account for differences in water use, values, and market and hydrologic conditions.

2. A minimum acceptable delivery as well as method and time of delivery need to be specified. Drought conditions may require a flexible water quantity provision.
3. The seller should retain the option of selling the water rights that support the option contract before contract termination, but the option purchaser should likewise be given a chance to match the price offered for the water right. This condition ensures water security for the option holder while maintaining seller flexibility.

Michelsen and Young conducted an empirical case study to evaluate the feasibility of exercising option contracts to provide water during drought from irrigated farmland in the Cache la Poudre River Basin to Fort Collins, CO. The area is characterized by urban growth which is putting pressure on agricultural water, a mature water economy, pressure to maintain agricultural communities, and sufficient water in normal years to meet the demands of urban and agricultural users. As long as there are no adverse third party impacts, temporary and permanent water transfers are permitted by state law.

As mentioned, a key component of an option contract is the exercise cost. Defined as "the minimum amount that must be paid to a farmer to maintain the same level of net income in the event of option exercise," the exercise cost is specific to individual farmers, depending on crop mix, precipitation, the quantity and cost of irrigation water, production costs, yields, and crop prices. Other costs that may factor into the exercise cost are short-run fixed production costs such as opportunity costs of family labor and management, taxes, depreciation, and cash overhead.

For the case study area, the estimated annual offering price of agricultural water is $85/AF. Under extreme river flow conditions and crop price conditions (high/low), estimated exercise costs ranged from $39 - $135/AF.

The PVOB equation is used to estimate the economic feasibility of water supply options for a base case scenario which is characterized by a 20-year contract term, a .05 annual exercise probability, an exercise cost of $90/AF, an initial water rights purchase cost of $600/AF, water rights management cost of $12/AF per year, real discount rate of 4% per year, and transactions and conveyance costs between the two alternatives assumed equal.

The analysis concludes that Fort Collins can afford to pay a maximum option price of $295/AF and still benefit over the outright purchase of a water right. The option value is sensitive to water right prices and appreciation rate. The water supply option value increases as discount rates increase because the opportunity cost of purchasing a water right increases while future option exercise costs and appreciation in water right prices are more heavily discounted. Conversely, as the appreciation rate of water right prices rises, the value of option contracts falls.

The region in the case study may not be reflective of regions with more scarce and more expensive water supplies. However, several scarcity scenarios were analyzed. The results showed that higher alternative water costs increased the option value significantly; as the cost of an alternative water supply climbs from $1,000 to $4,000/AF, the option value increases from $125 to $1,090/AF.

Water supply option contracts represent an economically efficient means of securing dry year supply for urban areas while still maintaining an agricultural base. Many areas of the western U.S. already have the fundamental economic, hydrologic, and institutional criteria in place for the implementation of option contracts, and the results of the case study indicate that water option benefits are a viable approach to dry year shortages under a wide range of economic conditions. In regions in which the transactions costs and conveyance costs are high, however, the net economic benefits of option contracts may be low or nonexistent.

2.3 ECONOMIC RATIONAL FOR DRY-YEAR OPTIONS .

In their emerging states, there are two fundamental sources of uncertainty or risk in water markets: supply uncertainty and price uncertainty. In an analysis of spot prices, option prices, and water markets, Howitt (1998) attributes thin markets and market inefficiencies to these uncertainties in water markets. Howitt explains that options markets are a middle ground between pure spot markets and water markets for the permanent acquisition of water and that through options markets, this risk and uncertainty can be spread between the suppliers and demander in a water market.

In spot markets, uncertainty is bourn by demanders of water, as they must rely on thinly traded markets with uncertain supply to meet their inelastic needs. In the case of permanent transfer markets, suppliers must bear the uncertainty about the future value of their water and risk selling their water rights too cheaply. In both spot and permanent purchase markets, these uncertainties lead to excessive transaction costs for the risk averse.

If appropriately arranged, dry-year options markets have the potential to spread the price and supply risk between suppliers and demanders of water during dry years. Demanders shift some of the spot market risk to suppliers by purchasing an option in advance of drought-induced supply shortage. Likewise, suppliers are relieved of some of the price risk inherent in permanent purchase markets, as options markets facilitate the *temporary* reallocation of water and suppliers would remain in possession of their water rights (Howitt 1998).

In addition to spreading the risks innate in water markets, Howitt also points to options markets to reduce third-party impacts of water transfers. The permanent transfer of water can have severe, permanent economic consequences in the area of origin. Because options are seasonal and temporary in nature, the suppliers (typically farmers) continue normal farming operations in most years and in years the options are exercised would be expected to continue participating in the local economy and spend at least some of the options payments locally. In comparison to spot markets, options markets also allow rural communities much more time to plan for changes in local spending patters that occur as a result of temporary water transfers, thus minimizing the impact of those changes

2.4 EXAMPLES OF DRY-YEAR OPTIONS IN PRACTICE

Dry-year option agreements are gaining attention both in theory and practice as a promising way to enhance dry-year supply reliability while providing flexibility to meet the needs of both buyers and sellers and minimizing third party impacts. A review of the experience of emerging dry-year options markets can provide practical guidance in structuring dry-year supply variability strategies for the Lower Colorado River Basin.

2.4.1 California

In recent years there have been a number of dry-year programs and transfers initiated in California as a result of supply shortage in southern California owing to drought, the Quantification Settlement Agreement, and low farm commodity prices (Howitt and Hanak 2005). A lead player in the emerging options market has been the Metropolitan Water District of southern California (MWD). MWD has successfully secured the option to use water from several Sacramento Valley irrigators. Options have been secured for $10/AF, and then growers are paid an additional $90/AF to exercise the option. Here, participating irrigators have switched to less water-intensive crop production in order to provide water for the transfers. In 2003 almost 100,000 acre-feet of water were transferred via dry-year options agreements in the Sacramento Valley (Metropolitan Water District of Southern California 2003).

An earlier example also involving MWD was a 1993 dry-year option arrangement whereby MWD secured option contracts from irrigators in the Palo Verde Irrigation District (PVID), which is located along in Colorado River in California. The option fee allowed MWD to call on water from participating PVID farmers generated by fallowing up to 25% of their land during dry years (Howitt 1998). During a two year pilot program, PVID farmers fallowed 20,215 acres of land for $620 per acre. The land fallowing generated approximately 92,421 acre-feet of conserved water at approximately $136/AF.

The conserved water was stored in Lake Mead and could be called on by MWD up to the year 2000 at which time any unused portion was forfeited.

California also initiated an option market in 1995 following several years of drought and the operation of the California Emergency Drought Bank. Options were purchased in December of 1999 at $3.50/AF (Howitt 1998). The exercise price, which would be paid by the option-holder in the event of a drought, was negotiated at between $36.50 and $41.50 per acre-foot. 29,000AF of water were secured as options at the end of 1994 for use before May of 1995. Improved hydrologic conditions, however, rendered the exercise of the options unnecessary.

2.4.2 Utah

Utah has also used dry-year options to secure its urban supply in some areas. For example, an irrigator in Utah was paid $25,000 by a municipality to secure a 25-year option to use some of the irrigator's water. Then, each year the option is exercised, the municipality pays the irrigator a pre-set exercise fee plus compensation for the quantity of alfalfa the irrigator would have grown had the water not been transferred to urban use (National Research Council 1992).

2.4.3 Texas

The Edwards Aquifer Region of Texas has also considered employing dry-year options to meet water demand in dry years. With the aim of raising aquifer levels, increasing springflows, and ensuring drought relief for municipalities if necessary, in 1997 the Edwards Aquifer region initiated the Pilot Irrigation Suspension Program (ISP). The ISP, which paid irrigators to forego irrigation in the 1997 cropping season, was unique from other forbearance programs in the West in that it applied to groundwater instead of surface water, was implemented despite the lack of fully defined water rights, and was, in part, motivated by enhanced springflows to support endangered species (Keplinger *et al.* 2000).

Eligible irrigators who submitted sealed bids to the Edwards Aquifer Authority (EAA) were selected based on four criteria: (1) location of the well and strength of the hydrologic connection to Comal Springs, (2) irrigation water requirements in 1995 and 1996, (3) irrigation equipment used, and (4) assurance of dryland crop on the proposed acres. The fourth criterion was included to minimize impacts to agriculture-dependant industries and to support community interests. Each bidder was assigned a score from 0 to 10 for each criterion, which was them summed, and then per acre bids were divided by the sum to produce the final score, a lower score being more attractive (Keplinger *et al.* 2000).

Bids ranged from $116 to $750 per acre, with a median bid of approximately $300. In the end, the EEA accepted bids from 39 irrigators, totaling 10,067 acres of land. Payments to all enrolled irrigators, whose participating farm sizes ranged from 45.3 to 1,269 acres, totaled $2,295,132. To fund the program, the EEA received pledges totaling $2,350,000 from 32 water utilities and other larger pumpers.

An analysis of the 1997 ISP by Keplinger *et al.* (2000) presents a number of interesting findings. First, at an average price of $234 per acre, the ISP was applied to 10,067 irrigable acres in the Edwards Aquifer region. This rate is higher than what regional lease rates and land prices would suggest which may be attributed to the newness of the ISP, its timing, collusion among farmers, and/or the belief that bids might affect future water prices or offers.

Keplinger *et al.* also analyzed the impact of the ISP on crop rotation and mixes of participating irrigators. Farmers who participated in the forbearance program tended to shift their crops from water-intensive corn, cotton, and vegetables to more water efficient sorghum and wheat. Despite a moderate reduction in the purchase of fertilizer, seed, and labor, secondary effects on the local economy appeared minimal.

Finally, farmers willingly participated in the pilot ISP, and regional suppliers willingly funded the program. Although some modifications to the selection criteria, bidding process, and timing of the program may help reduce program costs, the 1997 ISP was proven a feasible, reasonable response to meeting the needs created by low Edwards Aquifer levels.

Dry-year options arrangements, which the ISP was initially anticipated to be structured around, are identified by Keplinger *et al.* as a more direct alternative to reducing irrigation than the ISP. Dry-year options arrangements could not be implemented in 1997, however, because the necessary structure of tradable water rights was not in place.

2.4.4 Chile

In Chile, which is one of the few countries outside the U.S. that utilize water markets to manage water resources, farmers have negotiated options agreements amongst themselves to minimize dry-year supply variability (Thobani 1998). Instead of purchasing permanent water rights, farmers growing perennial fruits/crops secure the option to lease water for a season from a neighboring farmer engaged in annual crop production. This way, farmers save on purchasing water that will only be needed in dry years.

2.5 PROPOSALS FOR USE OF FORBEARANCE AND DRY-YEAR OPTIONS

Three recent proposals, one by a group of NGOs, one by the Yuma Desalting Plant/Cienega de Santa Clara Workgroup, and one by the Bureau of Reclamation, all point to irrigation forbearance and dry-year options in Arizona and the Lower Colorado River Basin as a reallocation mechanism.

2.5.1 Conservation Before Shortage

If a shortage were declared in the Lower Colorado River Basin, CAP water users would be among the first to experience reduced deliveries. At present, no criteria exist to guide the Secretary of the Interior in declaring a shortage, though a scoping process to develop shortage guidelines has recently been undertaken by the Department of the Interior. Other concerned parties have also developed proposals for shortage sharing.

One such proposal is “Conservation Before Shortage,” a document developed by several NGOs and released on July 18, 2005. The document proposes Colorado River drought management strategies aimed at avoiding extreme and uncompensated water shortages. The proposed conservation strategies hinge on the elevation of Lake Mead, such that when Lake Mead is drawn-down to specific elevations, conservation through predictable, small-scale reductions in use by Lower Basin users is triggered. A fundamental element of the “Conservation Before Shortage” strategy is voluntary forbearance agreements in the form of part-year fallowing programs, dry-year options, and other similar arrangements (Conservation Before Shortage 2005).

The rational for voluntary forbearance is that conservation of between 200,000 and 600,000 acre-feet of Colorado River water could be generated through forbearance of just 4-11% of Colorado River water used for crop irrigation in the Lower Basin. Based on current prices of short-term water leases between farmers and irrigation districts or municipal water districts as well as economic analyses of the net return of irrigation water, the document suggests water conserved through forbearance arrangements could be acquired for $20 - $100 per acre-foot. An economic study undertaken by the NGO Environmental Defense suggest that over 2.3 million acre-feet of irrigation water is currently being applied to crops in Arizona and California that yield profits under $100 per acre-foot. Of this, about 1 million acre-feet are being applied to crops that generate profits under $20 per acre-foot (Conservation Before Shortage 2005).

2.5.2 Yuma Desalting Plant

A consumptive use reduction and forbearance program based on voluntary, temporary land fallowing has also been suggested as one of the solutions to controversy surrounding the operation of the Yuma Desalting Plant (YDP). As laid out in the April, 2005 document "Balancing Water Needs on the Lower Colorado: Recommendations of the Yuma Desalting Plant/Cienega de Santa Clara Workgroup," the operation of the YDP would have both positive and negative impacts in the Lower Basin and Mexico. Its operation would reduce the bypass of drainage water to Mexico from the Wellton-Mohawk Irrigation and Drainage District (WMIDD) in southwestern Arizona. This would eliminate the need for additional releases from Lake Mead to make up for the bypass water, thus lessening the risk of shortage to Lower Basin water users. However, the operation of the plant would be costly, and the reduced bypass flow would likely have severe environmental consequences in the Cienega de Santa Clara, a large wetland in Mexico sustained by drainage water from WMIDD (Yuma Desalting Plant/Cienega de Santa Clara Workgroup 2005).

One component of the workgroup's recommendations is a Basin-wide pilot consumptive use reduction and forbearance program. The idea behind the program would be to pay farmers to voluntarily reduce their use of Colorado River water for irrigation and then credit the unused water to offset the obligation of the bypass flow. The irrigation forbearance could occur in the long term, on an annual basis, or temporarily through mechanism such as dry-year options (Yuma Desalting Plant/Cienega de Santa Clara Workgroup 2005).

Participation in the forbearance program would be open to eligible irrigators in the U.S. and in Mexico. The workgroup suggests that a target volume of water conserved through forbearance could be tied to the elevation of Lake Mead, available funding, or another related limit. The pilot program would be undertaken for a defined period of time, at the end of which it would be determined, based on cost and effectiveness, if forbearance should be phased in as a component of the long-term YDP plan.

2.5.3 Demonstration Program for System Conservation

The Bureau of Reclamation recently released a draft proposal for the establishment of a demonstration system conservation program. If implemented, the program will be aimed at providing the Bureau with a mechanism to determine whether system conservation via land fallowing could effectively mitigate the impacts of releasing water from the Colorado River system for bypass flow replacement or YDP reject stream (Bureau of Reclamation March 2006). If implemented, irrigators will be given the opportunity to submit proposals for system conservation (i.e. land fallowing) on up to 33% of their land. Alternatively, the Bureau may also establish a dollar amount it is willing to pay for the conserved water and seek offers at that price. The program is proposed to commence in 2006 and continue through Dec. 31, 2008.

2.6 EQUIMARGINAL PRINCIPAL APPLIED TO WATER

The principle of equimarginal value is based on the concept that in perfect competition, the marginal value is equal among all uses (Beattie and Taylor 1985). This principle can be applied to resource allocation decisions. In particular, the equimarginal principle applied to water markets states that the marginal benefit per unit of water should be equal across all users (Agudelo 2001). In other words, water is efficiently allocated when the value of the last unit of water used or consumed by each user group equivalent. Any further redistribution of the water would make at least one user group worse off and would thus be an inefficient allocation.

When agricultural, urban, and environmental water prices are different, the marginal value to each user group is different, which is not a socially optimally allocation of the water. As a market matures, we would expect the price of water for each user group to converge. The following graph depicts the expected price convergence.

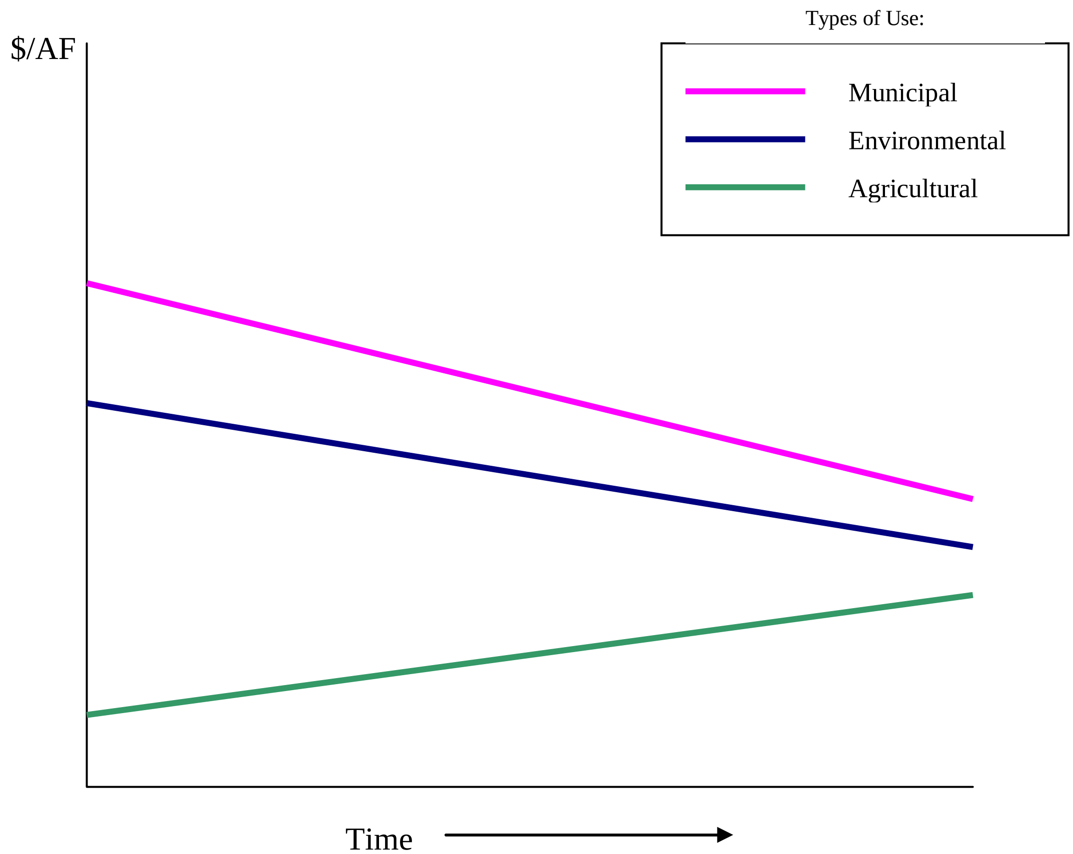


Figure 1.1 Equimarginal Principle of Price Convergence

In practice, however, it is often the case that water laws, regulations, and the nature of water rights deter the optimal market-based allocation of water (Wilson 2002).

2.7 VALUING AGRICULTURAL WATER

Information comparing the economic value of water across different uses is an important water management tool. In a water-short West, competing demands among various water uses such as municipal, recreation, and crop production create incentives to transfer water from low-value to higher-value uses. Data on the economic value of water helps parties negotiate fair prices for water transactions. A variety of methods have been developed.

Because agricultural water represents such a substantial portion of consumptive use in the West and because there are economic efficiency gains in transferring water out of low-value agriculture to higher value uses during times of shortage, most water transactions will necessarily involve agricultural water. As such, accurately valuing irrigation water is an important component of structuring and negotiating dry-year water transfers so that the necessary quantity of water needed is provided at a reasonable price.

An example of the importance of accurately valuing irrigation water is the California Drought Bank. The California Emergency Drought Water Bank was established in 1991 as an adaptation mechanism following five years of drought in the state (Clifford *et al.* 2004). The California Department of Water Resources (DWR) negotiated voluntary contracts to purchase water for $125 per acre-foot from farmers who chose to fallow their land or substitute groundwater for surface water irrigation. DWR negotiated 351 supply contracts in less than five months, making available over 820,000 acre-feet of water to meet the critical needs of the state. However, at the $125 offer price, DWR obtained more water than the end users were willing to pay for, and the state had to bear the unreimbursed costs. California's experience highlights the fact that irrigators vary their response based on offer price, so it is essential to set a price designed to obtain the desired quantity.

Young (2005) describes several widely-employed methods for valuing irrigation water:

2.7.1 Water-Crop Production Functions

The vale of irrigation water is based on a water-crop production function. A water-crop production function explains the link between the application of water and crop yield. In other words, it defines a relationship between a specific level of input (water) and its effect on output (crop production). These functions are crop, location, and soil specific and depend on assumptions about the level of other crop production inputs. Crop-production functions are typically estimated based on expert opinion but can also be approximated using field experiments and computer simulation (Young 2005).

2.7.2 Water Market Observation

Another method for valuing irrigation water is the direct observation of transactions made in water rights markets. Such observations can provide insight into users' valuation of short-term leases of irrigation water or the permanent purchase of agricultural water rights. In theory, water market transactions should reflect the economic value of water, which would fluctuate with its level of scarcity. In dry years, for example, the equilibrium price of irrigation water would be higher than in comparably wetter year because in the short run, water demands are price-inelastic. This makes assessing the long-term value of water using short-term lease rates potentially problematic. Other complications associated with this method include scant transaction data and scarce or constrained water markets (Young 2005).

2.7.3 Residual or Farm Budget Approach

A common nonmarket method for valuing irrigation water is the residual or farm budget method, which involves crop production cost and return analysis. The first step is typically to generalize to one or more representative farm models the approximate soil type, climate, labor supply and other crop production inputs, and cropping patterns for individual farmers in a specific location. A table detailing operations and inputs for each crop is then constructed based on assumptions about the representative farm. Data on the steps in the production process, timing, required production resources, and resulting outputs are gleaned from a crop- and location- specific crop budget. This data is then used to assemble a Unit Crop Budget to calculate and display net returns over variable costs per acre for each crop. This value represents the on-farm economic value of water in crop production and is calculated by subtracting variable production costs (exclusive of water costs) from gross returns per acre (Young 2005).

Although this approach can be fairly straightforward from an accounting perspective, bias that arises during the aggregation from an individual crop to a representative farm can be nontrivial. Young warns that farm budget analyses are quite sensitive to the assumptions made about the nature of the production function as well as input and output prices and quantities.

CHAPTER 3

3.1 DATA AND METHODOLOGY

The following sections describe the data and methodology used in the econometric analysis of water leases in the western U.S.

3.1.1 Data

The dataset consists of 660 temporary water transfers occurring in the western United States between 1987 and 2005. The leases are subdivided by state. The dataset is comprised of leases from Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming. The primary source of transaction data used in the analysis are three private publications, *The Water Strategist, Water Market Update,* and *Water Intelligence Monthly.* These subscription publications provide monthly coverage of marketing, legislation, litigation, and financial information on water resources. It should be noted that the sources used in compiling this data does not report transactions between users in the same water district. Such transfers, which are a regular component of farmers' water management strategies, can involve substantial volumes of water (Howitt and Hanak 2005).

The following is a brief description of the major explanatory variables compiled based on information provided in *The Water Strategist*, *Water Market Update,* and *Water Intelligence Monthly* and, if applicable, states the hypothesized sign of parameter estimates:

Price - The price, *lnAdj_Price*, is the natural log of the real price per acre-foot paid for leased water. All prices are adjusted to 2005 dollars using the Consumer Price Index. If the life of the lease is more than one year, the annual price per acre-foot is used to ensure comparative prices across leases of various lengths.

Date – For each temporary transfer, the date is a record of the month and year the transaction was reported. It should be noted, however, that due to a lag in reporting, this date does not correspond to the date the transaction was actually formalized. As a result, select variables are lagged to account for the discrepancy between the actual transaction date and the date it was reported.

The year a transaction occurred is used to construct a trend variable to assess if there is a statistically significant trend up or down in the price of leased water over time. Over time, water is becoming a scarcer resource (Griffin 2006). Factors such as population growth are shifting the demand curve for water outward, which increases the price of water. However, a negative time trend may also be reasonable. This is because as a lease market matures, transaction costs may be reduced and potential sellers may become more comfortable with the process and confident their long-term water rights will be protected. These factors may in turn increase the number of sellers in the market, causing the supply curve to shift out and price to decrease.

Quantity – The number of acre-feet of water transferred is captured in the variable *lnAF*, which is the natural log of total acre-feet transferred per lease transaction. Presumably, some of the transaction costs inherent in leasing water such as locating a partner and gaining approval for the transfer would not significantly increase with the quantity of water leased, and thus economies of scale come into play. Economies of scale, or a price per unit decrease as the number of units increases, would suggest a negative relationship between the quantity of water leased and its price per acre-foot. It should be noted, however, that the models estimated in this research are of reduced form, which creates difficulty in separating supply and demand side variables and hypothesizing the direction, either positive or negative, of a change on quantity on the price per acre-foot.

Original Use – This variable indicates how the water was originally used. Major categories include agriculture, municipal, industrial, and storage/surplus.

New Use - The new use variable indicates how the leased water is put to use. Major new use categories include agriculture, municipal (which includes landscape and golf course irrigation as well as new development), environmental, recreation, industrial, and storage.

Because the marginal value of water varies across uses, in developing lease markets water leased for lower values uses such as low-value crop production would be expected to be less than for relatively higher values uses such as municipal or environmental. In more mature markets, however, this relationship may not hold, as the equimarginal principle suggests a convergence of price across uses.

Type of Water – The type of water leased is categorized as either surface water, groundwater, or effluent. Consumers' tastes and preferences and aversion to risk may come into play in determining whether the type of water has a positive or negative impact on price. Because groundwater is less susceptible to the immediate effects of drought than surface water, thereby lessening the risk of shortage, people may value groundwater more highly than surface water or effluent and thus have a higher willingness to pay for groundwater supplies. In terms of quality, effluent is generally considered inferior in quality to surface and groundwater, so consumers' willingness to pay for reclaimed water may be relatively lower than for ground or surface water.

Length of Lease – This variable represents the number of years of the life of a lease. The sign of its coefficient is difficult to hypothesize. On the one hand, lessees may have a higher willingness to pay for a longer lease for the longer assured supply. On the other hand, a shorter term lease may represent an effort to meet an immediate need, and thus the willingness to pay might be higher due to relative price inelasticity of demand in the short run. The following chart shows the distribution of the length of water leases in the West that occurred between 1987 and 2005.

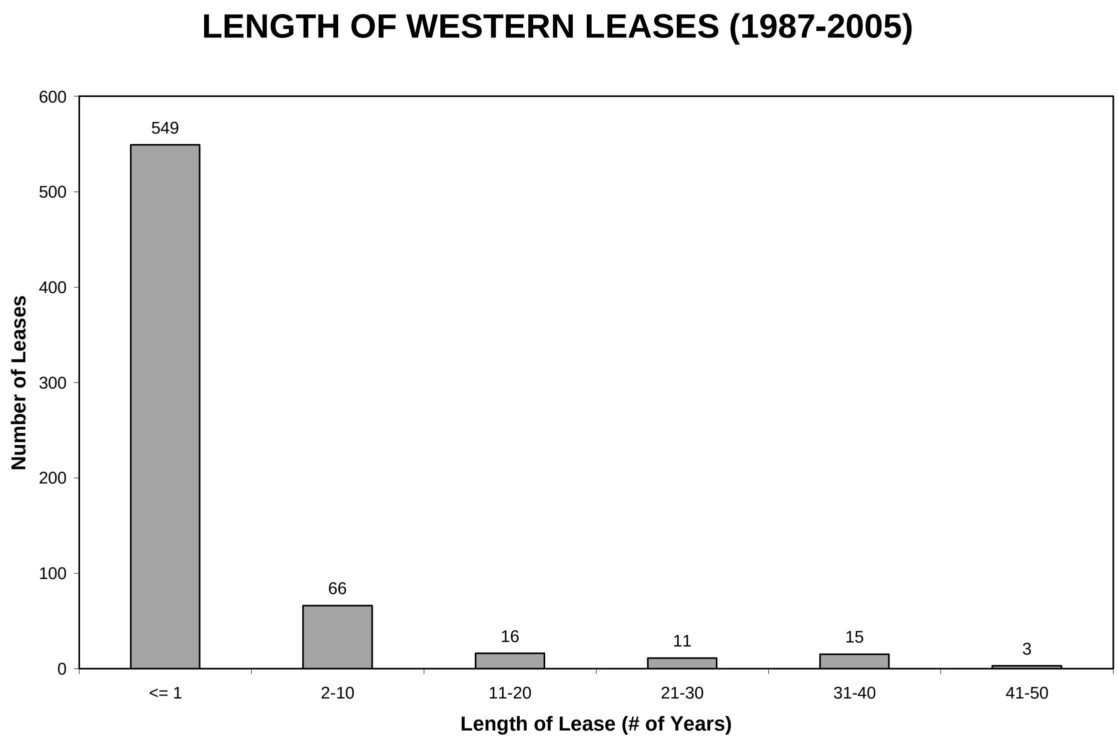


Figure 3.1 Length of Western Leases

The vast majority (83%) of all leases over the period are for a term of one year or less. 10% of the leases carry a term of 2 to 10 years, and each other term category represents less than 2.5% of all lease transactions across the period.

In addition to a variable representing the exact number of years of a life of a lease, a binary variable indicating whether a lease was either one year in length or, alternatively, some other time period was created. This binary variable was tested in each model but was only found to be statistically significant in very few models. Therefore, the length of lease variable was chosen in this analysis to explore the impact of the life of the lease on the price of leased water.

In addition to the variables compiled based on information provided in *The Water Strategist and Water Intelligence Monthly*, a number of other factors are hypothesized to influence the price of leased water. These supplementary variables will be briefly described here.

Drought Index – Relative dry and wet conditions are captured using the Standard Precipitation Index (SPI). The SPI was developed to monitor drought and is a measure of the probability of precipitation for a given time period (National Oceanic and Atmospheric Administration "Standard Precipitation Index"). The Index ranges from -4 to 4, with -4 representing extremely dry conditions and 4 extremely wet. A more detailed description of the SPI will be provided later in this section, but in general, as the SPI goes down and hydrologic conditions become dryer, the supply of water would shift in. This would imply a negative parameter estimate on the SPI variable. During drought, this may be further compounded by an increase in demand for water, as junior rights holder find themselves in a shortage situation and thus enter the lease market, shifting out the demand curve.

Climate Index - A newly developed climate index, the Multivariate ENSO Index (MEI) is also explored in this analysis. The El Nino/Southern Oscillation (ENSO) index is linked to yearly climate variability (Klaus 2004). Because the climate/hydrologic implications of the MEI varies from region to region, the expected sign varies as well. In general, in the southwestern U.S. a positive MEI value indicates an El Niño event, suggesting a wet winter. Thus, as the MEI increases corresponding to wetter conditions and a shift out of the supply curve, the price of leased water is expected to decrease. In the Pacific Northwest region, a positive MEI indicates an El Niño even, which corresponds to dry winter conditions. Thus, as the MEI increases the supply curve would shift in and the price of leased water is expected to increase. The MEI will also be described in more detail later in this section.

Economic Indicators – A state or region's economic vitality and population growth is also expected to have some impact on the price of water. Thus, a number of economic indicators were collected from the Census Bureau and Bureau of Economic Analysis. Theses included population, population growth, personal income (defined as income earned from all sources including participation in production as well as from government and business transfer payments (Bureau of Economic Analysis "Glossary")) and change in personal income, as well as per capita income and change in per capita income. In general, increases in these economic indicators would shift the demand curve out, and thus the expected sign on these parameter estimates would be positive. However, given the temporary nature of water leases and the reasons people lease water, the positive relationship between economic/population growth and price may not be so straightforward.

The following table provides a summary of expected sign and a brief explanation for the key variables analyzed here:

Independent Variable	Expected Sign	Explanation
Date	+	Scarcity value of water; population growth, etc. (increasing demand)
Quantity	-	Economies of scale
New Use	+/-	Depends on type of new use and market maturity
Type of Water (surface and effluent as compared to ground)	-	Groundwater less susceptible to short term drought effects; effluent perceived as inferior quality
Length of Lease	+/-	Longer assured supply with longer lease/higher willingness to pay to meet immediate need
SPI	-	As hydrologic conditions become dryer (SPI more negative), supply shifts in and demand shifts out
MEI	-	Dryer climatic conditions (MEI more negative) correspond to inward shift of water supply and increase in demand

Table 3.2 Expected Sign and Explanation for Select Variables

3.1.2 Details of the SPI and MEI

A valuable feature of the SPI is its capacity to measure drought at different time scales. The SPI can be calculated to cover the last 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 18, 24, 30, 36, 48, 60, or 72 months, and ending on the last day of the latest month (Western Regional Climate Center "Explanation of Terms"). Thus, the SPI can capture short-term droughts, droughts of three to six months which affect soil moisture and small rivers and ponds (and thus agricultural production), and longer term droughts of six months to several years which have implications for major river, aquifers, and other large bodies of water. As a result, choosing the most appropriate term over which to calculate the SPI should be specific to a particular area. If an area is heavily dependent on smaller, local rivers or lakes to meet its water needs, a shorter-term SPI might be more appropriate. If, however, an area depends on groundwater or large rivers or storage reservoirs that would only be affected by more sustained droughts, a longer-term SPI might better capture how drought conditions are affecting the water supply and likewise how that change in the water supply is affecting the price of leased water. Because many areas in the West depend on a variety of water sources (e.g. Arizona depends on groundwater, the Colorado River, and local rivers and streams) selecting the most appropriate SPI can be challenging.

Each state in the U.S. is divided into climate regions, and the SPI for each region is calculated using average precipitation and temperature data from 10 to 50 weather/climate data stations within that region. A climate region is said to be in drought when the SPI is continuously negative and reaches a value of -1 or less (National Oceanic and Atmospheric Administration "Standard Precipitation Index). The drought continues until the SPI climbs back into the positive region.

SPI data were obtained from the Western Region Climate Center database and assigned to each lease based on the year, month, and climate region in which the transaction took place. In most states analyzed, the transfer originated from the same climate region as where the water was put to a new use. Thus, only one SPI value was assigned per transaction. In California, however, it is quite common for transfers to cross climate regions, and to account for this SPI values were assigned to each transaction based on the climate region where the water transfer originated as well as the climate region where the water was ultimately transferred.

The new climate index, the MEI, was developed to represent the oceanic-atmospheric nature of ENSO by incorporating the main observed variables over the tropical Pacific. The MEI is a weighted average of sea-level pressure, the east-west and north-south components of the surface wind, sea surface temperature, surface air temperature, and the total fraction of cloudiness in the sky. The MEI is calculated on a sliding bi-monthly basis, and all seasonal values are standardized with respect to each season and to the 1950-1993 reference period to keep the MEI comparable (Klaus 2006).

El Nino, or a warm ENSO phase, is represented by positive MEI values, while negative MEI values reflect a La Nina, or cold ENSO phase. Therefore, a positive MEI would indicate a dry winter in the Pacific Northwest and a wet winter in the Southwest. Conversely, a negative MEI would suggest a wet winter in the Pacific Northwest and a dry winter in the Southwest.

Because we would often expect buyers and sellers to take into account long term hydrologic and climactic conditions, SPI and MEI of various lengths were explored. In particular, SPI and MEI indices based on 2, 6, and 12 month averages were considered. Lagged values of each time scale were also included. This is because negotiations and the water transfer approval process can take many months to finalize. Further, as mentioned, the month a transaction was finalized does not generally correspond to the date the transfer was reported. Thus a lag effect of 6 and 12 months for the SPI and MEI are assessed.

3.1.3 Sample Selection

Occasionally, the information reported on a specific transaction was limited, ambiguous, or raised questions about the legitimacy of the transaction as a true *market* transaction. The following criteria were employed in the sample selection process: when purchase price per acre-foot was reported as a dollar range, the midpoint was assigned to the transaction; transactions of less than $5 per acre-foot were deleted as too low to be based on supply and demand factors (in California the cutoff was set at $10 because of generally higher reported market values for water there); transactions for which the reported price per acre-foot was not set, varied, or was unclear were deleted. Transactions that included land or other infrastructure in addition to a water right were considered on an individual basis. If it was not obvious the transaction occurred solely for the acquisition/use of the water right, the transaction was deleted. Transactions were also eliminated if the length of the lease was over 40 years because we would expect transfers longer than this to take on the characteristics of a permanent transfer. The following table summarizes the variables included in the dataset.

Description of Variables

Name	**Description**
Month	The month in which the transaction was reported.
Year	The year in which the transaction was reported.
State	The state where the transaction occurred.
Price	The price paid per acre-foot of water.
Adj_Price	The price per acre-foot adjusted to 2005 dollars.
AF	The number of acre-feet of water transferred.
Supplier	The type of entitity that supplied the transferred water.
Acquirer	The type of entitity that leased the water.
OrigUse	The original use of the water.
NewUse	The intended new use of the leased water.
Water	Indicates if the water was surface water, groundwater, or effluent.
Years_Lease	The number of years of the life of the lease.
Trans_per_year	The number of transactions that occurred in a state in specific year.
Metro_Area	Indicates in the transfer occurred in a select metro area.
Region	The climate region in which the transfer took place.
SPI	2-month Sandard Precipitation Index (SPI) for the climate region.
SPIL6	2-month SPI lagged six months for the climate region.
SPIL12	2-month SPI lagged twelve months for the climate region.
SPI6	6-month SPI for the climate region.
SPI6L6	6-month SPI lagged six months for the climate region.

SPI6L12	6-month SPI lagged twelve months for the climate region.
SPI12	12-month SPI for the climate region.
SPI12L6	12-month SPI lagged six months for the climate region.
SPI12L12	12-month SPI lagged twelve months for the climate region.
SPI24	12-month SPI for the climate region.
SPI24L6	12-month SPI lagged six months for the climate region.
SPI24L12	12-month SPI lagged twelve months for the climate region.
MEI	2-month average Multivariate ENSO Index (MEI).
MEIL6	2-month average MEI lagged 6 months.
MEIL12	2-month average MEI lagged 12 months.
MEI6	6-month average MEI.
MEI6L6	6-month average MEI lagged 6.
MEI6L12	6-month average MEI lagged 12 months.
MEI12	12-month average MEI.
MEI12L6	12-month average MEI lagged 6 months.
MEI12L12	12-month average MEI lagged 12 months.
Adj_Alfalfa	Real 3-month average price of alfalfa at state level.
Population	Total annual state population.
Pop_change	Percent change in annual population at state level.
Per_capita	Nominal annual per capita income at state level.
Per_capita_adj	Real annual per capita income at state level.
Per_capita_change	Percent change in annual state per capita income.
Personal_Income	Nominal annual personal income at state level.
Personal_Income_adj	Real annual personal income at state level.
Income_change	Percent change in annual personal income at state level.

Table 3.3 Description of Variables

3.2 Methodology

A derived demand model of water lease markets is estimated for each state in the western U.S. with at least 30 lease transactions between 1987 and 2005. Because price and quantity are often simultaneously determined, which leads to endogeneity bias, the Hausmann-Wu test is performed on each model to determine whether or not price and quantity are endogenous in temporary water markets across the western U.S. If quantity is found to be endogenous in the price equation, this would, unaddressed, lead to inconsistency and bias in Ordinary Least Squares (OLS) analysis (Wooldridge 2003). The remedy applied here is two-stage least squares (2SLS). In the first stage, instrumental variables (which are assumed to be exogenous) are used to predict the value of quantity. Supply-side variables generally are used as instruments for quantity and demand-side variables are used in the price models. In the second stage, the predicted value of quantity is then substituted back into the price equation as an explanatory variable. This is performed in SAS using the canned procedure *syslin*.

If the Hausmann-Wu test indicates quantity is exogenous, however, OLS is applied in favor of 2SLS. This is because when the explanatory variables are exogenous, the 2SLS estimator is less efficient than OLS (Wooldridge 2003). After estimating a model using OLS, the Breusch-Pagan test and White's test for heteroskedasticity are conducted to determine whether the variance is constant. If the tests indicate a non-constant variance, the variance-covariance matrix is used to construct Huber-White robust standard errors so that valid hypothesis tests can be carried out. This is performed by specifying the ACOV option in the model statement in SAS. The resulting asymptotic standard errors are then used to calculate the chi-square test statistic for each independent variable using the *test* command in SAS. The chi-square test statistic is used to calculate whether each independent variable is equal to zero. It is calculated as the square of the ratio of the parameter estimate divided by the standard error (SAS Help and Documentation 2002). Here, the chi-square test statistic is the appropriate test statistic because of the asymptotic nature of the heteroskedasticity-robust standard errors.

CHAPTER 4

4.1 ECONOMETRIC ANALYSIS OF WESTERN WATER LEASES – MODELS AND RESULTS

Accurate price signals ease the reallocation of water from low-value uses to higher-value uses, and well-functioning water markets can provide incentive for the reallocation of water according to its use value. This empirical analysis is a first step towards identifying the factors that explain the price of leased water across the western U.S.

Temporary water leases in the West are analyzed using two-stage least squares (2SLS) techniques to compare and explain the determinants of the price of the West's water leases. Because each state has a distinct water supply system, distinct laws governing water rights and water transactions, and different patterns of demand, a cross-state comparison of water markets is of interest.

4.2 OVERVIEW OF WATER LEASES IN THE WEST

Temporary water transfers in the West are, by and large, particular to the state and, to a large extent, even the region within a state in which the transaction takes place. Water transfers are unique to a particular state because laws, regulations, and institutions surrounding water transfers are state-specific. As a rule, the prior appropriation doctrine is the underlying principle in western water law. Prior appropriation is based on the idea of "first in time, first in right," such that the first person who puts water to a beneficial use acquires the permanent rights to that water without interference from those with more junior water rights (Landry and Peck 1998). But although water rights in basically all states in the West are governed by the doctrine of prior appropriation, some states have complex legal definitions of water rights and closely regulate when, how, and for what purpose they can be transferred. Laws and regulations in other states, however, are much more straight forward and actively promote the reallocation of water.

Another factor influencing the nature of water transfers is a state's treatment of third party impacts. Environmental and rural community third party impacts associated with transferring water between users can carry considerable transactions costs, both in terms of time and money, and thus the way a state views and addresses third party impacts can affect the overall functioning of a water market.

The water infrastructure in a state can also encourage or impede the development of water markets. Some states have vast water storage capacity and natural or man-made means of transferring water around the state while others are far more limited in their ability to physically transport water between users.

Finally, climactic and demand-side variables can vary dramatically from state to state. Spot markets for water would presumably be more likely to develop in states that experience (or are affected by) frequent and/or prolonged drought. Also, states with rapidly growing populations, who, in turn, are placing increasing pressure on a finite water supply, may be more likely to turn to water markets as a way of meeting excess demand. As a result of all of these factors, temporary water markets across the West have evolved differently and are at different stages of development.

In addition to state-specific characteristics that influence water market development, there may also be a number of distinguishing characteristics within a state that differentiate markets within the same state. For example, the climate in most western states is not homogenous; a state can experience extremely different climactic and water supply conditions within its borders. Such is the case in California, for example, where the northern portion of the state typically receives abundant annual rainfall while southern California is much drier. Thus, a market to transfer water between users both located in northern California would likely be quite different than a market established to reallocate water from users in the north to meet demand in the south of the State. Also, some states have a unique system of laws and regulations for different types of water. Texas, for instance, governs surface and groundwater rights differently based not only on the type of water but also the basin in which the water is located (Griffin and Characklis 2002). As a result, Texas has a distinct surface water market in the Rio Grande Basin and groundwater market in the Edwards' Aquifer region, and markets in other portions of the State are quite different.

Population growth, environmental needs, and drought conditions in the West are increasingly stressing the West's water supply. Consequently, water market transactions for leased water are, in general, becoming more commonplace. The following graph depicts the increasing trend in temporary water transactions from year to year since 1987.

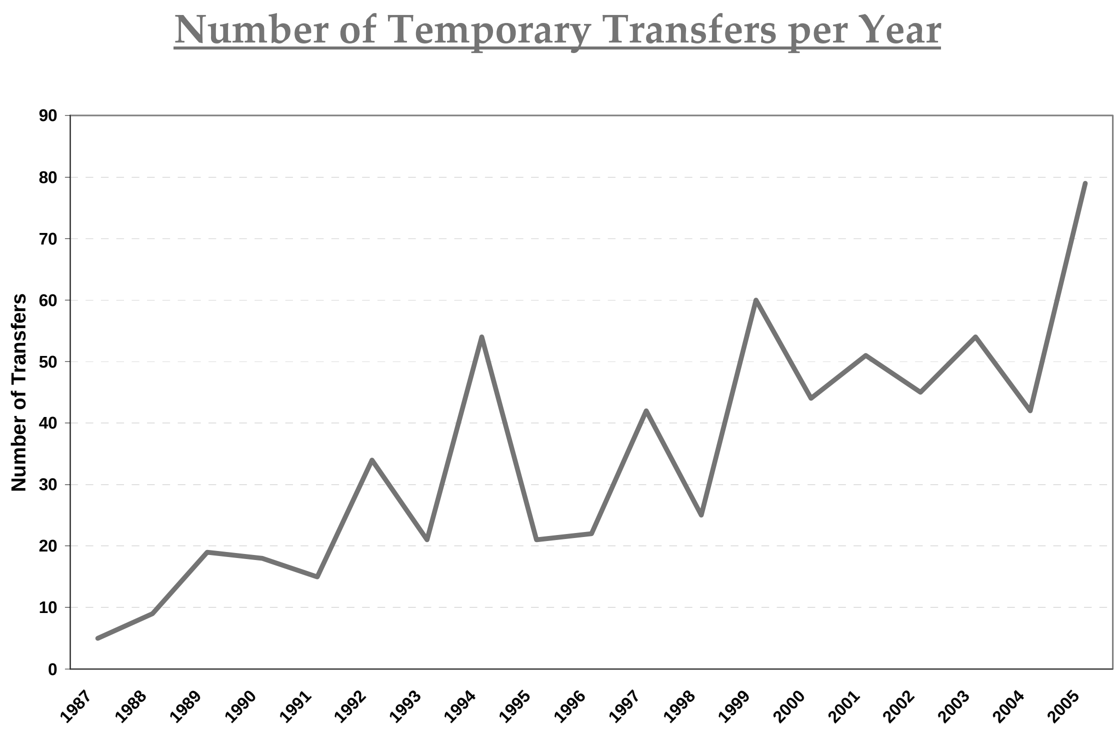


Figure 4.1 Number of Transfers Over Time

As water markets across the western U.S. develop and mature with increasing market activity, it would be expected that the price per acre foot of leased water would trend upward. Visual inspection of the annual average price (adjusted to 2005 dollars) of leased water across the West from 1987 to 2005, however, does not reveal any clear price trend.

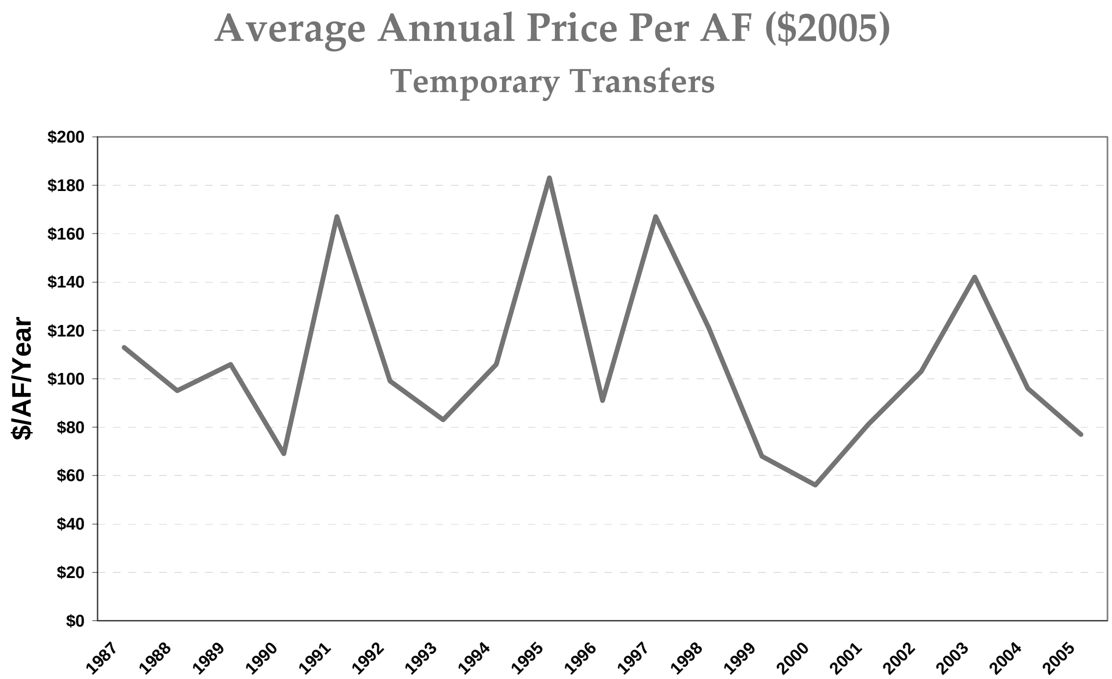


Figure 4.2 Average Price Trend Over Time

The following table provides an overview of water market activity for temporary water transfers in the western U.S. between 1987 and 2005 at the state level. All price figures are adjusted to 2005 dollars using the Consumer Price Index.

Summary of Western Water Leases, 1987-2005				
STATE	**TOTAL LEASES**	**TOTAL VOLUME (AF)**	**AVG VOLUME (AF)**	**AVG PRICE* ($/AF/YEAR)**
Arizona	47	4,486,175	95,451	$88.15
California	212	6,485,335	30,591	$127.38
Colorado	64	211,012	3,297	$140.55
Idaho	33	1,586,434	48,074	$50.91
Montana	9	27,088	3,010	$22.47
Nevada	3	59,850	19,950	$88.94
New Mexico	47	441,316	9,390	$58.37
Oregon	44	747,968	16,999	$42.57
Texas	131	1,039,182	7,933	$119.55
Utah	17	130,965	7,704	$32.50
Washington	27	106,326	3,938	$85.88
Wyoming	26	55,087	2,119	$62.61
TOTAL	660	15,376,737		
AVERAGE	55	1,281,395	20,705	$76.66

*2005 Dollars

Table 4.3 Summary of Western Water Leases

California has most active lease market over the 19 year period both in terms of total transactions and volume of water transferred. California's 212 leases represent approximately 32% of all western leases. California is followed by Texas with 20% of western leases, though the Arizona market is far more active than Texas based on total volume leased between users. The California and Texas markets also have the second and third highest average price per acre-foot. The highest average price per acre-foot, however, is in Colorado, where the water market is believed to be relatively mature and to most closely reflect supply and demand conditions (Brookshire *et al.* 2004). Nevada, Montana, and Utah have the least active lease markets in the West in terms of total transactions. In terms of total volume transferred, market activity in Wyoming is also low.

In the next sections, a brief overview of each state's pertinent water laws and transfer history will be discussed. Following each description, the model, summary statistics, and regression results for the state models of the price of leased water will be presented.

4.3 ARIZONA

4.3.1 Background

There are basically four distinct types of water supply that Arizona relies on to meet the needs of its burgeoning population and to irrigate its many acres of cropland. Each type of water is managed separately (Bureau of Land Management 2001a). The first type, Colorado River water, is allocated based on the Law of the River and through the Arizona Water Banking Authority. All other non-Colorado River surface water is governed by the prior appropriation doctrine with priority dates attached to the rights in reference to 1919. Surface water rights are marketable in Arizona if they carry a priority date earlier than 1919, and surface water transfers can take place with relatively few legal constraints as long as the transfer does not adversely affect other water rights holders (Colby *et al*. Forthcoming). The majority of surface water transactions in Arizona involve Colorado River or Salt River water, as these are the primary sources of surface water use across the state. Transfers of Central Arizona Project (CAP) water are occurring with increasing frequency.

The regulation of groundwater rights, however, is more complicated and dependent on whether the water is located within one of the State's Active Management Areas (AMAs). The 1980 Groundwater Management Act established AMA's around

Arizona's major urban areas and groundwater rights were henceforth classified in reference to 1980, the year the Act took effect. Rights established before 1980 are considered "grandfathered" rights, while "permitted" rights are those established post-1980. Grandfathered rights are further subdivide and regulated as either Type I non-irrigation rights (was converted to non-irrigation use sometime after 1965), Type II non-irrigation (groundwater that was not used for irrigation at the establishment of the AMAs), and irrigation rights (groundwater that was used for irrigation between 1975 and 1980) (Brookshire *et al*. 2004). Type I rights may not be transferred away from the land to which they are attached, while Type II rights can be transferred anywhere within an AMA. One offshoot of this distinguishing feature is that Type II rights are more marketable than Type I rights. Outside the AMAs, groundwater withdrawals are virtually unregulated, which effectively eliminates any incentive to lease or sell the water.

Between 1987 and 2005, Arizona transferred almost 4.5 million AF of water via 47 lease arrangements. The average price per acre-foot over this period was $88. The vast majority of these transfers (some 87%) involved CAP water.

4.3.2 Model

Results of the Hausmann-Wu test for endogeneity indicate that price and quantity are not endogenous in the Arizona temporary water market (Greene 2003). Thus, the number of acre-feet transferred in a water transaction is treated as exogenous and the price per acre-foot for leased water is modeled using OLS. Arizona leases are modeled as follows:

DESCRIPTION OF VARIABLES
ARIZONA PRICE MODEL

Name	Description
lnadj_price	Natural log of the price per acre-foot of water transferred.
lnAF	Natural log of the number of acre-feet of water transferred.
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
MEI6L12	6-month MEI lagged twelve months.
SPI12L6	12-month SPI lagged six months.
muni_NewUse	Binary variable equal to one if new use is municipal.
other_NewUse	Binary variable equal to one if new use is not muni, enviro, or ag.
effluent	Binary variable equal to one if water is effluent.
groundwater	Binary variable equal to one if water is surface.
phoenix	Binary variable equal to one if the transaction involved the Phoenix metro area.
pop_change	The annual percent change in state population.

Table 4.4 AZ Description of Variables

The double-log functional form of the model (and all subsequent state and regional models) narrows the range of the price and quantity variables, lessening the sensitivity of outliers on these variables. Taking this into consideration, the functional forms were chosen based on: (1) a comparison of the performance of linear, log-linear, linear-log, and double-log specifications; and (2) the functional forms used in other published water pricing studies (Crouter 1987; Loomis *et al*. 2003; Brookshire *et al*. 2004).

The model is tested for heteroskedasticity using the Breusch-Pagan and White's tests, coded in SAS's IML. In the Arizona lease market, the test results are ambiguous. The Breusch-Pagan test, which tests for an unknown form of heteroskedasticity, indicates that the model is homoskedastic (Greene 2003). White's test, however, which specifically tests whether the variance-covariance matrix of the OLS estimator is affected by the presence of heteroskedasticity (Kennedy 2003), suggests non-constant variance in the model. As a result of the inconsistent (though possibly legitimate due to the different nature of each test) results of the two tests, Huber-White robust standard errors and test statistics are estimated along with the standard errors produced from OLS. Using robust test statistics does not significantly change any inference.

4.3.3 Results

Summary statistics for variables included in the price model are as follows:

SUMMARY STATISTICS
ARIZONA PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnadj_price	4.28	0.50	0.25	3.32	6.55
lnAF	9.61	2.54	6.44	4.26	12.90
Trend	8.45	4.00	15.99	2.00	18.00
MEI6L12	0.20	0.89	0.79	-1.33	2.45
SPI12L6	0.44	1.01	1.03	-1.19	1.97
muni_NewUse	0.47	0.50	0.25	0.00	1.00
other_NewUse	0.09	0.28	0.08	0.00	1.00
effluent	0.06	0.25	0.06	0.00	1.00
groundwater	0.06	0.25	0.06	0.00	1.00
phoenix	0.62	0.49	0.24	0.00	1.00
pop_change	3.24	0.99	0.99	1.20	4.40

Table 4.5 AZ Summary Statistics

OLS regression results are presented and discussed below.

REGRESSION RESULTS
ARIZONA PRICE MODEL*

Variable Name	Parameter Estimate	Standard Error	Robust St. Error	T-Stat	Chi-Square	P-Value	Robust P-Value
Intercept	4.234	0.539	0.483	7.85	76.73	<.0001	<.0001
lnAF**	-0.039	0.032	0.031	-1.23	1.66	0.2277	0.1978
Trend	-0.041	0.023	0.021	-1.79	4.01	0.0819	0.0453
MEI6L12	0.474	0.127	0.139	3.74	11.59	0.0006	0.0007
SPI12L6	-0.577	0.118	0.173	-4.9	11.16	<.0001	0.0008
muni_NewUse**†	-0.032	0.146	0.141	-0.22	0.05	0.8285	0.821
other_NewUse†	-0.359	0.298	0.205	-1.2	3.07	0.2367	0.0796
effluent‡	-0.402	0.278	0.240	-1.45	2.82	0.156	0.0931
groundwater**‡	0.051	0.289	0.252	0.18	0.04	0.8606	0.8391
phoenix	0.250	0.150	0.136	1.67	3.39	0.1045	0.0656
pop_change	0.262	0.113	0.123	2.31	4.56	0.0267	0.0328
Observations	47						
R^2	0.52						

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at the 10% level
† Base group is ag_NewUse
‡ Base group is surface water

Table 4.6 AZ Regression Results

With a few notable exceptions, most results are expected. The first unexpected result is the negative, significant sign on the variable *Trend* which indicates that there has been a slight downward trend in the price of Arizona water leases over time. This result is confirmed by fitting a trend line through the price per acre foot over time.

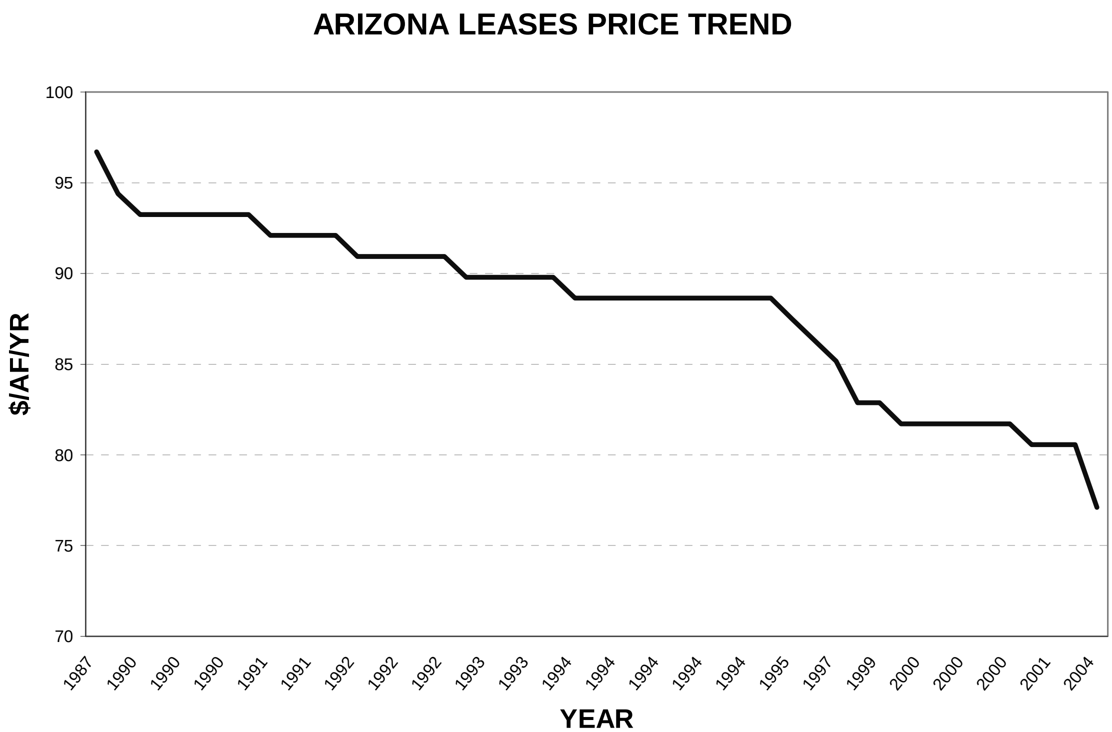


Figure 4.7 AZ Price Trend

As the Arizona lease market matures, we would expect a positive price trend, reflecting the development and increasing efficiency of the spot market. The absence of such a trend might be interpreted as in indication of constraints existing in Arizona's lease market. In particular, the price of leased CAP water is not driven by supply and demand forces but is rather set annually by the Board of Directors of Central Arizona Water Conservancy District (Central Arizona Project 1997). Instead of allowing for the free, market-based exchange of CAP water from users with a lower use value to other users with a relatively higher use value, CAP exchanges are directed by administrative decisions (Wilson 2002).

Both the climate index, the MEI, and the drought index, the SPI, are significant at the 1% level. The negative sign on the SPI parameter estimate indicates that as conditions become dryer (i.e. the SPI becomes more negative), the price of leased water increases. This result makes intuitive sense; as a resource becomes scarcer, its price will correspondingly increase. The positive sign on the MEI parameter estimate, however, is unexpected. In the southwestern U.S. a positive MEI value indicates an El Niño event, suggesting a wet winter. Thus, as the MEI increases corresponding to wetter conditions, the price of leased water would be expected to decrease. Regression results, however, imply just the opposite; as the MEI increases, all else constant, the price of water also increases. Inconsistent results regarding the MEI in the southwest will be addressed later in this chapter.

The reference group for the "new use" binary variables is agricultural new use. Results suggest that the price of water leased for municipal purposes is not statistically different than water leased for agriculture. Again, this may be due to constraints in the Arizona market. If the water is leased for some other purpose (which could include mining or other industrial uses, environmental use, storage, etc.), the water is expected to be less expensive than if it is leased for agricultural use.

If the type of water leased is effluent, results suggest that, all else constant, the price per acre-foot is less than if the leased water is from a surface source. This is likely reflecting a perception of differential quality; in general, people perceive the quality of effluent to be below surface water and thus are likely to be willing to pay a premium for surface water over effluent. The positive, significant coefficient on groundwater also makes intuitive sense, particularly when considering the lease of water to cope with drought since surface water supplies are affected by drought earlier than groundwater.

The statistically significant, positive coefficient on *Phoenix* indicates that a lease involving Phoenix or the surrounding metro area, holding all other variables constant, is predicted to carry a higher price per acre-foot than leases elsewhere in Arizona. Similarly, the annual percent change in Arizona's population is estimated to have a positive impact on the price of leased water, which makes intuitive sense. As the population increases and places additional pressure on a finite water supply, the effects of temporary shortages induced by drought or other factors are even more acute. For this reason, it would follow that population growth would indicate an increasing willingness to pay for leased water to curb supply variability.

4.4 CALIFORNIA

4.4.1 Background

The distribution of California's water supply system both in time and space gives rise to the need for reallocation. Over 75% of the demand for water is generated in the southern portion of the state, while more than 71% of average annual runoff originates in the northern half of the state (Yolles 2000). Further, there is great seasonal variability in precipitation; 75% of average annual precipitation occurs between November and March. The summer months, when agricultural and urban water demands are at their peak, are quite dry. And, the State is prone to multi-year droughts.

To address seasonal and annual variability in water supply and increasing demand due to rapid population growth, California has historically relied on the control of its water supply through storage and conveyance systems. Today, however, California's extensive water infrastructure is inadequate to meet the expanding demands of its major water users: agriculture, municipal, and the environment. Consequently, water markets have received much attention as a mechanism to stimulate the efficient reallocation of water to meet demand.

Water rights in California are use rights, meaning the actual ownership of the water remains with the State (Bureau of Land Management 2001b). California's water rights are regulated by both the riparian doctrine and the prior appropriation system. The riparian doctrine establishes a use right as a result of land ownership adjacent to a surface water source, and no permit is necessary. Appropriative rights, however, require an application and approval from the State Water Board. Riparian rights are generally senior to appropriative rights.

California has experienced growth and development, albeit limited, of its water market since the mid 1980s, likely spurred by the 1987-1992 drought (Howitt and Hanak 2005). Since 1985, the California water market grew an average of 11.4% annually. Yet although California is making strides toward creating an institutional environment more conducive to efficient water marketing, the state still lacks a vigorous water market to effectively address the situation of fluctuating supplies and changing patterns of demand.

Between 1987 and 2005, California water users leased approximately 6,485,335 AF of water at an average price of $127.38/AF (2005 dollars). The average volume per transaction over the period was 30,591 AF.

4.4.2 Models

Tests indicate endogeneity in the price model, so 2SLS techniques are used to address this. Variable descriptions, summary statistics, and regression results for all instrumental variable equations can be found in Appendix 1. Using the predicted values of quantity from the first-stage regression, the second stage equation is modeled and described as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 \ln AFhat + \beta_2 Trend + \beta_3 MEI6l6 + \beta_4 SPI24orig + \beta_5 ag\_NewUse + \beta_6 Enviro\_NewUse + \beta_7 other\_NewUse + \beta_8 BasinDummy + \beta_9 effluent + \beta_{10} grnd\_water$$

DESCRIPTION OF VARIABLES
CALIFORNIA PRICE MODEL

Name	Description
lnprice	The natural log of the real price per acre-foot.
lnafhat	Natural log of the predicted value of AF after IV estimation.
trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
MEI6L6	6-month MEI lagged six months.
SPI24orig	24-month SPI for the climate region of origin.
ag_NewUse	Binary variable equal to one if new use is agricultural.
enviro_NewUse	Binary variable equal to one if new use is environmental.
other_NewUse	Binary variable equal to one if the new use falls into some other category.
BasinDummy	A binary variable equal to one if the transfer was intra-basin
effluent	A binary variable equal to one if the transferred water was effluent.
grnd_water	A binary variable equal to one if the transferred water was groundwater.

Table 4.8 CA Variable Descriptions

4.4.3 Results

SUMMARY STATISTICS
CALIFORNIA PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	4.55	0.78	0.61	2.62	6.35
lnafhat	9.22	0.89	0.79	5.96	11.86
trend	12.34	5.19	26.91	2.00	19.00
MEI6L6	0.47	0.81	0.65	-1.13	2.51
SPI24orig	-0.16	0.90	0.81	-2.08	2.23
ag_NewUse	0.22	0.41	0.17	0.00	1.00
enviro_NewUse	0.22	0.41	0.17	0.00	1.00
other_NewUse	0.11	0.32	0.10	0.00	1.00
BasinDummy	0.75	0.43	0.19	0.00	1.00
effluent	0.12	0.33	0.11	0.00	1.00
grnd_water	0.18	0.38	0.15	0.00	1.00

Table 4.9 CA Summary Statistics

REGRESSION RESULTS
CALIFORNIA PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	4.495	0.343	13.1	<.0001
lnafhat**	0.023	0.030	0.74	0.4587
trend**	0.004	0.010	0.42	0.6715
MEI6L6**	0.098	0.061	1.6	0.1111
SPI24orig	-0.097	0.057	-1.69	0.0927
ag_NewUse†	-0.557	0.129	-4.33	<.0001
enviro_NewUse†	-0.386	0.131	-2.94	0.0037
other_NewUse†	0.331	0.173	1.91	0.0573
BasinDummy‡	-0.310	0.117	-2.65	0.0088
effluent**^	0.237	0.164	1.44	0.1509
grnd_water^	0.593	0.129	4.6	<.0001
Observations	212			
R^2	0.30			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is muni_NewUse.
‡Base group is inter-basin transfer.
^Base group is surface water.

Table 4.10 CA Regression Results

Both the *trend* and *lnafhat* variables are insignificant in the California, indicating no statistically significant price trend over time and no significant relationship between the number of acre-feet of water leased and the lease price.

The climate index, *MEI*, is not significant at the 10% level. The drought index, however, is negative and significant, which is expected. Because the majority of temporary transfers originate in northern California, as does much of southern California's water supply, the SPI in the climate region of origin was used to test the relationship between hydrologic conditions and the price of leased water in California. The negative coefficient on the SPI, which is specific to the climate region in which the transfer originated, implies a sensitivity of the price of water to drought conditions.

The negative and significant sign on *ag_NewUse* suggest that, all else constant, the price per acre-foot of water is lower for agricultural leases relative to the reference group, municipal use. This result is indicative of agriculture's relatively lower-valued use of water and represents an opportunity for efficiency reallocation. The coefficient on *enviro_NewUse* is also negative and significant. This may be attributed to the large number of environmental purchases made by the federal government to satisfy environmental protection mandates in California.

The negative, significant coefficient on *BasinDummy* indicates the price of intra-basin transactions ia less than inter-basin transfers, all else equal. This result may be capturing the higher transactions costs of moving water between basins. The positive coefficient on *grnd_water* is a signal that groundwater is more highly valued than surface water. This result may suggest that buyers and sellers value the availability and or predictability of a water source. Due to general over-allocation problems in California as well as drought, which effects surface water levels before groundwater, the supply of surface water may not be as reliable as groundwater.

4.5 COLORADO

4.5.1 Background

The Colorado water market is often cited as one of the most active, mature water markets in the world (Landry and Anderson 1999; Brookshire *et al.* 2004). Demographic realities, growth patterns, the State's policies and water supply system, and climate variability all lend themselves to the transfer of water. The majority of Colorado's population lives in the Colorado Front Range, a north-south corridor east of the Rocky Mountains that includes Denver, Boulder, Fort Collins, and Colorado Springs. The Front Range has also experienced steady population growth and is expected to continue to grow at a pace rivaling the fastest growing regions in the country. The majority of Colorado's water supply originates away from its population on the west slope of the Rocky Mountains. Water is transported to the Front Range through the South Platte and Arkansas river watersheds, areas with agricultural-based economies (Howe and Goemans 2003).

Colorado water rights are governed by the prior appropriation doctrine, and priority dates are established based on the date the water was originally put to beneficial use (Bureau of Land Management 2001c). Water courts in the State's major basins are responsible for carrying out the adjudication process and for evaluating applications for water transfers. All cases must all be handled by an attorney. Water in Colorado is considered publicly owned, but individual water rights are regarded as real property that may be bought, sold, and leased among users (Bureau of Land Management 2001c).

4.5.2 Models

To evaluate whether quantity is endogenous to price in the Colorado lease market, the Hausmann-Wu test was preformed. Test results verify that *lnAF* is endogenous to price, which, unaddressed, leads to biased and inconsistent OLS estimators (Wooldridge 2003). To correct for this, two-stage least squares (2SLS) is employed. First, the predicted value of *lnAF* is estimated using a variety of instrumental variables (IVs), which are described and summarized in Appendix 1. In general, supply-side variables were chosen as instruments. The R^2 for the IV equation is .48.

Using the predicted value of quantity, *lnAFhat*, Colorado leases are modeled as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 \ln AFhat + \beta_2 Trend + \beta_3 MEI12L6 + \beta_4 SPI12L6 + \beta_5 muni\_NewUse + \beta_6 indust\_NewUse + \beta_7 enviro\_NewUse + \beta_8 other\_NewUse + \beta_9 FrontRang + \beta_{10} Years\_Lease$$

The following table describes the variables included in the price model:

DESCRIPTION OF VARIABLES
COLORADO PRICE MODEL

Name	Description
lnprice	The natural log of the price per AF.
lnafhat	The natural log of the predicted value of AF after IV estimation.
trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
MEI12L6	12-month MEI lagged six months.
SPI12L6	12-month SPI lagged six months.
muni_NewUse	Binary variable equal to one if new use is municipal.
Indust_NewUse	Binary variable equal to one if new use is industrial.
enviro_NewUse	Binary variable equal to one if the new use is environmental.
other_NewUse	Binary variable equal to on if the new use is not muni, indust., enviro, or ag.
FrontRange	A binary variable equal to one if the transaction involved the Front Range.
years_lease	The number of years of the life of the lease.

Table 4.11 CO Variable Descriptions

5.5.3 Results

Summary statistics for the second stage price model and results for the second stage OLS regression are presented below:

SUMMARY STATISTICS
COLORADO PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	3.91	1.34	1.79	2.10	7.14
lnafhat	6.40	1.64	2.69	2.71	9.39
trend	13.45	5.00	24.98	3.00	19.00
MEI12L6	0.46	0.59	0.82	-0.74	1.42
SPI12L6	-0.14	1.10	1.20	-2.54	2.51
muni_NewUse	0.34	0.48	0.23	0.00	1.00
Indust_NewUse	0.03	0.18	0.03	0.00	1.00
enviro_NewUse	0.22	0.42	0.17	0.00	1.00
other_NewUse	0.13	0.33	0.11	0.00	1.00
FrontRange	0.47	0.50	0.10	0.00	1.00
years_lease	7.55	13.21	0.19	1.00	40.00

Table 4.12 CO Summary Statistics

REGRESSION RESULTS
COLORADO PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	3.987	0.806	4.95	<.0001
lnafhat	-0.137	0.080	-1.72	0.0916
Trend**	0.044	0.037	1.21	0.2322
MEI12L6**	-0.025	0.254	-0.1	0.9235
SPI12L6	-0.585	0.170	-3.45	0.0011
muni_NewUse**†	0.513	0.399	1.28	0.2049
Indust_NewUse**†	0.622	0.911	0.68	0.4982
enviro_NewUse**†	-0.178	0.458	-0.39	0.6992
other_NewUse**†	0.013	0.515	0.03	0.9793
FrontRange**	0.361	0.341	1.06	0.2945
years_lease	-0.027	0.015	-1.83	0.0725
Observations	64			
R^2	0.39			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at the 10% level
†Base group is ag_NewUse

Table 4.13 CO Regression Results

The results of 2SLS estimation of the price of leased water in Colorado are a combination of both expected and unexpected results. The predicted value of quantity, *lnAFhat*, is negative and significant, suggesting that there may be economies of scale in the Colorado lease market.

The MEI is insignificant at the 10% level. The SPI, however, is negative and significant, indicating that all else constant, the price of leased water in Colorado rises and falls with dry and wet conditions as expected.

The "new use" binary variables, in reference to agricultural new use, are all insignificant. The Colorado market is relatively developed, and the insignificance of the "new use" variables may be evidence that the market is reaching equilibrium price where the price of water is equal across all uses.

The parameter estimate on *FrontRange* is not significant. This result suggest that temporary water transactions occurring in the Front Range area of the State are not statistically different in price from leases occurring elsewhere in the State. The variable *Years_Lease*, however, is negative and significant. As mentioned in Chapter 3 when discussing the predicted sign for the length of the lease, the sign of its coefficient is difficult to hypothesize. The negative parameter estimate here may be indicative of an immediacy of need and therefore a higher willingness to pay for a shorter term lease in Colorado.

4.6 IDAHO

4.6.1 Background

Water in Idaho is publicly owned. Thus, a water right represents the entitlement to divert water for beneficial use but is not a property right (Idaho Department of Water Resources "What is a Water Right?). Both surface and groundwater rights in Idaho are established by an application/permit/license appropriation procedure. Riparian rights are not recognized in the State.

Idaho operates a Water Supply Bank that exists to facilitating water transfers, both permanent and temporary, between willing buyers and sellers, thereby encouraging the highest beneficial use of the water (Idaho Department of Water Resources "Idaho Water Supply Bank"). The bank has helped meet the water needs of irrigators, municipalities, and salmon recovery efforts in the State. The price of water leased and sold via the water bank, however, is not freely determined by the market. The price is set by rental pool committees and is subject to the approval of the Idaho Water Resources Board.

There have been 33 leases of water in Idaho since 1987, temporarily transferring over 1.5 million AF of water. The relatively low average price of $50 per AF may be reflective of the fixed price of water leased through the Idaho Water Supply Bank.

4.6.2 Model

Results from the Hausmann-Wu test for endogeneity suggested that quantity is not endogenous to price in the Idaho lease market, thus Idaho leases are modeled as follows:

$$\ln Adj\_\Pr ice = \beta_0 + \beta_1 \ln AF + \beta_2 Trend + \beta_3 MEI12l6 + \beta_4 SPI12L6 + \beta_5 muni\_NewUse + \beta_6 Enviro\_NewUse + \beta_7 other\_NewUse$$

DESCRIPTION OF VARIABLES
IDAHO PRICE MODEL

Name	Description
trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
lnaf	12-month MEI lagged six months.
MEI6L6	6-month MEI lagged six months.
SPI24L6	24-month SPI lagged six months for climate region.
muni_NewUse	Binary variable equal to one if new use is municipal.
enviro_NewUse	Binary variable equal to one if new use is environmental.
other_NewUse	Binary variable equal to one if new use is not muni, enviro, or ag.

Table 4.14 ID Variable Descriptions

4.6.3 Results

Summary statistics and the results of heteroskedasticity robust OLS regression of Idaho water leases are presented below:

SUMMARY STATISTICS
IDAHO PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	2.797	1.208	1.459	1.66	6.47
trend	13.909	4.889	23.898	3.00	19.00
lnaf	8.965	2.359	5.564	4.61	12.46
MEI6L6	0.105	0.567	0.322	-0.96	1.08
SPI24L6	0.045	1.131	1.278	-2.09	2.37
muni_NewUse	0.061	0.242	0.059	0.00	1.00
enviro_NewUse	0.364	0.489	0.239	0.00	1.00
other_NewUse	0.091	0.292	0.085	0.00	1.00

Table 4.15 ID Summary Statistics

REGRESSION RESULTS
IDAHO PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	Chi-Square	Robust P-Value
Intercept	3.774	0.669	31.86	<.0001
trend**	0.012	0.017	0.5	0.4799
lnaf	-0.220	0.068	10.46	0.0012
MEI6L6**	0.176	0.161	1.2	0.2728
SPI24L6	-0.368	0.098	13.99	0.0002
muni_NewUse**†	-0.547	0.610	0.81	0.3694
enviro_NewUse†	1.923	0.422	20.81	<.0001
other_NewUse†	1.680	0.296	32.17	<.0001
Observations	33			
R^2	0.56			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at the 10% level
† Base is ag_NewUse

Table 4.16 ID Regression Results

The negative, significant parameter estimate on *lnAF* suggests that, all else constant, when a transaction involves relatively more acre-feet of water, the price per acre-foot is lower. As in Colorado, this may be driven by economies of scale. The time trend is not significant in the model, however, suggesting there has not been a significant trend in the price of leased water either up or down in Idaho over the 19 years of observations. This may be at least partially explained by the Idaho Water Bank setting the price of leased water instead of allowing “free market” transfers where the price per acre-foot is determined by the market.

The MEI is again insignificant in the Idaho model, though the sign is expected. The SPI, on the other hand, is significant in explaining the price of leased water. The negative sign on the parameter estimate confirms the inverse relationship between price and SPI: all else held constant, as the SPI increases (hydrologic conditions become wetter) the price of water is predicted to decrease.

Only two of the three “new use” dummies, *environmental*, and *other*, are significant in reference to the base group, *agriculture*. Water leased for municipal use is not statistically different from water leased for agriculture. However, water leased for environmental needs or some other need is predicted to be more expensive than water leased for agriculture. In an immature market, the price of leased water for municipal use would be expected to be statistically different than water leased for agricultural use, but again, the prices set by the Idaho Water Bank may be skewing this.

4.7 NEW MEXICO

4.7.1 Background

Water rights in New Mexico are governed by the prior appropriation doctrine, and water transactions between users occur with relative ease given the supportive nature of laws and regulations surrounding water transfers. Surface water rights are prioritized in reference to 1907, the year surface water was declared public (Brookshire *et al.* 2004). Surface water rights established post- 1907 are considered permitted and therefore cannot be transferred. However, surface rights that were developed before 1907 all share a common priority date and are treated as owned property that can be leased out or sold. This standardized priority date creates a uniformity of water rights, which lends itself to the development of a water market because transaction costs are lower and a single market clearing price can be established (Brookshire *et al.* 2004; Howe and Goemans 2003).

Both ground and surface water transactions are subject to the approval by the State Engineer. Transfers do not often face protest and generally receive timely approval by the State Engineer (National Research Council 1992).

The majority of temporary water transfers in New Mexico occur to meet municipal, recreation, or instream flow needs to support endangered species. The primary supplier of water for temporary transfers is agriculture. Between 1987 and 2005, there were 47 reported leases of water in New Mexico at an average price of approximately $58/AF.

4.7.2 Models

The Hausmann-Wu test for endogeneity revealed that price and quantity are indeed endogenous in the New Mexico lease market, so 2SLS is employed to correct for bias and inconsistency. The R^2 for the first stage IV equation is .51. Using the IV estimates for *lnAF*, the second stage least squares equation is modeled as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 Trend + \beta_2 \ln AFhat + \beta_3 MEI24l6 + \beta_4 SPI12L6 + \beta_5 ag\_NewUse + \beta_6 Enviro\_NewUse + \beta_7 other\_NewUse + \beta_8 Albuq$$

The explanatory variables included in the New Mexico second stage price model are described and summarized below:

DESCRIPT ION OF VARIABLES
NEW MEXICO PRICE MODEL

Name	Description
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
Lnafhat	Natural log of predicted value of AF after IV estimation.
MEI6L12	12-month MEI lagged six months.
SPI24L6	12-month SPI lagged six months for climate region.
ag_NewUse	Binary variable equal to one if the water was originally used for agriculture.
enviro_NewUse	Binary variable equal to one if the water was originally used for environmental purposes.
other_NewUse	Binary variable equal to one if the water was originally used for some other purpose.
Albuq	Binary variable equal to one if the transaction involved the Albuquerque metro area.

Table 4.17 NM Variable Descriptions

SUMMARY STATISTICS
NEW MEXICO PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
Trend	10.66	5.42	29.40	2.00	19.00
Lnafhat	7.50	1.45	2.11	4.42	10.89
MEI6L12	0.26	0.68	0.46	-1.25	2.51
SPI24L6	0.32	0.85	0.72	-1.73	1.64
ag_NewUse	0.02	0.15	0.02	0.00	1.00
enviro_NewUse	0.53	0.50	0.25	0.00	1.00
other_NewUse	0.28	0.45	0.20	0.00	1.00
Albuq	0.47	0.50	0.25	0.00	1.00

Table 4.18 NM Summary Statistics

4.7.3 Results

The results from the second stage regression New Mexico price model are as follows:

REGRESSION RESULTS
NEW MEXICO PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	2.913	0.447	6.52	<.0001
Trend	0.051	0.026	1.95	0.0586
lnafhat	0.116	0.048	2.43	0.0229
MEI6L12	0.306	0.129	2.37	0.0229
SPI24L6	-0.469	0.114	-4.13	0.0002
ag_NewUse**†	-0.733	0.620	-1.18	0.2445
enviro_NewUse†	-1.541	0.272	-5.67	<.0001
Other_NewUse†	-0.538	0.265	-2.03	0.0491
Albuq	0.989	0.231	4.27	0.0001
Observations	47			
R^2	0.69			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is muni_NewUse

Table 4.19 NM Regression Results

2SLS regression results indicate that there is a statistically significant positive time trend associated with the price of leased water in New Mexico. The number of acre-feet transferred is also significant in predicting the price of leased water in New Mexico. As mentioned previously, a potential explanation for this positive price-quantity relationship is that transaction costs are higher as the quantity increases. That is, it may be more difficult and time consuming to receive authorization for a transfer involving more water, and third party impacts on the area of origin and the environment may be more significant, potentially inflating transaction costs for larger transfers. Additionally, the Marginal Value Product of water for a supplier may be relatively low for the first "block" of water, but as the quantity increases, the Marginal Value Product of those additional blocks may rise, corresponding to a higher price for larger quantities.

The climate and drought indices are both significant, though the sign on the climate index, MEI, is again not expected. This has been a general trend in all models of southwestern states presented so far, and potential reasons will be addressed following the presentation of all models and results. The SPI, however, does take on the expected sign in New Mexico, indicating a premium for leased water when hydrologic conditions are dry.

The agricultural and environmental new use variables are significant with the expected sign (although *ag_NewUse* is not significant at the 10% level). In comparison to water leased for municipal purposes, water leased for agriculture or the environment is predicted to be less expensive than water leased for municipal use. This is likely reflecting the relatively higher use value of municipal water than, for instance, the value of water used to irrigate low-value crops. Finally, water leases in the Albuquerque metropolitan area is also predicted to carry a higher premium than transactions in the rest of the State, all else constant.

4.8 OREGON

4.8.1 Background

Although traces of the riparian rights system that used to govern Oregon water rights still remain, by and large Oregon's water rights system is based on the prior appropriation doctrine (Bureau of Land Management 2001d). Both permanent and temporary transfers are permitted by Oregon water law, though temporary transfers may not exceed 5 years in length. Oregon water law also states that water cannot be sold at a profit; the sale price cannot exceed the costs incurred in the operation and sale of the water right. This stipulation is not rigorously enforced, however.

Oregon has been a pioneer in establishing water markets as a means of acquiring water for instream flow augmentation for salmon recovery (Landry and Peck 1998). In 1997 some 490,000 acre-feet of water were transferred via water market from farmers and ranchers throughout Oregon to enhance streamflow. The water for instream flow is being acquired by two main groups: the federal government and private individuals or non-governmental organizations. The Bureau of Reclamation has coordinated programs and negotiations for the bulk of market-based transfers for instream flow (Landry 1998). These acquisitions have typically been short-term leases for a single irrigation season. Reforms in State water law have also made it possible for private organizations to participate in the water market for instream flow. The Oregon Water Trust, for example, is a non-profit group that was established in 1993 with the aim of employing market-based strategies to acquire water for stream flow restoration (Oregon Water Trust). The Trust has relied on market-based incentives to negotiate many deals with farmers and ranchers to leave their water instream instead of diverting it for irrigation. Many of these deals are temporary leases of the water and irrigators resume normal farm operations in years when streamflow is adequate to meet environmental needs.

From 1987 to 2005, Oregon water users leased just under 750,000 AF of water at an average price of $43/AF.

4.8.2 Models

The Hausmann-Wu test for endogeneity indicates that price and quantity are not endogenous in the Oregon lease market. Thus, OLS regression is used to estimate the price of leased water. Leases are modeled and described as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 \ln AF + \beta_2 Trend + \beta_3 MEI + \beta_4 SPI6L12 + \beta_5 enviro\_NewUse + \beta_6 Other\_NewUse$$

DESCRIPT ION OF VARIABLES
OREGON PRICE MODEL

Name	Description
Lnprice	The natural log of the real price per acre-foot of leased water.
Lnaf	Natural log of acre-feet.
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
MEI	2-month MEI value.
SPI6L6	6-month SPI lagged six months.
enviro_NewUse	Binary variable equal to one if the water was originally used for environmental purposes.
other_NewUse	Binary variable equal to one if the water was originally used for some other purpose.

Table 4.20 OR Variable Descriptions

4.8.3 Results

SUMMARY STATISTICS
OREGON PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	2.93	1.13	1.27	1.69	5.86
lnaf	7.71	2.05	4.19	3.45	12.90
trend	14.55	3.30	10.86	8.00	19.00
MEI	0.60	1.01	1.03	-0.87	2.84
SPI6L6	0.24	1.14	1.30	-2.99	2.66
enviro_NewUse	0.41	0.50	0.25	0.00	1.00
other_NewUse	0.02	0.15	0.02	0.00	1.00

Table 4.21 OR Summary Statistics

White's test and the Breusch-Pagan test for heteroskedasticity both suggest a constant variance, thus the standard test statistics are used to calculate test statistics.

REGRESSION RESULTS
OREGON PRICE MODEL*

Variable Name	Parameter Estimate	Standard Error	T-Stat	P-Value
Intercept	2.817	0.620	4.55	<.0001
lnaf**	0.036	0.057	0.63	0.5296
trend	-0.066	0.031	-2.15	0.0383
MEI	0.211	0.119	1.77	0.0849
SPI6L6	-0.205	0.100	-2.05	0.0477
enviro_NewUse†	1.572	0.225	6.98	<.0001
other_NewUse†	3.473	0.688	5.04	<.0001
Observations	44			
R^2	0.74			

*Dependent variable is log of adjusted price per acre-foot

**Insignificant at the 10% level

†Base group is ag_NewUse

Table 4.22 OR Regression Results

OLS regression results suggest that there is a statistically significant, negative price trend over time. Both the climate index, *MEI*, and the drought index, *SPI*, are significant and the parameter estimates carry the expected signs. In the Pacific Northwest region, a positive MEI indicates an El Niño even, which corresponds to dry winter conditions. Thus, as the MEI increases and conditions become dryer in Oregon, results suggest the price of leased water increases, all else constant. Similarly, hydrologic drought, characterized by negative SPI values, is predicted to increase the price of leased water in the Oregon lease market.

The Oregon water market is distinct from other state models in this analysis in that through 2005, no water was leased to meet municipal needs. As mentioned, Oregon has a particularly active lease market for environmental needs, however, which is reflected in these results. Ceteris paribus, water leased for environmental purposes is predicted to be more expensive than water leased for agricultural needs. A lease market can be effective in dealing with drought-induced supply shortage, and because additional water for instream flow may only be necessary during drought, it follows that environmental leases would carry a premium.

One measure of model performance is the R^2 statistic. While the R^2 should not be considered in isolation as an indicator of overall model performance, the R^2 of .72 for this model is relatively higher than in other state models and indicates that the regressors included are doing a relatively good job explaining the variation in price.

4.9 TEXAS

4.9.1 Background

Texas water transfers are complicated by four different state water doctrines that are location and water-type specific (Griffin and Characklis 2002). Water in the Rio Grand Basin, which is defined for administrative purposes as the area flowing south out of Amistad Reservoir and on to the Gulf of Mexico, is heavily dependent on surface water. Water rights in the Basin are transferable and distinct from land rights but do not carry seniority dates. Approximately 99% of water rights in the Rio Grande Basin are devoted to either municipal or irrigation uses, but in times of shortage, municipal use, which composes some 15% of annual water use, has priority over agricultural use. Decisions regarding water allocation to irrigators are made by the Rio Grande Watermaster after the "municipal reserve" quota (225,000 acre-feet/month) is met, and as a result, drought impacts fall heavily on irrigated agriculture in the region (Texas Commission on Environmental Quality). Permanent and temporary water transfers in the region are carried out with few restrictions imposed by consideration for third party impacts or environmental implications, and as a result, water market activity in the region is fairly active (Griffin and Characklis 2002). Temporary water transfers account for between 20,000 and 80,000 acre-feet of water reallocation each year.

Outside the Rio Grande Basin, however, surface water transactions are much more rare. The thinness of these markets is attributed to a number of factors. First, Texas lacks the man-made infrastructure and natural channels to convey water between basins. Second, except for in the Rio Grande Basin, water rights are not clearly defined or consistently enforced. Finally, the monopolistic presence of river authorities over much of the 18 river basins in Texas deters water transfers (Griffin and Characklis 2002). By comparison, there is no water authority in the Rio Grande Basin. Given these impediments to free market transactions, the lease and sale of surface water outside the Rio Grande Basin is rare, though there have been a number of significant transfer agreements between municipalities, the Lower Colorado River Authority, and irrigation districts.

San Antonio and the surrounding area rely principally on Edwards Aquifer groundwater to meet municipal needs. Historically, groundwater pumping rights in the region were not assigned, but severe groundwater overdraft, particularly during dry conditions, has threatened several endangered species that rely on the springflow produced by the aquifer. The need to comply with Endangered Species Act requirements has stimulated an adjudication process to assign and quantify groundwater pumping rights. As part of this process, the Edwards Aquifer Authority has defined two types of groundwater rights: uninterruptible “senior” pumping rights, and interruptible "junior" rights. The senior rights are subject to reduction only when the Authority declares Critical Period Management Rules to be in effect. The groundwater associated with junior pumping rights, however, may only be withdrawn if the aquifer is above a specific level (Edwards Aquifer Authority 2006).

San Antonio and other cities in the Edwards Aquifer region have been actively purchasing groundwater rights from irrigators, though permanent agriculture to urban water transfers are restricted to 50% of an irrigator's adjudicated volume (Griffin and Characklis 2002). Temporary dry-land fallowing programs have also been initiated whereby cities pay farmers to forgo irrigation for a season so that the water can be used to meet municipal demand.

The average price per acre-foot paid for leased water in Texas between 1987 and 2005 was $119.55. Over the period Texas water users leased approximately 1,039,182 AF of water.

4.9.2 Models

Because quantity was found to be endogenous in the Texas lease market, 2SLS is used to ensure consistent, unbiased estimates. The second stage component of the regression is modeled as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 Trend + \beta_2 \ln AFhat + \beta_3 MEI + \beta_4 SPI12L12 + \beta_5 Indust\_NewUse + \beta_6 ag\_NewUse + \beta_7 mining\_NewUse + \beta_8 enviro\_NewUse + \beta_9 RioGrande$$

DESCRIPTION OF VARIABLES
TEXAS PRICE MODEL

Name	Description
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
Lnafhat	Natural log of the predicted value of AF after IV estimation.
MEI	2-month MEI.
SPI12L12	12-month SPI lagged twelve months.
Indust_NewUse	Binary variable equal to one if new use is industrial.
ag_NewUse	Binary variable equal to one if new use is agricultural.
Mining_NewUse	Binary variable equal to one if new use is mining.
enviro_NewUse	Binary variable equal to one if new use is environmental.
RioGrande	Binary variable equal to one if the transaction took place in the Rio Grande Basin.

Table 4.23 TX Variable Descriptions

4.9.3 Results

SUMMARY STATISTICS
TEXAS PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	4.06	0.99	0.99	2.20	7.80
trend	13.27	3.92	15.35	3.00	19.00
lnAFhat	7.14	0.99	0.97	5.25	10.46
MEI	0.25	0.96	0.91	-1.20	2.84
SPI12L12	0.12	1.03	1.05	-1.88	2.00
Indust_NewUse	0.03	0.17	0.03	0.00	1.00
ag_NewUse	0.27	0.44	0.20	0.00	1.00
mining_NewUse	0.14	0.35	0.12	0.00	1.00
enviro_NewUse	0.03	0.17	0.03	0.00	1.00
RioGrande	0.78	0.42	0.17	0.00	1.00

Table 4.24 TX Summary Statistics

REGRESSION RESULTS
TEXAS PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	4.023	0.397	10.14	<.0001
trend**	0.027	0.017	1.57	0.1187
lnafhat**	0.017	0.038	0.45	0.6501
MEI**	0.115	0.072	1.59	0.1138
SPI12L12	-0.137	0.066	-2.08	0.0392
Indust_NewUse†	0.841	0.366	2.3	0.0233
ag_NewUse†	-0.276	0.159	-1.74	0.0849
mining_NewUse†	1.903	0.249	7.63	<.0001
enviro_NewUse**†	0.379	0.391	0.97	0.3342
RioGrande	-0.868	0.170	-5.1	<.0001
Observations	131			
R^2	0.54			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is muni_NewUse

Table 4.25 TX Regression Results

Neither the trend nor quantity variables are found to be statistically significant in explaining the price of water leased in Texas. The type of new use, however, does have some explanatory power. As compared to water leased for municipal needs, water leased for industry or mining is predicted to be more expensive, while water purchased for agriculture is, all else constant, less expensive than water leased to meet municipal demand.

Whether or not the lease took place in the Rio Grande Basin is also significant. The negative parameter estimate suggests that the price of lease transactions in the Rio Grande Basin is less than elsewhere in the State. As mentioned in previous discussion, outside the Rio Grande basin, surface water transfers are thinly traded and infrastructure to transport water is lacking. The result may be higher transaction costs attached to leases outside the Rio Grande Basin and thus a relatively higher price per acre-foot.

Finally, the negative, coefficient on the drought index, *SPI*, confirms again that the price of leased water is influenced in an intuitive way by hydrologic conditions; dry conditions with scarcer supply correspond to a higher price for leased water.

4.10 Cross-State Comparison

The following table compares the sign and elasticities (or semi-elasticities) for key independent variables across each state model analyzed. For log-level variables and binary independent variables, the semi-elasticity is calculated as:

$$\%\hat{\Delta}y = 100 * \left[\exp(\hat{\beta}) - 1\right]$$

This calculation allows for evaluation of the *exact* percentage change in price, even when *lnprice* becomes large (Wooldridge 2003).

Comparison of Elasticity Estimates Across State Models**

	Trend	lnAF	SPI	MEI	ag_NewUse	muni_NewUse	enviro_NewUse
AZ	-4.0	-3.9**	-43.8	60.6		-3.14**	
CA	0.4**	2.3**	-9.2	10.3**	-42.7		-32.0
CO	4.5**	-13.7	-44.3	-2.5**		67.0**	-16.3**
ID	1.2**	-22.0	-30.8	19.2**		-42.1**	584.1
NM	5.2	11.6	-37.4	35.8	-51.9**		-78.6
OR	-6.4	3.6**	-18.5	23.5			381.6
TX	2.7**	1.7**	-12.8	12.2**	-24.1		46.1**

**Indicates insignificance at the 10% level.

Table 4.26 Comparison of Elasticity Across State Models

A comparison across states highlights a number of interesting issues. In terms of the number of acre-feet of water leased, *lnAF*, results suggest that in some states (namely Colorado and Idaho) the price per acre-foot of leased water decreases as the quantity increases, a phenomenon commonly attributed to economies of scale. In New Mexico, however, the price per acre-foot is found to increase as the number of acre-feet in the lease transaction increases. A possible explanation for this difference is disparity among states in transactions costs associated with water transfers. Three factors contributing to transactions costs are applicant costs, transfer protests, and state agency cots (Colby 1990). A study by Colby *et al.* (1989) and verified by MacDonnell (1990) demonstrate that the magnitude of these transactions costs can vary significantly among different state. For instance, MacDonnell finds that compared to Colorado and Utah, transfers in New Mexico that involved a larger quantity of water generally took a much longer time to win state approval for the transfer than for relatively smaller transfers (MacDonnell 1990). Because a longer approval process would likely imply increased transaction costs, this may be one possible explanation for the positive coefficient on the quantity variable in New Mexico but not elsewhere.

This comparison also reveals that the drought index, the SPI, significantly influences the price of leased water in each western state analyzed, but the extent of that impact varies from state to state. Results suggest that the impact of worsening drought on the price of water in Arizona, Colorado, Idaho, and New Mexico are relatively strong; a one percent decrease in the severity of drought as measured by a one percent decrease in the SPI corresponds to an increase in the price of lease water by over 30% in each of these states. In the remaining states, however, the impact of drought on the price of leased water is less severe.

4.10 Regional Analysis

The next section focuses on econometric analysis of western leases at the regional and west-wide levels. The disaggregated scope of the data allows for a more broad-scale analysis of western water leases and the assessment of whether there is a statistically significant distinction between western states in explaining the price of leased water. This analysis will also differ from the state analyses in the way the type of transfer is examined. Instead of including binary variables indicating the new use of the water, binary variables indicating the overall type of transfer will be included. Each transfer is classified into one of the following 7 categories based on original use and new use of the leased water: (1) agriculture to agriculture, (2) agriculture to municipal, (3) agriculture to environment, (4) storage/surplus to agriculture, (5) storage/surplus to municipal, (6) storage/surplus to environmental, and (7) other. Storage/surplus water is water that was being stored unused in a lake or reservoir, for instance, and was then leased out for use. In Arizona, for example, unused or excess Central Arizona Project water has historically been leased out for various uses, and would thus fall into category 4-6. In Colorado, it is common for federal project water stored in a reservoir or lake to be leased out, and the Colorado Water Conservancy District also leases out its stored water. Another example of temporary transfers of stored/surplus water is in New Mexico where cities have leased out unused project water (such as the San Juan Chama project). Thus, depending on the specific transaction, the “owner” of the stored or surplus water varies.

The ‘other’ category is composed of all transactions that do not fall into one of the other categories. Common ‘other’ transactions include municipal to municipal leases or agriculture to industry transfers. Less common transfers that are categorized as 'other' include water transfers involving a tribal settlement, dairy or other unusual agriculture, or mining. The breakdown of type of transfer across the western states is depicted in terms of total transfers and volume transferred in the following tables.

DOMINANT TYPES OF TRANSFERS BY NUMBER OF TRANSACTIONS (1987 - 2005)

STATE	Ag-Ag	Ag-Muni.	Ag-Enviro	Storage-Ag	Storage-Muni	Storage-Enviro	Other	Total
AZ	1	6	0	13	17	3	7	47
CA	17	28	20	14	27	15	91	212
CO	3	3	4	11	15	6	22	64
ID	1	1	8	11	1	4	7	33
MT	0	0	1	1	0	0	7	9
NV	0	0	0	0	2	0	1	3
NM	0	2	8	1	3	10	23	47
OR	4	0	16	15	0	3	6	44
TX	33	48	2	1	6	0	41	131
UT	0	1	0	12	1	1	2	17
WA	5	1	12	3	3	0	3	27
WY	0	0	0	7	11	0	8	26
TOTAL	64	90	71	89	86	42	218	660
% of Total	9.7%	13.6%	10.8%	13.5%	13.0%	6.4%	33.0%	100.0%

Table 4.27 Dominant Western Transfers by Number

Dominant Types of Transfers by Volume (AF) Transferred (1987-2005)

STATE	Ag - Ag	Ag- Muni.	Ag- Enviro	Storage- Ag	Storage- Muni	Storage- Enviro	Other	Total
AZ	4,500	17,530	0	1,891,523	2,538,000	29,500	5,122	4,486,175
CA	511,561	959,081	727,820	274,806	1,231,827	769,424	2,087,542	6,562,061
CO	11,264	12,151	507	50,135	18,087	30,468	88,400	211,012
ID	214	3,000	982,304	90,110	100	351,040	159,666	1,586,434
MT	0	0	3,614	5,390	0	0	18,084	27,088
NV	0	0	0	0	58,850	0	1,000	59,850
NM	0	449	51,358	150	2,682	244,516	142,161	441,316
OR	6,469	0	629,987	58,810	0	441	52,260	747,967
TX	334,741	169,839	8,500	5,448	415,749	0	104,906	1,039,183
UT	0	3,051	0	103,678	2,662	9,500	12,074	130,965
WA	45,814	44	19,403	2,500	2,055	0	36,511	106,327
WY	0	0	0	9,045	43,317	0	2,725	55,087
TOT	914,563	1,165,145	2,423,493	2,491,595	4,313,329	1,434,889	2,710,451	15,453,465
% of Tot	5.9%	7.5%	15.7%	16.1%	27.9%	9.3%	17.5%	100.0%

Table 4.28 Dominant Western Transfers by Volume

In terms of number of transactions, the most common type of transfers in the West over the 19 year period are agriculture to municipal use, storage/surplus to municipal use, and storage/surplus to agriculture use. Based on volume, storage/surplus to municipal and storage/surplus to agricultural use are still the leading types of transfers, but transfers out of agriculture for environmental needs have also moved a significant quantity of water. Among other things, the following results will analyze the role the type of transfer plays in determining price. Three models (Pacific Northwest, Southwest, and west-wide) will be presented in turn.

4.11.1 Pacific Northwest

The Pacific Northwest dataset is composed of 104 transactions from Idaho, Oregon, and Washington between 1987 and 2005.

4.11.1.1 Model

Consistent with test results from the Oregon price model, price and quantity are not endogenous in the broader Pacific Northwest region, and thus OLS is used to estimate the model.

$$\ln Adj\_Price = \beta_0 + \beta_1 Trend + \beta_2 \ln AF + \beta_3 washington + \beta_4 idaho + \beta_5 SPI12l6 +$$
$$\beta_6 ag\_muni + \beta_7 ag\_enviro + \beta_8 storage\_ag + \beta_9 storage\_muni + \beta_{10} storage\_enviro + \beta_{10} other\_type$$

DESCRIPTION OF VARIABLES
PACIFIC NORTHWEST PRICE MODEL

Name	Description
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
Lnaf	Natural log of AF.
Washington	Binary variable equal to one if the transaction occurred in Washington.
Idaho	Binary variable equal to one if the transaction occurred in Idaho.
SPI12L6	12-month SPI lagged six months.
MEI	2-month MEI.
ag_muni	Binary variable equal to one if the transfer was ag. to municipal.
ag_enviro	Binary variable equal to one if the transfer was ag. to environment.
Storage_ag	Binary variable equal to one if the transfer was storage to ag.
Storage_muni	Binary variable equal to one if the transfer was storage to municipal.
Storage_enviro	Binary variable equal to one if the transfer was storage to environmental.
other_type	Binary variable equal to one if the transfer was some other type.

Table 4.29 PacNW Variable Descriptions

4.11.1.2 Results

SUMMARY STATISTICS
PACIFIC NORTHWEST PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	3.13	1.21	1.47	1.66	6.47
trend	14.12	4.11	16.88	3.00	19.00
lnaf	7.82	2.33	5.44	0.43	12.90
washington	0.26	0.44	0.19	0.00	1.00
idaho	0.32	0.47	0.22	0.00	1.00
SPI12L6	-0.02	1.05	1.09	-2.34	2.79
MEI	0.40	0.95	0.90	-1.51	2.87
ag_muni	0.02	0.14	0.02	0.00	1.00
ag_enviro	0.34	0.47	0.23	0.00	1.00
storage_ag	0.28	0.45	0.20	0.00	1.00
storage_muni	0.06	0.23	0.05	0.00	1.00
storage_enviro	0.07	0.25	0.06	0.00	1.00
other_type	0.14	0.35	0.12	0.00	1.00

Table 4.30 PacNW Summary Statistics

REGRESSION RESULTS
PACIFIC NORTHWEST PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	Chi-Square	Robust P-Value
Intercept	2.832	0.520	29.71	<.0001
trend**	-0.014	0.020	0.47	0.4942
lnaf**	-0.031	0.060	0.27	0.6013
washington†	0.622	0.227	7.51	0.0062
idaho**†	-0.067	0.263	0.06	0.8005
SPI12L6	-0.296	0.076	15.11	0.0001
MEI	0.309	0.097	10.17	0.0014
ag_muni**‡	0.742	0.468	2.51	0.113
ag_enviro‡	1.123	0.314	12.81	0.0003
storage_ag**‡	-0.387	0.272	2.02	0.1548
storage_muni**‡	0.677	0.585	1.34	0.2468
storage_enviro‡	0.977	0.564	3.00	0.083
other_type**‡	0.522	0.410	1.62	0.2037
Observations	104			
R^2	0.46			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is Oregon.
‡Base group is ag_ag.

Table 4.31 PacNW Regression Results

Tests for heteroskedasticity suggest non-constant variance needs to be corrected for in this model, thus the variance-covariance matrix was used to construct Huber-White robust standard errors. Using the robust standard errors does not change inferences in any significant way. Both the time trend and the number of acre-feet of water leased are insignificant in this model. The price of water leased in Washington is predicted to be less than water leased in Oregon, though the price of lease water in Idaho is not statistically different from the price of leased water in Oregon. Both the drought and climate indices are significant with the expected sign in this model.

Agriculture to agriculture is the comparison group for the type-of-transfer binary variables. Results indicate that, all else constant, transfers between agricultural users are less expensive that transfers out of agriculture to meet municipal or environmental needs and less expensive than transfer of storage/surplus water to meet municipal or environmental needs (though ag_muni and storage_muni are not significant at the 10% level). Temporary transfers of stored/surplus water, however, are found to be less expensive than transfers between agricultural users.

4.11.2 Southwest

The Southwest dataset includes 178 temporary water transactions in Arizona, Colorado, New Mexico, Nevada, and Utah that occurred between 1987 and 2005.

4.11.2.1 Models

To address endogeneity indicated by the Hausmann-Wu test, predicted values of quantity are estimated in a first-stage least squares equation using a range of instrumental variables. The R^2 for the first-stage regression is .5. The second stage equation, including the instrumented quantity variable, *lnAFhat*, is then estimated as follows:

$$\ln Adj\_Price = \beta_0 + \beta_1 Trend + \beta_2 \ln AFhat + \beta_3 arizona + \beta_4 new\_mexico + \beta_5 nevada + \beta_6 utah + \beta_7 MEI + \beta_8 SPI12L6 + \beta_9 years\_lease + \beta_{10} surf\_water + \beta_{11} effluent + \beta_{12} ag\_muni + \beta_{13} ag\_enviro + \beta_{14} storage\_ag + \beta_{15} storage\_muni + \beta_{16} storage\_enviro + \beta_{17} other\_type$$

DESCRIPTION OF VARIABLES
SOUTHWEST PRICE MODEL

Name	Description
Lnprice	The natural log of the price per AF.
Trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
Lnafhat	Natural log of the predicted value of AF.
Arizona	Binary variable equal to one if the transaction occurred in Arizona.
new_mexico	Binary variable equal to one if the transaction occurred in New Mexico.
Nevada	Binary variable equal to one if the transaction occurred in Nevada.
Utah	Binary variable equal to one if the transaction occurred in Utah.
MEI	2-month MEI.
SPI12L6	12-month SPI lagged six months.
years_lease	The number of years of the life of the lease.
surf_water	Binary variable equal to one if the leased water was surface water.
Effluent	Binary variable equal to one if the leased water was groundwater.
ag_muni	Binary variable equal to one if the transfer was ag. to municipal.
ag_enviro	Binary variable equal to one if the transfer was ag. to environment.
Storage_ag	Binary variable equal to one if the transfer was storage to ag.
Storage_muni	Binary variable equal to one if the transfer was storage to municipal.
Storage_enviro	Binary variable equal to one if the transfer was storage to environmental.
other_type	Binary variable equal to one if the transfer was some other type.

Table 4.32 SW Variable Descriptions

4.11.2.2 Results

The results of 2LSL regression in the southwest water lease market are summarized and presented below:

SUMMARY STATISTICS
SOUTHWEST PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	3.85	1.11	1.23	1.88	7.14
trend	11.09	5.26	27.63	2.00	19.00
lnafhat	7.77	1.81	3.28	4.12	11.79
arizona	0.26	0.44	0.20	0.00	1.00
new_mexico	0.26	0.44	0.20	0.00	1.00
nevada	0.02	0.13	0.02	0.00	1.00
utah	0.10	0.29	0.09	0.00	1.00
MEI	0.33	0.89	0.79	-1.33	2.84
SPI12L6	0.16	1.00	0.99	-2.54	2.51
years_lease	4.78	9.23	85.18	1.00	40.00
surf_water	0.90	0.29	0.09	0.00	1.00
effluent	0.06	0.23	0.05	0.00	1.00
ag_muni	0.07	0.25	0.06	0.00	1.00
ag_enviro	0.07	0.25	0.06	0.00	1.00
storage_ag	0.21	0.41	0.17	0.00	1.00
storage_muni	0.21	0.41	0.17	0.00	1.00
storage_enviro	0.11	0.32	0.10	0.00	1.00
other_type	0.31	0.46	0.21	0.00	1.00

Table 4.33 SW Summary Statistics

REGRESSION RESULTS
SOUTHWEST PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	3.928	0.643	6.11	<.0001
trend**	-0.010	0.016	-0.67	0.5044
lnafhat**	-0.011	0.036	-0.3	0.768
arizona†	0.482	0.232	2.08	0.0392
new_mexico**†	-0.079	0.208	-0.38	0.7057
nevada**†	-0.319	0.571	-0.56	0.5772
utah†	-0.799	0.284	-2.81	0.0056
MEI	0.156	0.086	1.83	0.0696
SPI12L6	-0.241	0.078	-3.09	0.0024
years_lease**	0.012	0.009	1.29	0.1979
surf_water‡	-0.634	0.378	-1.68	0.0954
effluent‡	-0.807	0.476	-1.69	0.0921
ag_muni^	1.757	0.571	3.08	0.0025
ag_enviro^	0.909	0.556	1.63	0.1042
storage_ag**^	0.309	0.522	0.59	0.5545
storage_muni**^	0.717	0.522	1.37	0.1715
storage_envi**^	0.457	0.536	0.85	0.3954
other_type**^	0.632	0.493	1.28	0.2018
Observations	178			
R^2	0.39			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is Colorado
‡Base group is groundwater
^Base group is ag_ag

Table 4.34 SW Regression Results

Unexpectedly, only two of the four state binary variables are significant in the model. This implies that, ceteris paribus, the price of leased water in New Mexico and Nevada are not statistically different from the price in Colorado, which is the reference group. Lease transactions are predicted to be more expensive in Arizona and less expensive in Utah, both in comparison to Colorado.

The drought index is again found to be significant with the expected sign. The number of years of the life of the lease, however, is not significant in the southwest model. Both the surface water and effluent binary variables are just significant at the 10% level, suggesting some relationship between the type of water leased and its price in the southwest. Both surface water and effluent are found to be less expensive, all else constant, than leased groundwater.

Compared to leases within agriculture, transfers out of agriculture to municipal and environmental uses are predicted to be more expensive. The price per acre-foot of temporary transfers out of storage for agricultural, municipal, or environmental use, however, is not found to be statistically different from the price of leases within agriculture.

4.11.3 West-wide

The west-wide dataset includes temporary water transactions between 1987 and 2005 from all contiguous western states, which includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming. There are a total of 660 observations in the dataset.

4.11.3.1 Models

The aggregated data including transactions from across the West is also shown to be endogenous, so again, 2SLS is employed. The R^2 from this first-stage equation is .27. Explanatory variables included in the second-stage equation are consistent with the regional model previously presented, including state and type-of-use dummies.

$$\ln Adj\_Price = \beta_0 + \beta_1 Trend + \beta_2 \ln AFhat + \beta_3 SPI12L6 + \beta_4 arizona + \beta_5 california + \beta_6 idaho + \beta_7 montana + \beta_8 nevada + \beta_9 new\_mexico + \beta_{10} oregon + \beta_{11} texas + \beta_{12} utah + \beta_{13} washington + \beta_{14} wyoming + \beta_{15} ag\_muni + \beta_{16} ag\_enviro + \beta_{17} storage\_ag + \beta_{18} storage\_muni + \beta_{19} storage\_enviro + \beta_{20} other\_type$$

DESCRIPTION OF VARIABLES
WEST-WIDE PRICE MODEL

Name	Description
lnprice	The natural log of price per AF.
trend	A time trend equal to 1 if year = 1987, 2 if year = 1988, etc.
lnafhat	Natural log of the predicted value of AF.
SPI12L6	12-month SPI lagged six months.
arizona	Binary variable equal to one if the transaction occurred in Arizona.
california	Binary variable equal to one if the transaction occurred in California.
idaho	Binary variable equal to one if the transaction occurred in Idaho.
montana	Binary variable equal to one if the transaction occurred in Montana.
nevada	Binary variable equal to one if the transaction occurred in Nevada.
new_mexico	Binary variable equal to one if the transaction occurred in New Mexico.
oregon	Binary variable equal to one if the transaction occurred in Oregon.
texas	Binary variable equal to one if the transaction occurred in Texas.
utah	Binary variable equal to one if the transaction occurred in Utah.
washington	Binary variable equal to one if the transaction occurred in Washington.
wyoming	Binary variable equal to one if the transaction occurred in Wyoming.
ag_muni	Binary variable equal to one if the transfer was ag. to municipal.
ag_enviro	Binary variable equal to one if the transfer was ag. to environment.
storage_ag	Binary variable equal to one if the transfer was storage to ag.
storage_muni	Binary variable equal to one if the transfer was storage to municipal.
storage_enviro	Binary variable equal to one if the transfer was storage to environmental.
other_type	Binary variable equal to one if the transfer was some other type.

Table 4.35 West Variable Descriptions

4.11.3.2 Results

SUMMARY STATISTICS
WEST-WIDE PRICE MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnprice	3.99	1.12	1.25	1.66	7.80
trend	12.50	4.86	23.63	2.00	19.00
lnafhat	8.02	1.26	1.59	4.99	10.49
SPI12L6	0.12	1.00	1.00	-3.44	2.79
arizona	0.07	0.26	0.07	0.00	1.00
california	0.32	0.47	0.22	0.00	1.00
idaho	0.05	0.22	0.05	0.00	1.00
montana	0.01	0.12	0.01	0.00	1.00
nevada	0.00	0.07	0.00	0.00	1.00
new_mexico	0.07	0.26	0.07	0.00	1.00
oregon	0.07	0.25	0.06	0.00	1.00
texas	0.20	0.40	0.16	0.00	1.00
utah	0.03	0.16	0.03	0.00	1.00
washington	0.04	0.20	0.04	0.00	1.00
wyoming	0.04	0.19	0.04	0.00	1.00
ag_muni	0.14	0.34	0.12	0.00	1.00
ag_enviro	0.11	0.31	0.09	0.00	1.00
storage_ag	0.13	0.34	0.12	0.00	1.00
storage_muni	0.13	0.34	0.12	0.00	1.00
storage_enviro	0.06	0.24	0.06	0.00	1.00
other_type	0.33	0.47	0.22	0.00	1.00

Table 4.36 West Summary Statistics

Second stage regression results are as follows:

REGRESSION RESULTS
WEST-WIDE PRICE MODEL*

Variable Name	Parameter Estimate	Robust St. Error	T-Stat	Robust P-Value
Intercept	3.684	0.225	16.37	<.0001
trend**	-0.003	0.008	-0.4	0.6889
lnafhat	-0.054	0.017	-3.16	0.0017
SPI12L6	-0.137	0.036	-3.82	0.0001
arizona[†]	0.689	0.187	3.68	0.0003
california[†]	0.792	0.140	5.64	<.0001
idaho[†]	-0.823	0.200	-4.12	<.0001
montana[†]	-1.022	0.323	-3.17	0.0016
nevada**[†]	-0.052	0.537	-0.1	0.9227
new_mexico**[†]	-0.211	0.179	-1.18	0.2395
oregon[†]	-0.695	0.183	-3.8	0.0002
texas[†]	0.333	0.149	2.23	0.0261
utah[†]	-0.572	0.255	-2.24	0.0255
washington**[†]	-0.045	0.213	-0.21	0.8338
wyoming**[†]	-0.179	0.211	-0.85	0.3976
ag_muni[‡]	0.566	0.148	3.81	0.0001
ag_enviro[‡]	0.845	0.167	5.04	<.0001
storage_ag**[‡]	-0.069	0.164	-0.42	0.6758
storage_muni[‡]	0.860	0.159	5.42	<.0001
storage_enviro[‡]	0.603	0.189	3.18	0.0015
other_type[‡]	0.775	0.135	5.75	<.0001
Observations	660			
R^2	0.37			

*Dependent variable is log of adjusted price per acre-foot
**Insignificant at 10% level
†Base group is Colorado.
‡Base group is ag-ag.

Table 4.37 West Regression Results

There is no statistically significant trend in the price of leased water across the West, though the predicted value for quantity, *lnafhat*, is negative and significant. The sign on this coefficient has varied from state to state in analysis of single-state models, but the negative sign suggests a predominance of economies of scale in temporary water transactions in the West. That is, as the quantity of water leased increases, the price of water is predicted to decrease.

The state binary variables appear to be picking up more variation in the price of leased water across the West than they were in the regional models. With Colorado as the reference group, the price of leased water in Arizona, California, and Texas are predicted to be higher than Colorado at the 5% significance level. Idaho, Montana, Oregon, and Utah are also all statistically significant but with negative coefficients. Thus, the price of leased water in theses states is predicted to be less than in Colorado, all else constant.

In terms of type-of-transfer, except for stored/surplus water that is leased for agricultural use, each type of transfer combination is positive and significant. This implies that throughout the western U.S., water temporarily transferred out of agriculture for municipal or environmental purposes or water transferred out of storage to meet municipal or environmental needs is more expensive than water being transferred between two agricultural users. This finding is significant, as we would expect the use value of water for municipal or instream flow purposes to generally be higher than for irrigated agricultural use. The results here confirm that western water markets are, at least to a degree, reflecting the differential use values of water.

Elasticity estimates for key variables in the regional models follows:

Comparison of Elasticity Estimates Across Regional Models**

	Trend	lnAF	SPI	MEI	ag_ muni	ag_ enviro	storage_ag	storage_muni	storage_enviro
PacNW	-1.4**	-3.1**	-25.6	36.2	110.0**	207.4**	-32.1**	96.8**	165.6
SW	-1.0**	-11**	-21.4	39.1	479.5	148.2	36.2**	104.8**	57.9**
West	-0.3**	-5.4	-12.8		76.1	132.8	-6.7**	136.3	82.8

**Indicates insignificance at the 10% level.

Table 4.38 Comparison of Elasticity Across Regional Models

4.12 GENERAL FINDINGS

Water lease markets are particularly conducive to minimizing drought-induced water supply variability. When conditions are dry, leading to a temporary supply shortage, water users can lease water from other users to meet their short-term needs. Economic theory would suggest that during times when water is in short supply, the price will go up to reflect its scarcity value. This analysis considered two drought/climate indices, the MEI and the SPI, to assess whether temporary water markets across the West are sensitive to drought conditions.

In essentially every model evaluated, the price of leased water is found to have an inverse relationship with water supply conditions. That is, when water is less abundant, its price per acre-foot rises. More interestingly, results here suggest that this price sensitivity is very location specific. Particularly in the southwestern U.S., the SPI is found to better reflect the effect of climate/drought on the price of water than the MEI. The MEI is often not significant, and when it is, the sign tends to be counterintuitive. One possible explanation is that the MEI is a single value for entire West. Although the MEI does have different water supply implications for the Southwest and the Pacific Northwest, hydrologic conditions *within* these regions can vary dramatically. The SPI, on the other hand, is specific to intra-state climate divisions, thus allowing for very location-specific analysis of the impact of drought on the price of leased water. The significance and expected sign of the coefficient on the SPI in essentially all models suggests that the price of water is driven more by local hydrologic conditions than the overall regional climate.

Another note-worthy (though difficult to explain) finding is that in general, economic indicators such as personal income, per capita income, and population growth are not significant determinants of price in western water leases. There are two somewhat plausible explanations. First, perhaps this is due to the short-term nature of lease markets. Presumably, water users most often enter the water lease market to meet an immediate need that is created by some non-permanent force such as drought. Lease markets are not appropriate for permanent supply augmentation to meet increased demand created by population growth, for instance. For this reason, population may not be correlated with the price of leased water. Another explanation may be that because water supplied via market transactions represents such a small fraction of the total water used in the West, the economic indicators are simply too far removed to have any significant impact on the price of leased water.

4.13 LIMITATIONS AND FURTHER RESEARCH

The results of this study are based on some assumptions that may be limiting and create bias. First, there may be selection bias generated based on the assumptions used in the sample selection process, and this should be tested for. If the observations deleted from the sample were in fact random, then sample selection bias would not be a problem. However, if the process was not found to be random, the bias should be corrected for.

There is also a possibility of omitted variable bias in the models as they are now specified. There are a number of other attributes of water transfers that would intuitively have an effect on the price of water, such as the type of water right purchased (i.e. how senior or junior was the water right). The omission of this variable may create bias because there may be endogniety between the type of seller and the type of water right, as agriculturalists tend to dominate sales and hold the most senior water right.

A potentially interesting continuation of this research could be an evaluation of the relative maturity/efficiency of a particular market based on whether the price of leased water is converging over time.

4.14 CONCLUDING REMARKS

Western water rights are governed by prior appropriation, or a "first-in-time, first-in-right" system. As such, many irrigators across the West hold senior water rights while municipalities or newer uses such as the environment or recreation have a junior priority status. This implies that in the event of shortage, irrigators with senior water rights will receive their full allocation, while junior rights holder may receive only a portion of their allotment or no water at all. When there is a shortage, this is often an inefficient allocation of water because the value of the water used to irrigate low-value crops is much lower than the value to, say, a municipal water district. In other words, the value of marginal product (VMP) of applying another unit of water to low-value crop production is lower than the VMP of supplying another unit of water to a municipality (Brozovic *et al.* 2002).

Particularly during drought, well-functioning water markets can facilitate the temporary transfer of water from low-value uses to uses with a relatively higher marginal value. By taking advantage of each user's differential value, the water is allocated more efficiently. Both the patterns and peculiarities/inconsistencies revealed in this analysis are useful in systematically identifying the determinants of the price of leased water in the West and can contribute to enhancing market efficiency and maturation.

CHAPTER 5

5.1 FARM BUDGET APPROACH TO VALUING IRRIGATION WATER

Arizona's semi-arid to arid climate necessitates the application of irrigation water on almost all agricultural acreage in the state. As a result, agriculture represents the largest consumptive use of water in Arizona (Tadayon 2005). However, rapid population growth over the last decade has placed increasing pressure on the state's water resources. From 1990 to 2004, the population of Arizona increased approximately 56.4%, swelling from 3.67 million in 1990 to about 5.74 million in 2004 (U.S. Census Bureau). Corresponding, water withdraws for municipal use have steadily increased and now represents the second largest consumptive use sector in the State (Tadayon 2005).

Irrigation water in Arizona comes from three primary sources: (1) Colorado River surface water directly from the mainstem or pumped through the Central Arizona Project canal; (2) surface water from other major Arizona streams; and (3) groundwater (Governor's Drought Task Force Irrigated Agriculture Work Group 2004). This research focuses on the potential for voluntary and temporary transfers of mainstem Colorado River surface water out of agriculture during drought to support municipal and environmental water needs.

Long-term drought on the Colorado River has led to a growing recognition of the limits of the massive Colorado River storage system and has brought to the forefront the need to devise alternative strategies for coping with severe drought. Dry-year options, discussed in Chapter 2, are one such alternative. Dry-year options are leasing agreements that provide for voluntary and temporary drought-triggered water transfers out of agriculture for municipal or environmental restoration use. Such an arrangement represents an alternative to the permanent transfer of agricultural water rights and the permanent fallowing of irrigated land.

Option contracts can logically follow the seasonal hydrologic pattern. In the fall, a buyer pays an initial fee to secure the option to lease a specific quantity of water from an irrigator in the spring (Howitt and Hansen 2005). Then, if the year turns out to be dry and the buyer needs water in the spring, he/she can choose to exercise the option. In purchasing the option, buyers are protecting themselves against drought-induced supply variability and minimizing transactions costs that may be associated with frantic negotiations to secure water in the spring. When an option is exercised, an irrigators will temporarily fallow all or a portion of their land in exchange for an exercise payment. This payment must compensate them to a level *at least* equivalent to the level of foregone profit from crop production in order for the arrangement to be attractive to irrigators.

5.2 IRRIGATED AGRICULTURE

5.2.1 Value of Agriculture in the West

Although census crop sales data on the value of total crop production is actually an underestimate due to the exclusion of the value of crops produced and consumed on-farm (prevalent in irrigated forage and feed crops), census crop sales data provides the basis for estimates of irrigated crop values (Gollehon 2000). Based on this data, in 1997 there were 57.7 million hectors (142 million acres) of harvested cropland in the West, generating $45 billion in crop sales. While irrigated crops represent only 27% of the total land area, they produce 72% (approx. $32 billion) of total sales value in the West. Average sales per harvested hectare are estimated at $2100 for irrigated cropland and $300 for non-irrigated cropland.

Over 60% of the West's total sales from irrigated crops come from high-value orchards, berries, vegetables, and nursery crops, though these high-value crops occupy only 15% of harvested irrigated land. By contrast, field and forage crops, which accounted for the remaining 40% of total value of sales, occupy 71% of irrigated acreage (Gollehon and Quimby 2000). This discrepancy means irrigators have significant flexibility in adjusting to changes in water supply. Water shortages can be addressed by shifting cropping choices to maintain production of higher-valued crops. Water leases represent an opportunity for farmers and water suppliers to transfer water and maintain higher-valued crops during drought.

5.2.2 Agriculture in Arizona

Irrigated agriculture is an important contributor to Arizona's economy; it is estimated to contribute $6 to $7 billion dollars annually to the overall economy of the State (Governor's Drought Task Force Irrigated Agriculture Work Group 2004). Net farm income in Arizona was estimated at $1,399,446 in 2004, up from the five previous years. However, the number of farms in operation and the total acreage in farms has declined yearly since at least 1998 (Arizona Agricultural Statistics 2005).

Major field crops grown in the state include hay alfalfa, cotton, and wheat. These crops compose the vast majority of the value of field crop production in Arizona: approximately 88% in 2004. Arizona also produces a number of other field crops including corn, barley, and sorghum, but the value of production and acreage devoted to these crops is much less substantial. In addition to field crops, Arizona produces a number of vegetables (various varieties of lettuce and broccoli are the most dominant) as well as melons and potatoes. Vegetable production is typically rotated with field crops such as wheat and cotton. Alfalfa fields, however, are typically dedicated solely to the production of hay alfalfa (Nolte 2006).

5.2.3 Summary of Crop Acreage and Irrigation Water Use in Yuma and La Paz Counties

Because dry-year transfers out of agriculture are exercised voluntarily and temporarily, they have the potential to maintain the viability of Arizona agriculture in the long run while meeting municipal and environmental water needs during drought. Counties along the Colorado River account for 88% of irrigated acreage in Arizona (Frisvold 2004). Yuma and La Paz counties were chosen as prospects for dry-year transfers because they produce a large quantity of relatively low-value crops using senior, mainstem Colorado River surface water.

La Paz and Yuma counties have access to mainstem Colorado River water, and thus a majority of their irrigation withdrawals come from surface water. Of the 874.71 million gallons/day (mgal/day) total irrigation withdrawals in La Paz County in 2000, 589.62 mgal/day were surface water (Hutson *et al.* 2004). In Yuma county in 2000, surface water composed 1078.56 mgal/day of its total 1431.72 mgal/irrigation withdraw. Yuma County diverts 1.2 million acre-feet of Colorado River water annually (Bequette *et al.* 2001). This represents over one-third of Arizona's total 1.2 million acre-feet of Colorado River allocation.

The warm, dry climate of La Paz and Yuma counties in southwestern Arizona, coupled with plentiful arable land and access to surface water from the Colorado River, create conditions for a successful agricultural sector in the region. La Paz County is characterized by 98,245 acres of cropland, of which 91,347 (93%) are irrigated (USDA-NASS 2002 Census of Agriculture). Yuma County is comprised of a total of 212,995 acres of cropland, with 197,424 (93%) irrigated acres. In 2002 there were 101 farms in La Paz County and 531 farms in Yuma County.

Western La Paz County along the Colorado River is also home to the Colorado River Indian Tribes (CRIT). Active cropland on the CRIT reservation is estimated at 84,900 acres, with 50,000 additional acres available for development (Inter Tribal Council of Arizona "Colorado River Indian Tribes"). The CRIT also hold senior water rights to Colorado River water. The Tribe's 717,000 acre-feet of senior Colorado River water rights represent almost one-third of Arizona's total Colorado River allocation (Inter Tribal Council of Arizona "Colorado River Indian Tribes").

Cropland in Study Area*

	ARIZONA	LA PAZ COUNTY	YUMA COUNTY
Number of Farms			
2002	7294	101	531
1997	8507	97	465
Total Cropland (Acres)			
2002	1261849	98245	212995
1997	1354820	not available	214774
Irrigated Cropland (Acres)			
2002	931735	91347	197424
1997	1075336	101417	195605

*Data from NASS 2002 and 1997 Census of Agriculture

Table 5.1 Cropland Summary

The dominant field crops in both counties are alfalfa, upland cotton, and durum wheat. Production of these crops has either remained relatively steady or increased over the past five years. As mentioned, cotton and wheat are typically rotated with vegetables (Nolte 2006). Head lettuce is by far the most dominant vegetable produced in Arizona in terms of harvested acres, with almost all acreage concentrated in Yuma County.

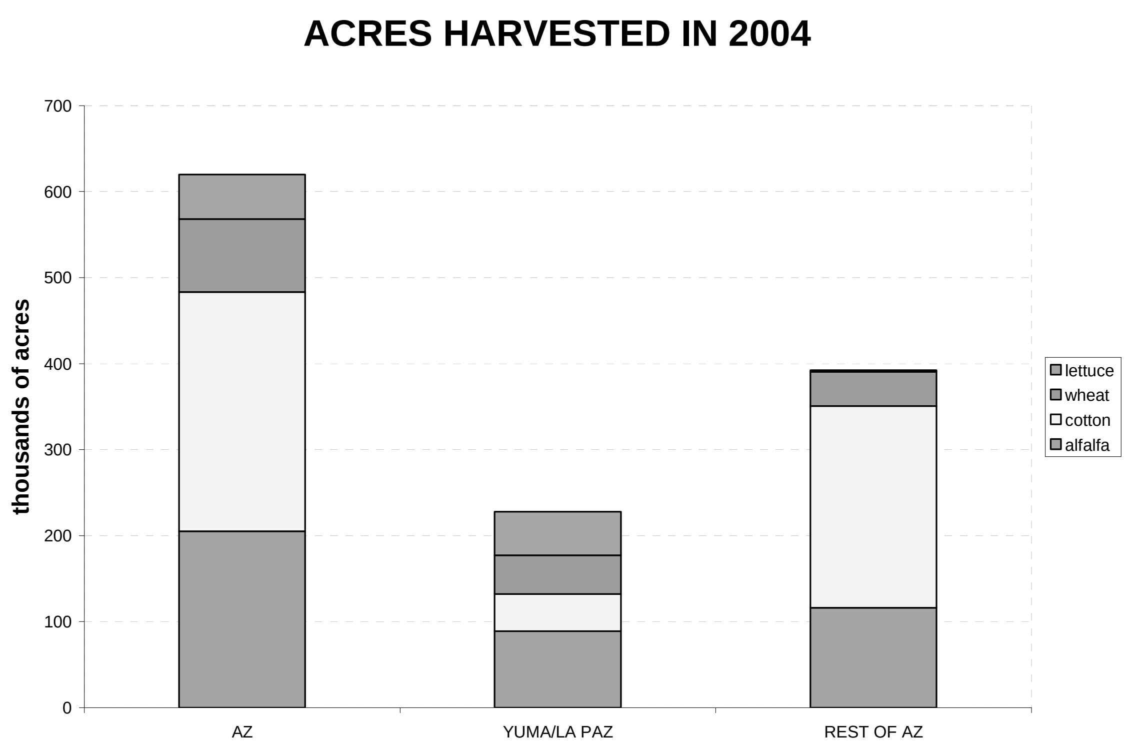


Figure 5.2 Summary of Harvested Acres

Because land fallowing can potentially impact crop mix and crop rotations, head lettuce is also included in this analysis for Yuma County. Due to its high net returns, lettuce is an unlikely candidate for fallowing yet it is an important component of the seasonal crop mix.

The following tables give an idea of the five-year movement (2000 to 2004) in the price and production for the crops and vegetable included in this analysis. Graphs visually depicting the five year trend in acres planted, yield per acre, and price per unit are available in Appendix 2. It should be noted that prices reported in the following two tables represent the market or spot value of the crops as reported by NASS. This price does not reflect federal farm program payments.

YUMA COUNTY - Five Year Trends						
Hay Alfalfa	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	NA	NA	NA	NA	NA	NA
Acres Harvested	30000	31500	32000	31000	28000	30500
Yield per Acre (tons)	8.67	8.25	8.32	9.68	10	8.984
Production (tons)	260000	260000	275700	300000	280000	275140
Price per Ton	$94.00	$99.00	$100.00	$89.00	$98.50	$96.10
Cotton, Upland	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	25400	26000	18200	24600	26800	NA
Acres Harvested	25300	25500	17900	24500	26700	23980
Yield per Acre (pounds)	1385	1129	1397	1254	1438	1320.6
Production (bales)	73000	60000	52100	64000	80000	65820
**Price per Pound	$0.40	$0.28	$0.46	$0.66	$0.50	$0.46
Wheat, Durum	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	38600	36800	44300	46000	43000	NA
Acres Harvested	38600	36400	44300	46000	43000	41660
Yield per Acre (bushels)	101.6	95.8	96.4	102.7	100	99.3
Production (bushels)	3923000	3488300	4272000	4724500	4250000	4131560
Price per Bushel	$3.95	$4.40	$4.46	$4.25	$4.20	$4.25
Lettuce, Head	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	50300	52000	51000	50000	47000	NA
Acres Harvested	50300	51800	50000	49600	46000	49540
Yield per Acre (cwt)	350	390	350	360	360	362
Production (thousand cwt)	17650	20202	17500	17856	16740	17989.6
Price per cwt	$13.10	$16.50	$38.70	$10.30	$22.20	$20.16

*Source: National Agricultural Statistics Service

**Market price received by growers

Table 5.3 Yuma 5-Year Trend

LA PAZ COUNTY - Five Year Trends						
Hay Alfalfa	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	NA	NA	NA	NA	NA	NA
Acres Harvested	59000	61100	63000	61000	65000	61820
Yield per Acre (tons)	8.47	8.38	7.94	8.03	6.92	7.948
Production (tons)	500000	512000	500000	490000	450000	490400
Price per Ton	$94.00	$99.00	$100.00	$89.50	$98.50	$96.20
Cotton, Upland	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	18000	17500	12200	16100	20500	NA
Acres Harvested	17900	17000	12000	16000	20400	16660
Yield per Acre (pounds)	1378	1200	1248	1350	1553	1345.8
Production (bales)	51400	42500	31200	45000	66000	47220
**Price per Pound	$0.40	$0.28	$0.46	$0.66	$0.50	$0.46
Wheat, Durum	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	6500	5100	5600	8000	10000	NA
Acres Harvested	6500	5100	5600	8000	10000	7040
Yield per Acre (bushels)	94.6	96.2	92.7	101.3	88	94.56
Production (bushels)	615000	490500	519000	810000	880000	662900
Price per Bushel	$3.50	$3.95	$4.40	$4.65	$4.20	$4.14

*Source: National Agricultural Statistics Service

**Market price received by growers

Table 5.4 La Paz 5-Year Trends

5.3 THE RESIDUAL METHOD TO VALUE IRRIGATION WATER

A common method for valuing irrigation water is the residual method, which involves crop production cost and return analysis (Young 2005). Mathematically estimating the marginal physical productivity of irrigation water using a crop-production function would in general be a more favorable method, but crop production functions in most regions and for most crops have not been developed (Gibbons 1986). Thus, crop-budget analysis is employed as an alternative method to infer the return to water for production of a specific crop in a specific location.

The first step in crop-budget analysis is to glean data on the steps in the production process, timing, required production resources, and resulting outputs from a crop- and location- specific crop budget. This study uses Arizona's comprehensive set of crop budgets developed by the University of Arizona Department of Agricultural and Resource Economics (Teegerstrom *et al.* 2001; Teegerstrom and Knowles 1999; Teegerstrom and Ticks 1999). Because crop-budget valuation is very sensitive to the market value of crops, input prices, assumptions about operations and application rates, etc., the 1999/2001 farm budgets are updated to reflect more current crop yields and prices, chemical application rates, typical production operations, and fuel and labor costs. Updated crop yields and prices were obtained from USDA-NASS. Up to date seed prices were quoted and averaged from several seed companies located in Yuma and La Paz counties (H&H Seed Co 2006; Barkley Seed Inc. 2006; Carr Seed Co. 2006). Current chemical prices were quoted from Fertizona, an agricultural chemical dealer in Arizona (Osborn 2005; Osborn Feb. 2006; Osborn April 2006). Chemical application rate were updated to reflect current practices. These application rates were provided by a University of Arizona Agricultural Extension Officer for Yuma County (Nolte 2005). It should be noted that application rates for head lettuce were not available at the time this research was concluded, thus application rates used in calculations of NROVC for head lettuce are based on information from 2001.

Extension officers also provided information about changes in standard production operations since the last farm budgets were published (Nolte 2006). Estimates of current fuel costs for agricultural use were supplied by several gas companies in each county and averaged (Parker Oil 2006; Amerigas 2006; Union Oil

2006; Ferrel Gas 2006). Labor costs were abstracted from the 2004 Arizona Agricultural Statistical Bulletin (Arizona Agricultural Statistics 2005).

Because federal farm support payment can substantially improve the profitability of certain crops in certain location, this analysis also includes loan deficiency payments (LDP) in calculations of returns (Center for Agricultural and Rural Development 2005). In Arizona, the LDP payment is currently only applicable to cotton. Other federal payments, in particular counter-cyclical payments and direct payments, are de-coupled, and the receipt of these payments would not be affected by land fallowing (Reinertson 2006).

Next, a Unit Crop Budget is assembled and used to calculate net returns over variable costs (NROVC) per acre for each crop. NROVC represents the on-farm economic value of water in crop production and is calculated by subtracting variable production costs (exclusive of water costs) from gross returns per acre. In other words, the residual from the difference between the gross value of crop production and all non-water input costs is an estimate of the return to irrigation water in crop production (Naeser and Bennett 1998). In theory, this value is the maximum value an irrigator would be willing to pay for water and still cover the costs of production. This value can also be translated into NROVC per acre-foot of water applied to a specific crop.

The method described above is a reasonable approach to estimate the short-run value of irrigation water since only variable costs of production are accounted for. Fixed costs are assumed to be sunk and not a chief consideration in yearly production decisions

(Naeser and Bennett 1998). A longer-run estimate of the value of irrigation water, however, requires the inclusion of the fixed costs of production.

The following tables present variable cost calculations, exclusive of water costs, for each location-specific crop in this analysis.

TOTAL VARIABLE COSTS PER ACRE (LESS WATER)

YUMA COUNTY	Alfalfa	Upland Cotton	Durum Wheat	Head Lettuce
Variable Costs per Acre				
Cash Land Preparation and Growing Expenses				
Paid Labor:				
Tractor	7.06	42.31	19.08	35.95
Hand	0	24.27	0	0
Irrigation	40.71	9.51	20.46	42.09
Other/Contract	0	0	0	1.87
Chemicals and Custom Applications				
Fertilizer	15.37	93.5	138.55	221.42
Insecticide	23.78	299.66	17.34	251.65
Herbicide	27.16	5.74	43.86	124.02
Other Chemicals	0	0	0	52.85
Farm Machinery/Vehicles:				
Diesel Fuel	9.57	48.31	26.42	52.22
Gasoline	0	10.43	0	2.05
Repairs and Maintenance	4.2	27.8	12.83	28.87
Other Purchased Inputs				
Seeds/Transplants	14.31	0.13	26.5	114.48
Other Services and Rentals	0	245.88	42.88	239.1
Total Land Prep and Growing Expenses	142.16	807.54	347.92	1166.57
Cash Harvest and Post Harvest Expenses				
Paid Labor:				
Tractor	25.29	5.99	0	0
Other/Contract	31.15	7.98	0	0
Chemicals and Custom Applications				
Insecticide	0	27.26	0	0
Other Chemicals	0	42.04	0	0
Farm Machinery/Vehicles:				
Diesel Fuel	68.56	21.02	0	0
Repairs and Maintenance	137.05	50.38	0	0
Other Materials	55.97	0	0	0
Custom Harvest/Post Harvest	0	53.43	73.43	2167.2

Cotton Ginning	0	112.67	0	0
Crop Assessment	0	9.38	0	0
Other Materials	0	1.6	0	0
Total Harvest and Post Harvest Expenses	318.02	331.75	73.43	2167.2
Operating Overhead				
Pickup use	21.04	25.24	12.62	21.04
Operating Interest	25.59	29.84	7.9	18.75
TOTAL VARIABLE COSTS PER ACRE	506.81	1194.37	441.87	3373.56

Table 5.5 Yuma Variable Costs

TOTAL VARIABLE COSTS PER ACRE (LESS WATER)

LA PAZ COUNTY	**Alfalfa (w/ sheep)**	**Upland Cotton**	**Durum Wheat**
Variable Costs per Acre			
Cash Land Preparation and Growing Expenses			
Paid Labor:			
Tractor	2.23	33.45	11.19
Hand	0	30.68	0
Irrigation	40.84	24.26	37.06
Other/Contract	0	0	0
Chemicals and Custom Applications			
Fertilizer	28.64	102.63	58.21
Insecticide	45.91	187.67	8.44
Herbicide	13.59	29.25	20.68
Other Chemicals	0	110.57	0
Farm Machinery/Vehicles:			
Diesel Fuel	2.91	77.27	20.64
Gasoline	0	32.03	0
Repairs and Maintenance	1.11	0	8.31
Other Purchased Inputs			
Seeds/Transplants	10.73	0.13	34.45
Other Services and Rentals	0	55.38	0
Total Land Prep and Growing Expenses	145.96	683.32	198.98
Cash Harvest and Post Harvest Expenses			
Paid Labor:			
Tractor	14.04	6.55	1.95
Other/Contract	26.63	12.78	0
Chemicals and Custom Applications			
Insecticide	0	0	0
Other Chemicals	0	59.45	0
Farm Machinery/Vehicles:			
Diesel Fuel	43.42	36.49	3.02

Repairs and Maintenance	90.59	82.91	1.64
Other Materials	27.3	0	0
Custom Harvest/Post Harvest	0	3.36	67.58
Cotton Ginning	0	108.87	0
Crop Assessment	0	9.56	0
Other Materials	0	1.59	0
Total Harvest and Post Harvest Expenses	201.98	321.56	74.19
Operating Overhead			
Pickup use	16.92	25.38	12.69
Operating Interest	21.23	30.52	7.03
TOTAL VARIABLE COSTS PER ACRE	386.09	1060.78	292.89

Table 5.6 La Paz Variable Costs

5.4 ESTIMATED VALUE OF WATER IN CROP PRODUCTION

Using calculations of total variable costs per acre, the following tables compare NROVC for each crop based on four different scenarios: (1) 2004, representing the average Arizona market price and Yuma County crop yield in 2004; (2) 5yr Avg, representing the 5-year average (2000 – 2004) Arizona market price and Yuma County crop yield; (3) High, representing the combined high Arizona market price between 2000 and 2004 and high Yuma County crop yield between 2000 and 2004; and (4) Low, representing the combined low Arizona market price between 2000 and 2004 and low Yuma County crop yield between 2000 and 2004. NROVC are also calculated per acre-foot of water applied. Estimates of crop-specific water application rates for Arizona were obtained from the 2003 Farm and Ranch Irrigation Survey (USDA National Agricultural Statistical Service). It should be emphasized that these rates are simply estimates. Actual water application will vary from region to region and farmer to farmer depending on a number of factors such as type of soil and type of irrigation technology employed. Agriculture on the Colorado River Indian Tribe’s Reservation, for example, tends to apply (but not consume) generally more water per acre than elsewhere in Arizona due to the sandy nature of the soil and the plentiful water supply (Wilson 2006). As a result, NROVC per acre-foot of water for CRIT farmers may vary significantly from the county average numbers presented in this research. Similar tables for other crops included in this analysis can be found in Appendix 2.

Yuma Upland Cotton	2004[1]	5yr Avg[2]	High[3]	Low[4]
Revenue per Acre				
Yield/acre (lint)	1438	1438	1438	1438
Price/unit (lint)	0.5	0.46	0.664	0.284
Yield/acre (seed)	1.69	1.69	1.69	1.69
Price/unit (seed)	140	140	140	140
County LDP Rate	0.1173	0.1173	0.1173	0.1173
Price Plus LDP per unit	0.6173	0.5773	0.7813	0.4013
Gross Revenue ($/Acre)	1124.2774	1066.7574	1360.1094	813.6694
Total Variable Costs per Acre	1194.37	1194.37	1194.37	1194.37
Net Returns Over Variable Costs Per Acre	-70.0926	-127.6126	165.7394	-380.701
A/F of water applied per acre	4.2	4.2	4.2	4.2
Net Returns Over Variable Costs Per Acre-foot of water applied	-16.69	-30.38	39.46	-90.64

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

Table 5.7 NROVC, Upland Cotton

Except in the case of the five year high price and yield, NROVC of production of upland cotton in Yuma County are negative. These calculations do not, however, include federal price support payments that cotton producers receive on top of the market price and the loan deficiency payment. These payments are not included because a farmer's decision to fallow land does not affect their receipt (Reinertson 2006). Thus, even if farmers cease irrigation for a season to lease out their water, they will still receive these payments and therefore they do not affect calculations of the return to water.

The following tables summarizes full-season NROVC/acre and NROVC/AF for all crops analyzed in Yuma and La Paz using the 5-year average price per unit and yield per acre.

YUMA COUNTY NROVC

CROP	NROVC/ACRE	AF WATER/ACRE	NROVC/AF
Alfalfa	$363.22	5.8	$62.62
Durum Wheat	-$29.78	3.5	-$8.51
Upland Cotton	-$210.01	4.2	-$50.00
Head Lettuce	$5,130.72	3.6	$1,425.20

Table 5.8 NROVC, Yuma Crops

LA PAZ COUNTY NROVC

CROP	NROVC/ACRE	AF WATER/ACRE	NROVC/AF
Alfalfa	$390.74	5.8	$67.37
Durum Wheat	$99.53	3.5	$28.44
Upland Cotton	-$192.96	4.2	-$45.94

Table 5.9 NROVC, La Paz Crops

NROVC are useful in that they can be used as a baseline from which negations over the exercise payment can begin. The exercise payment should never be below NROVC for a specific crop, since in that case the farmer would be better off producing crops. Often times, the actual exercise payment will be substantially larger than NROVC for a number of reasons including as an incentive for farmers to participate in an options program and to cover other transaction costs.

The calculation of NROVC in Yuma and La Paz counties expose two important issues. First, the negative NROVC of upland cotton and durum wheat in Yuma County and upland cotton in La Paz County suggests the potential for significant financial benefits for producers who participate in dry-year options arrangements instead of engaging in unprofitable crop production. Second, the very high value of NROVC for head lettuce drives home the point that to be cost effective, dry-year options arrangements must be structured so that low-value crops can temporarily be taken out of production while high-value vegetables continue to be produced. In western Arizona, vegetables are typically harvested around the month of November, after which time irrigators switch to production of field crops for the summer months (Nolte 2006). Because the timing of vegetable harvest may not coincide with the need for leased water, however, options agreements need to be carefully and creatively structured to take advantage of fallowing low-value crops.

In reviewing and comparing the NROVC for crops in Yuma and La Paz counties, the question also naturally arises as to why growers do not focus more on the high return specialty crops such as lettuce. Suppliers of head lettuce in the U.S. are almost exclusively in Arizona and California, respectively representing 26% and 73% of national production in 2004 (Boriss and Brunke 2005). In Arizona, head lettuce production is timed so that harvest dates coincide with the times of the year when the harvest of head lettuce in California is low, typically in November and December and again in late March and into April. These harvest dates also take advantage of the micro-climates in California and Arizona that are most conducive to high-quality head lettuce production (Teegerstrom 2006). Successfully entering the head lettuce market requires extensive planning and very well established networks (Teegerstrom 2006). For any chance of financial success in production, the decision to produce head lettuce cannot be made without careful forethought.

Though the potential returns are high, head lettuce production is extremely high risk and capital intensive. The market for lettuce is unstable with respect to price received by producers and is locally, not globally, driven (Kerns *et al.* 1999). Unlike other field crops, lettuce cannot be stored and sold when market prices are high. Its perishable nature means lettuce is sold immediately after harvest, and if market conditions are not favorable at the time of harvest, a grower has no choice but to accept the low prices.

The market price of lettuce has historically been volatile and is particularly sensitive to changes in supply. Flooding and disease or insect outbreaks, for instance, can dramatically reduce supply and correspondingly boost the market price. If there is surplus supply, however, the market price will plummet and only the highest quality heads (without insect damage or contamination) will be accepted by packers (Kerns *et al.* 1999). And because growers cannot reliably predict what supply conditions will prevail during harvest, they must consistently incur the added costs of ensuring only the highest quality production.

The following three graphs depict the volatile nature of market prices for head lettuce. The first graph shows average seasonal market prices received by growers in Arizona between 1980 and 2004. The second graph shows the monthly fluctuation in prices received by Arizona growers between Nov.1997 and April 2004. The third graph depicts the weekly price of head lettuce in California and Arizona and shows that even on a week to week basis, the market price of lettuce can fluctuate dramatically.

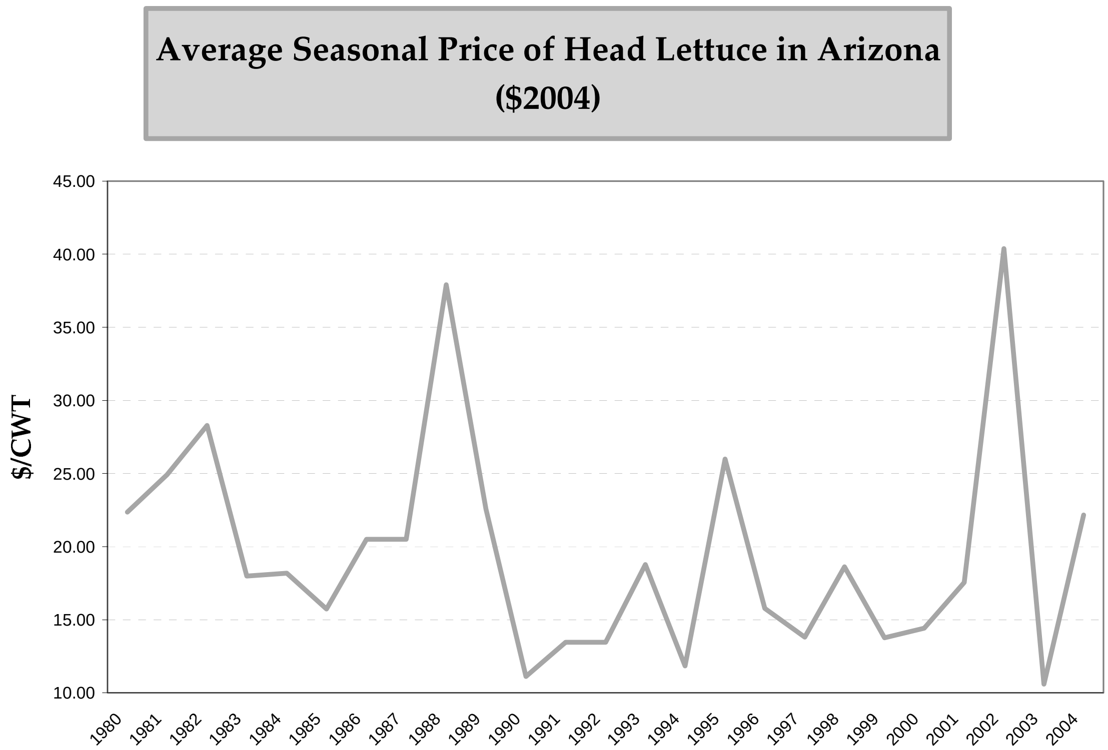


Table 5.10 Seasonal Price of Head Lettuc

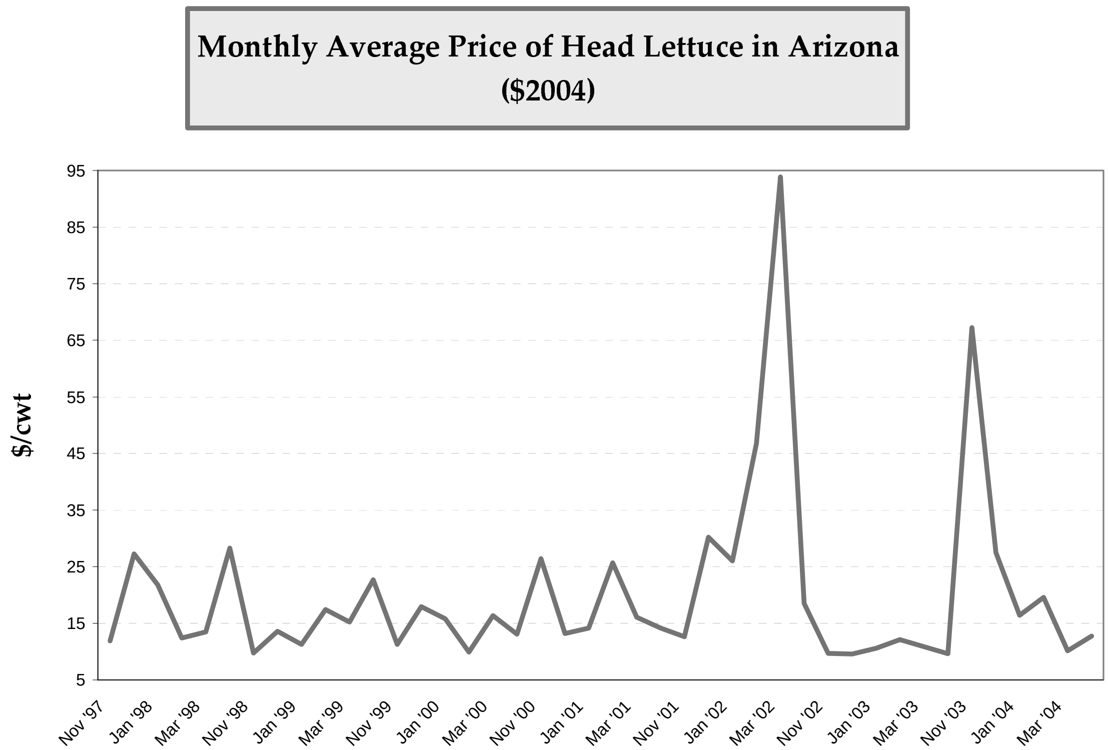


Table 5.11 Monthly Average Price of Head Lettuce

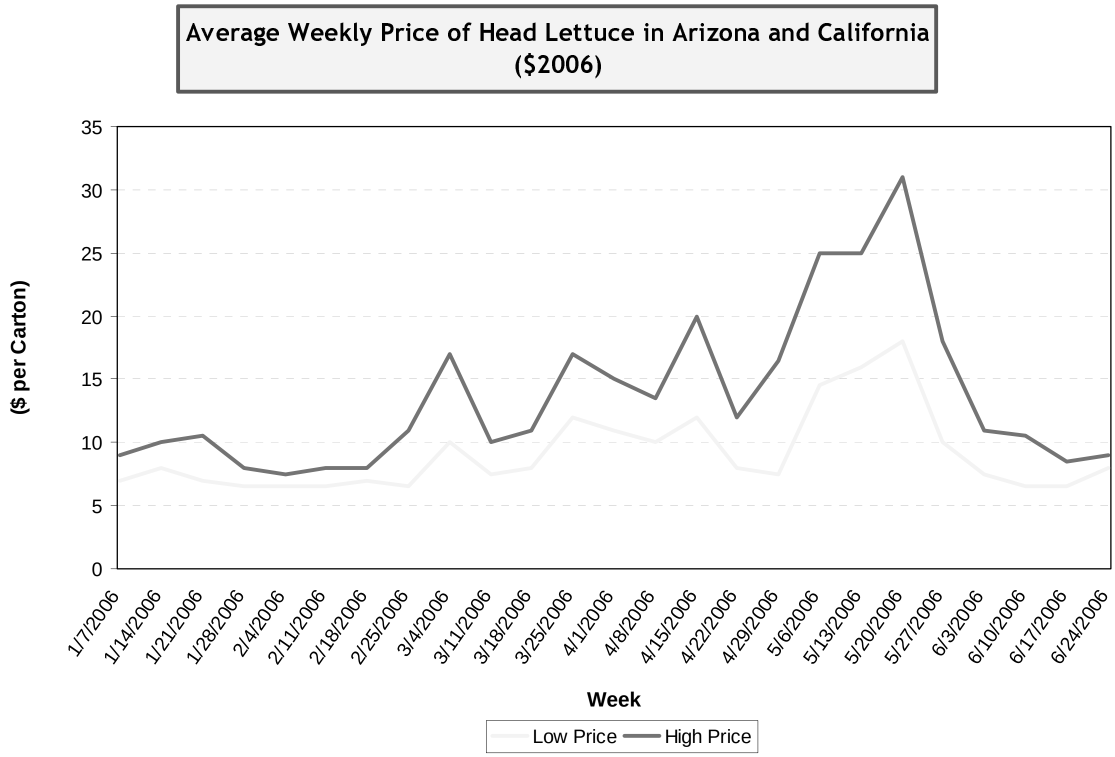


Table 5.12 Weekly Average Price of Head Lettuce

In making production decisions, a grower must consider not only the potential profitability of a crop but also the input costs and risks inherent in the production and marketing of that crop. The variable costs of production for head lettuce and other vegetables are very high compared to lower-valued field crops. If a farmer has the necessary networks in place and decides to incur the high production costs associated with head lettuce production, he is also taking on the risk of volatile, unpredictable market conditions. If the market price for head lettuce is low when he harvests his crop, he has no choice but to accept those prices and will likely incur a large financial loss for the season on his lettuce acreage.

5.5 FULL SEASON VS. PARTIAL/LATE SEASON COMPENSATION

The time of year when options are exercised and farmers are asked to fallow their land has implications for the minimum compensation payment because in some instances, farmers will have already produced some crop (increasing revenue) and may have also already incurred some of the variable costs of production (increasing costs). To accurately account for the value of foregone crop production, the timing of the fallowing must be taken into account. The following table provides a monthly account of the variable costs of production for upland cotton in Yuma County. Similar tables for the other crops in Yuma and La Paz counties can be found in Appendix 2.

County:		**Yuma**				
Crop:		**Upland Cotton**				
Tot. Variable Cost:		**$1,194.36**				
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Variable Cost**	**Running Total (%)**
Dec	Rip	Land Prep	10.10	10.10	0.85	0.85
Dec	Disk	Land Prep	12.48	22.58	1.04	1.89
Jan	Laser Level	Land Prep	52.46	75.04	4.39	6.28
Jan	Roll Beds	Growing	2.38	77.42	0.20	6.48
Jan	List	Land Prep	6.97	84.39	0.58	7.07
Feb	Preirrigate	Growing	6.39	90.78	0.54	7.60
Mar	Mulch	Land Prep	5.52	96.30	0.46	8.06
Mar	Plant	Land Prep	8.30	104.60	0.69	8.76
Mar	Remove Cap	Growing	4.46	109.06	0.37	9.13
Apr	Cultivate	Growing	20.70	129.76	1.73	10.86
Apr	Soil Fertility	Growing	3.00	132.76	0.25	11.12
May	Irrigate/Run Fertilizer	Growing	56.02	188.78	4.69	15.81
Jun	Irrigate	Growing	6.39	195.17	0.54	16.34
Jun	Hand Weeding	Growing	100.00	295.17	8.37	24.71
Jun	Apply Insecticide/Ground	Growing	43.43	338.60	3.64	28.35
Jun	Apply Herbicide/Ground	Growing	10.49	349.09	0.88	29.23
Jul	Apply Insecticide/Ground	Growing	198.40	547.49	16.61	45.84
Jul	Apply Insecticide/Ground	Growing	15.57	563.06	1.30	47.14
Jul	Hand Weeding	Growing	100.00	663.06	8.37	55.52
Jul	Apply Insecticide/Air	Growing	14.89	677.95	1.25	56.76

Aug	Apply Insecticide/Air	Growing	10.95	688.90	0.92	57.68
Aug	Apply Insecticide/Air	Growing	16.17	705.07	1.35	59.03
Aug	Irrigate/Run Fertilizer	Growing	48.97	754.04	4.10	63.13
Sep	Apply Insecticide/Air	Growing	15.70	769.74	1.31	64.45
Sep	Apply Defoliant/Air	Harvest	43.59	813.33	3.65	68.10
Sep	Apply Defoliant/Air	Harvest	25.71	839.04	2.15	70.25
Sep	Dust Control	Growing	24.97	864.01	2.09	72.34
Sep	Prepare Ends	Harvest	1.22	865.23	0.10	72.44
Sep	Cotton, First Pick	Harvest	67.46	932.69	5.65	78.09
Sep	Cotton, Make Mounds	Harvest	13.60	946.29	1.14	79.23
Sep	Cotton, Rood	Harvest	43.33	989.62	3.63	82.86
Sep	Haul	Harvest	6.80	996.42	0.57	83.43
Sep	Cotton Ginning	Post Harvest	112.67	1109.09	9.43	92.86
Dec	Cotton Classing	Marketing	3.30	1112.39	0.28	93.14
Dec	Crop Assessment	Marketing	9.38	1121.77	0.79	93.92
Dec	Cut Stalks	Post Harvest	4.69	1126.46	0.39	94.31
Dec	Disk Residue	Land Prep	12.82	1139.28	1.07	95.39
Misc.	Pickup Use		25.24	1164.52	2.11	97.50
	Operating Inerest 6%		29.84	1194.36	2.50	100.00
	TOTAL		1194.36	1194.36	100.00	100.00

Table 5.13 Cotton Operations

Using this table (and equivalent tables for other crops in an irrigator's annual crop mix), compensation payments can be tied to the time of year an option is exercised. If, for example, an option is exercised before November for the upcoming season, a farm engaged in cotton production would not have incurred any variable costs associated with cotton production, and thus the baseline calculation of NROVC for upland cotton would apply. If, however, cotton producers were asked to fallow their land late in the growing season (i.e. after July 30), they would have already incurred almost 57% of variable costs without any production, so approximately $677 should be added on to NROVC per acre, substantially increasing NROVC per acre-foot.

Unlike cotton and wheat, alfalfa production in western Arizona is a year-round process, and harvesting occurs regularly (approx. every three weeks) throughout the months of April to October and once a month from November to January (Nolte 2006). As a result, NROVC are affected by the time of year irrigators are asked to fallow their land based on variable costs already incurred, and also based on crop already harvested.

The production of other field crops, however, is seasonal. Farmers in western Arizona typically mix field crop production with vegetable production within the same year (Nolte 2006). Durum wheat is planted in December and harvested in June. This is followed by the planting of vegetables, often either head lettuce, cauliflower, or broccoli. Land preparation for upland cotton begins in December. The cotton is typically planted in March and then harvested in August. Like wheat, cotton harvesting is followed by vegetable planting.

5.5.1 Applying Climate Prediction to Cost Efficiently Structure Dry-Year Options

As pointed out, the time of year when an option is exercised has significant consequences for NROVC and likewise minimum exercise payments. NROVC for head lettuce production, for example, is very high relative to the field crops analyzed here. If land fallowing interrupts the production of lettuce (or other vegetables), the compensation payment would necessarily be substantially higher to account for the foregone profit of lettuce production.

The most cost efficient scenario for an irrigator with a field crop/vegetable annual crop mix is if irrigators are asked to cease irrigation in the winter prior to beginning production of field crops and then resume production of vegetables in the summer to late summer. However, this timing may not correspond to the drought-induced need for additional water by municipalities or the environment. If, however, advanced climate prediction tools can be used to anticipate the extent of need for additional water the upcoming year, options can be exercised early in the season and the conserved water banked by the lessee for use later in the year. This strategy rests on two assumptions: (1) the capacity to predict climate (and it's associated implications for water supply) are accurate enough to inform water users whether or not they will need to augment their supply in the coming year, and (2) if climate science suggests a dry year, the severity of the drought and the timing of its impacts on water supply sources can be predicted well enough to anticipate the volume of additional water that will be needed.

5.6 FURTHER CONSIDERATIONS

In assessing the value of water in crop production, there are a few additional factors that should be considered. The first is the effect of land fallowing on federal price support payments. In particular, the value of foregone crop production would change depending on whether or not counter-cyclical payments, which are tied to the market price of cotton, and direct payments are made in the event of temporary land fallowing. According to County Executive Director of the Yuma and La Paz Counties Arizona Farm Services Agency, these decoupled federal payments would not be affected by a farmer's decision to temporarily fallow land (Reinsrtson 2006). The farmer would, however, still be responsible for managing noxious weeds.

Another consideration is crop insurance. According to University of Arizona Extension Economist Russell Tronstad, farmers who temporarily fallow their land to lease out their water do not receive crop insurance for that year (Tronstad 2006). The loss of crop insurance payments is not factored into NROVC calculations here but may come into play in a farmer's decision to lease out water.

A final consideration is the role of fixed costs of production. Growers may negotiate to include some fixed costs of production in payments received to fallow land. One possible rationale is to maintain the economic vitality of their overall farmer operation which cannot survive indefinitely if only variable costs of production are covered.

5.7 CAUTIONS IN APPLYING RESULTS

Many factors that influence the cost of production as well as yields and gross returns can vary widely within a county. For instance, crop yields can be different for different soil types, and soil type is not homogenous throughout Yuma and La Paz counties. Also, the type of irrigation system a farmer uses impacts the per acre application rate of water. Additionally, the production operations, chemicals applied and their application rates, etc., can all vary from farm to farm within the same county. Finally, farm budget analysis is particularly sensitive to input and output prices. Wherever possible, input and output prices used in this research were updated to reflect the most recent information available, but many of these prices fluctuate regularly. Thus, the results presented in this chapter should be treated as *estimates* generalized to the county in which the analysis is located. Nevertheless, estimates of NROVC are straightforward calculations and, following the basic procedure applied here, could easily be modified to fit the farming operations and market conditions faced by a specific farm.

CHAPTER 6

6.1 CONCLUSION

The vast majority of consumptive water user in the Lower Colorado River Basin is dedicated to irrigated agriculture. This can be a sub-optimal use of water under drought conditions that threaten water supplies for other sectors. Western water rights are governed by prior appropriation, or a "first-in-time, first-in-right" system. As such, many irrigators in the Lower Basin hold senior water rights while municipalities or newer uses have junior priority status. In the event of shortage, this means irrigators with senior water rights will receive their full allocation, while junior rights holders may be shorted.

6.1.1 Significant Findings

Water leases are particularly conducive to minimizing drought-induced water supply variability. This research contributes to the understanding of lease water markets as a reallocation mechanism in two ways. First, statistical analysis of lease water transactions across the western United States provides insight into the determinants of the price of leased water. This information is useful in providing water users and managers with a clear concept of the determinants of the price of water under different circumstances.

Economic theory suggests that when water is in short supply, the price will go up to reflect its scarcity value. Results of this analysis conclude in essentially every model evaluated that the price of leased water has an inverse relationship with water supply conditions. That is, when water supply is less abundant due to drought, its price per acre-foot rises.

Perhaps of more interest is what the results suggest about *what* drought conditions price is reacting to. Particularly in the southwestern U.S., results of this analysis show the SPI better reflects the effect of climate/drought on the price of water than the MEI. While the MEI would be indicative of the large-scale climate/water supply situation in a region, the SPI is specific to intra-state climate divisions, thus allowing for very location-specific analysis of the impact of drought on the price of leased water. The MEI is not significant in a majority of the models examined here, and when it is, the sign tends to be counterintuitive. The significance and expected sign of the coefficient on the SPI variable in essentially all models may suggest that the price of leased water is driven more by local hydrologic conditions than the overall regional climate.

In most state and regional models, the "new use" of the water is also found to be significant. In general, water leased for agriculture is predicted to be less expensive than water leased for municipal or environmental purposes, which is expected based on differential use values. In Colorado, however, the "new use" binary variables are insignificant, possibly reflecting the relatively mature state of the water market there and that use values are beginning to converge.

In addition to empirical analysis of water leases, this research also identifies dry-year options agreements as a particularly promising mechanism to enhance dry-year supply reliability in the Lower Basin. These temporary, drought-triggered transfers out of agriculture for municipal or environmental use are especially appropriate to facilitate reallocation in the Lower Basin given the region's vast irrigated agricultural base coupled with burgeoning populations, urban development, the tendency to experience drought, and the associated pressure on water supply.

A critical component of structuring and negotiating dry-year option contracts is determining the appropriate exercise payment, which is the compensation a farmer receives if the option is exercised and farmland is fallowed. This research uses the residual or farm budget approach to determine net returns over variable costs for alfalfa, upland cotton, and durum wheat production in Yuma and La Paz counties in western Arizona. This calculation can be used as a baseline in negotiating exercise payments.

The results indicate that, based on five year average crop yields and prices, the minimum alfalfa farmers in Yuma County would need to be compensated to be just as well off had they irrigated is $363.33/acre (or $62.62/AF of water). NROVC for wheat and cotton are both negative in Yuma, suggesting that any positive exercise payment for land fallowing would leave farmers financially better off than they would have been producing crops. In La Paz County, NROVC estimates suggest an exercise payment of at least $390.74/acre ($67.37/AF of water) for alfalfa, $99.53/acre ($28.44/AF of water) for durum wheat, and again simply a positive exercise payment for upland cotton. NROVC for head lettuce, the only vegetable included in this analysis, are significantly higher than any of the field crops. NROVC for head lettuces are estimated at $5,130.72/acre or $1,425.20/AF.

Results from the farm budget analysis also highlight the importance of timing in accurately establishing a baseline for exercise payment negotiations. If irrigators are asked to fallow their land before field crop production begins, compensation to the level that would leave them just as well off had they irrigated is much less costly than asking them to cease irrigation later in the season when some variable costs of production have already be incurred. Foregone crop revenue is also substantially higher if temporary land fallowing interrupts vegetable production, so creativity and care are necessary in negotiating options agreements so that each party benefits from the arrangement in the most cost effective way possible.

6.1.2 Further Research

This research could be extended in a number of interesting directions. In terms of the econometric analysis of lease markets, it would be interesting to further analyze the "type of transfer" (i.e. ag to ag, ag to municipal, etc.) on the price of leased water and statistically test whether the use value of leased water is converging over time in the more developed markets across the West. If data could be obtained, it would also be interesting to analyze whether the priority status of a water right influences the price of water, particularly during drought.

Because seasonal differences in alfalfa yield were not available prior to the completion of this research, the implications of fallowing land in alfalfa at different times of year are not calculated. However, given sufficient information about how the price and yield of alfalfa varies throughout the year, it would be simple and useful to calculate how the exercise payment might change depending on when alfalfa land was temporarily taken out of production.

6.1.3 Concluding Remarks

The precarious balance of water supply and demand in the Lower Colorado River Basin leaves water users particularly susceptible to drought-induced supply variability. The economic, environmental, and social costs associated with variable supply are diverse and can be far reaching. Particularly in dry years, temporary water transfers are a viable mechanism to enhance supply reliability and help mitigate the negative effects of drought.

Dry-year transfers have the advantage of providing flexibility for both water suppliers and demanders. Suppliers can choose to use their water for its original purpose during years when the demand for water (and likewise the price) is low and similarly take advantage of higher prices by leasing out their water in dry years. Dry-year transfers also provide demanders the flexibility to lease water only when supply augmentation is necessary. Instead of incurring the costs of purchasing permanent water rights that will not be used in most years, an active, reliable market allows for year to year decisions about leasing additional water. Further, by maintaining the ownership of the water right with the original user, third-party impacts and transaction costs can be minimized.

In many states and regions in the West, the physical infrastructure, political climate, and appropriate water laws and regulations are already in place to facilitate the development of water markets. If fully embraced, temporary water transfers could significantly reduce drought costs and impacts in the Lower Colorado River Basin, averting potentially devastating crises.

APPENDIX 1

A.1 INSTRUMENTAL VARIABLES, STATS, AND RESULTS

A.1.1 California

DESCRIPT ION OF VARIABLES
CALIFORNIA QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
trend	The real three month average price of alfalfa at the state level.
adj_alfalfa	Natural log of real, annual personal income at the state level.
Indust_OrigUse	Binary variable equal to one if the water was originally used for industrial purposes.
munic_OrigUse	Binary variable equal to one if the water was originally used for municipal purposes.
storage_OrigUse	Binary variable equal to one if the water was originally in storage.
reclaim_OrigUse	Binary variable equal to one if the water was originally reclaimed water.
lnincome	Natural log of annual personal income at the state level.
MEI12L6	12-month MEI lagged six months.
SPI24orig	24-month SPI in the climate region of origin.
BasinDummy	Binary variable equal to one if the transfer was intra-basin.
years_lease	Number of years of the life of the lease.
effluent	Binary variable indicating if the type of water transferred was effluent.
grnd_water	Binary variable indicating if the type of water transferred was groundwater.
north	Binary variable indicating if the transfer originated in northern California.
droughtbank	Binary variable indicating if the transfer occurred in a droughtbank year.
trans_per_year	Number of lease transactions that occurred in each year.
lnpopulation	The natural log of annual state population.

SUMMARY STATISTICS
CALIFORNIA QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnaf	9.22	1.73	2.99	3.71	13.12
trend	12.34	5.19	26.91	2.00	19.00
adj_alfalfa	128.21	20.37	414.90	92.97	172.17
Indust_OrigUse	0.04	0.19	0.04	0.00	1.00
munic_OrigUse	0.22	0.41	0.17	0.00	1.00
storage_OrigUse	0.31	0.46	0.22	0.00	1.00
reclaim_OrigUse	0.02	0.15	0.02	0.00	1.00
lnincome	20.85	0.13	0.02	20.60	21.01
MEI12L6	0.40	0.72	0.52	-1.10	2.49
SPI24orig	-0.16	0.90	0.81	-2.08	2.23
BasinDummy	0.75	0.43	0.19	0.00	1.00
years_lease	2.79	6.21	38.54	0.00	40.00
effluent	0.12	0.33	0.11	0.00	1.00
grnd_water	0.18	0.38	0.15	0.00	1.00
north	0.11	0.32	0.10	0.00	1.00
droughtbank	0.20	0.40	0.16	0.00	1.00
trans_per_year	13.74	5.71	32.61	1.00	27.00
lnpopulation	17.32	0.07	0.00	17.14	17.40

REGRESSION RESULTS
CALIFORNIA QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	-996.618	402.840	-2.47	0.0142
trend	-0.673	0.320	-2.1	0.0369
adj_alfalfa	0.003	0.008	0.47	0.642
Indust_OrigUse	0.224	0.619	0.36	0.718
munic_OrigUse	-0.209	0.311	-0.67	0.5028
storage_OrigUse	0.410	0.265	1.55	0.123
reclaim_OrigUse	1.193	0.821	1.45	0.1481
lnincome	-8.831	4.368	-2.02	0.0446
MEI12L6	-0.040	0.180	-0.22	0.8244
SPI24orig	-0.096	0.161	-0.59	0.5536
BasinDummy	-0.942	0.267	-3.52	0.0005
years_lease	0.018	0.018	0.99	0.3239
effluent	-1.752	0.377	-4.65	<.0001
grnd_water	-0.206	0.342	-0.6	0.548
north	-0.216	0.371	-0.58	0.5616
droughtbank	-1.219	0.532	-2.29	0.0231
trans_per_year	-0.005	0.026	-0.19	0.8457
lnpopulation	69.224	22.983	3.01	0.0029
Observations	212			
R^2	0.26			

*Dependent variable is natural log of AF

A.1.2 Colorado

DESCRIPTION OF VARIABLES
COLORADO QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
adj_alfalfa	The real three month average price of alfalfa at the state level.
lnIncome	Natural log of real, annual personal income at the state level.
trans_per_year	Number of lease transactions that occurred in each year.
MEI12L6	12-month MEI lagged six months.
SPI12L6	12-month SPI lagged six months for climate region.
ag_OrigUse	Binary variable equal to one if the water was originally used for agriculture.
storage_OrigUse	Binary variable equal to one if the water was originally in storage.
reclaim_OrigUse	Binary variable equal to one if the water was originally reclaimed water.
other_origuse	Binary variable equal to one if the water was originally used for some other purpose.
years_lease	Number of years of the life of the lease.
jan - nov	Binary variables indicating which month the transaction was reported.

SUMMARY STATISTICS
COLORADO QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
Lnaf	6.40	2.36	5.57	0.69	10.13
adj_alfalfa	105.76	16.79	281.88	74.46	138.06
lnIncome	18.80	0.21	0.04	18.34	18.99
trans_per_year	6.69	4.08	16.63	1.00	13.00
MEI12L6	0.46	0.59	0.34	-0.74	1.42
SPI12L6	-0.14	1.10	1.20	-2.54	2.51
ag_OrigUse	0.17	0.38	0.14	0.00	1.00
storage_OrigUse	0.61	0.49	0.24	0.00	1.00
reclaim_OrigUse	0.09	0.29	0.09	0.00	1.00
other_origuse	0.02	0.13	0.02	0.00	1.00
years_lease	7.55	13.21	174.51	1.00	40.00
Jan	0.09	0.29	0.09	0.00	1.00
Mar	0.16	0.37	0.13	0.00	1.00
May	0.13	0.33	0.11	0.00	1.00
Jun	0.11	0.31	0.10	0.00	1.00
Jul	0.03	0.18	0.03	0.00	1.00
Sep	0.25	0.44	0.19	0.00	1.00
Oct	0.08	0.27	0.07	0.00	1.00
Nov	0.02	0.13	0.02	0.00	1.00

REGRESSION RESULTS
COLORADO QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	-42.133	45.794	-0.92	0.3625
adj_alfalfa	0.009	0.023	0.41	0.6857
lnincome	2.569	2.409	1.07	0.292
trans_per_year	-0.102	0.129	-0.79	0.4345
MEI12L6	0.481	0.730	0.66	0.513
SPI12L6	0.554	0.347	1.6	0.1167
ag_OrigUse	-0.972	1.029	-0.94	0.3503
storage_OrigUse	0.930	1.059	0.88	0.3846
reclaim_OrigUse	1.515	1.243	1.22	0.229
other_origuse	1.330	2.513	0.53	0.5993
years_lease	-0.064	0.032	-2	0.0512
jan	1.000	1.552	0.64	0.5226
mar	-0.355	1.218	-0.29	0.7719
may	0.457	1.376	0.33	0.7415
jun	-0.350	1.359	-0.26	0.7981
jul	-0.943	1.630	-0.58	0.5657
sep	-0.996	1.067	-0.93	0.3558
oct	-0.570	1.385	-0.41	0.6827
nov	-1.549	2.471	-0.63	0.5338
Observations	64			
R^2	0.48			

*Dependent variable is natural log of AF

A.1.3 New Mexico

DESCRIPTION OF VARIABLES
NEW MEXICO QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
adj_alfalfa	The real three month average price of alfalfa at the state level.
lnincome	Natural log of real, annual personal income at the state level.
trans_per_year	Number of lease transactions that occurred in each year.
MEI12L6	12-month MEI lagged six months.
SPI12L6	12-month SPI lagged six months for climate region.
munic_OrigUse	Binary variable equal to one if the water was originally used for municipal purposes.
storage_OrigUse	Binary variable equal to one if the water was originally in storage.
reclaim_OrigUse	Binary variable equal to one if the water was originally reclaimed water.
years_lease	Number of years of the life of the lease.
jan-nov	Binary variables indicating which month the transaction was reported.

SUMMARY STATISTICS
NEW MEXICO QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnaf	7.50	2.04	4.17	3.89	11.51
adj_alfalfa	149.70	16.78	281.46	122.00	201.57
lnincome	17.45	0.55	0.30	14.99	17.79
trans_per_year	4.49	2.46	6.04	1.00	9.00
MEI12L6	0.23	0.74	0.55	-1.10	1.63
SPI12L6	0.18	0.73	0.53	-1.08	1.98
munic_OrigUse	0.04	0.20	0.04	0.00	1.00
storage_OrigUse	0.51	0.51	0.26	0.00	1.00
reclaim_OrigUse	0.15	0.36	0.13	0.00	1.00
years_lease	4.04	5.61	31.43	1.00	20.00
jan	0.23	0.43	0.18	0.00	1.00
feb	0.09	0.28	0.08	0.00	1.00
mar	0.06	0.25	0.06	0.00	1.00
jun	0.11	0.31	0.10	0.00	1.00
sep	0.06	0.25	0.06	0.00	1.00
oct	0.13	0.34	0.11	0.00	1.00
nov	0.21	0.41	0.17	0.00	1.00

REGRESSION RESULTS
NEW MEXICO QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	8.964	11.932	0.75	0.4584
adj_alfalfa	-0.095	0.026	-3.64	0.001
lnincome	0.751	0.671	1.12	0.2724
trans_per_year	0.049	0.192	0.25	0.8014
MEI12L6	-0.798	0.556	-1.44	0.1613
SPI12L6	-0.623	0.592	-1.05	0.3007
munic_OrigUse	0.403	1.509	0.27	0.7914
storage_OrigUse	1.416	1.026	1.38	0.1778
reclaim_OrigUse	-2.664	1.761	-1.51	0.1409
years_lease	-0.089	0.068	-1.31	0.1998
jan	-0.308	1.163	-0.26	0.793
feb	0.254	1.383	0.18	0.8555
mar	-0.081	1.566	-0.05	0.9589
jun	0.171	1.321	0.13	0.898
sep	0.830	1.436	0.58	0.5676
oct	-1.069	1.274	-0.84	0.4081
nov	-0.947	1.474	-0.64	0.5256
Observations	4			
R^2	0.51			

*Dependent variable is natural log of AF

A.1.4 Texas

DESCRIPTION OF VARIABLES
TEXAS QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
trend	Time trend equal to one if year = 1987, two if year = 1988, etc.
adj_alfalfa	The real three month average price of alfalfa at the state level.
lnincome	Natural log of real, annual personal income at the state level.
trans_per_year	Number of lease transactions that occurred in each year.
MEI12L6	12-month MEI lagged six months.
SPI24L6	24-month SPI lagged six months for climate region.
munic_OrigUse	Binary variable equal to one if the water was originally used for municipal purposes.
storage_OrigUse	Binary variable equal to one if the water was originally in storage.
other_OrigUse	Binary variable equal to one if the water was originally used for some other purpose.
feb-dec	Binary variables indicating which month the transaction was reported.
RioGrande	Binary variable equal to one if the transaction invovled the Rio Grande basin.
SanAntEdwards	Binary variable equal to one if the transaction invovled the San Antonio/Edwards Aquifer region.

SUMMARY STATISTICS
TEXAS QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnaf	7.14	2.35	5.51	0.69	12.69
trend	13.27	3.92	15.35	3.00	19.00
adj_alfalfa	156.99	18.74	351.09	120.00	185.55
lnincome	20.24	0.15	0.02	19.86	20.42
trans_per_year	12.39	5.34	28.53	1.00	20.00
MEI12L6	0.40	0.80	0.63	-0.85	2.21
SPI24L6	0.23	0.99	0.98	-1.39	1.94
munic_OrigUse	0.12	0.33	0.11	0.00	1.00
storage_OrigUse	0.06	0.24	0.06	0.00	1.00
other_OrigUse	0.24	0.43	0.19	0.00	1.00
feb	0.09	0.29	0.08	0.00	1.00
mar	0.10	0.30	0.09	0.00	1.00
may	0.02	0.15	0.02	0.00	1.00
jun	0.11	0.31	0.10	0.00	1.00
jul	0.11	0.31	0.10	0.00	1.00
aug	0.05	0.23	0.05	0.00	1.00
sep	0.08	0.27	0.07	0.00	1.00
oct	0.09	0.29	0.08	0.00	1.00
nov	0.05	0.23	0.05	0.00	1.00
dec	0.15	0.35	0.12	0.00	1.00
RioGrande	0.78	0.42	0.17	0.00	1.00
SanAntEdwards	0.16	0.37	0.14	0.00	1.00

REGRESSION RESULTS
TEXAS QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	-313.336	208.589	-1.5	0.1359
trend	-0.579	0.366	-1.58	0.1169
adj_alfalfa	-0.024	0.017	-1.37	0.1725
lnincome	16.501	10.575	1.56	0.1216
trans_per_year	-0.008	0.060	-0.13	0.8949
MEI12L6	-0.106	0.450	-0.24	0.8138
SPI24L6	-0.187	0.330	-0.57	0.5722
munic_OrigUse	0.278	1.207	0.23	0.8186
storage_OrigUse	1.566	1.321	1.19	0.2382
other_origuse	-1.479	1.130	-1.31	0.1931
feb	0.012	0.942	0.01	0.9895
mar	1.376	0.899	1.53	0.1286
may	-0.229	1.512	-0.15	0.8797
jun	0.781	0.987	0.79	0.4304
jul	0.423	0.837	0.5	0.6147
aug	1.551	1.235	1.26	0.2119
sep	-0.058	1.076	-0.05	0.957
oct	-0.087	0.914	-0.09	0.9245
nov	0.743	1.092	0.68	0.4979
dec	1.614	0.908	1.78	0.0782
RioGrande	-2.607	1.142	-2.28	0.0244
SanAntEdwards	-2.241	1.170	-1.91	0.0582
Observations	131			
R^2	0.18			

*Dependent variable is natural log of AF

A.1.5 Southwest

DESCRIPT ION OF VARIABLES
SOUTHWEST QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
adj_alfalfa	The real three month average price of alfalfa at the state level.
lnincome	Natural log of real, annual personal income at the state level.
trans_per_year	Number of lease transactions that occurred in each year.
SPI24L6	24-month MEI lagged six months.
MEI6	6-month MEI.
ag_sup	Binary variable equal to one if the water was supplied by agriculture.
city_sup	Binary variable equal to one if the water was supplied by a city.
state_sup	Binary variable equal to one if the water was supplied by a state.
county_sup	Binary variable equal to one if the water was supplied by a county.
fed_sup	Binary variable equal to one if the water was supplied by the fed.
private_sup	Binary variable equal to one if the water was supplied by a private individual/group.
watdist_sup	Binary variable equal to one if the water was supplied by a water district.
jan - dec	Binary variables indicating which month the transaction was reported.
arizona	Binary variable equal to one if the transaction took place in Arizona.
new_mexico	Binary variable equal to one if the transaction took place in New Mexico.
nevada	Binary variable equal to one if the transaction took place in Nevada.
utah	Binary variable equal to one if the transaction took place in Utah.

SUMMARY STATISTICS
SOUTHWEST QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnaf	7.77	2.57	6.62	0.69	12.90
adj_alfalfa	122.19	27.55	759.15	71.82	201.57
lnincome	18.24	0.68	0.46	14.99	18.99
trans_per_year	5.27	3.47	12.07	1.00	13.00
SPI24L6	0.16	1.16	1.35	-2.49	2.54
MEI6	0.62	1.01	1.01	-1.36	2.52
ag_sup	0.11	0.32	0.10	0.00	1.00
city_sup	0.34	0.47	0.22	0.00	1.00
state_sup	0.04	0.21	0.04	0.00	1.00
county_sup	0.03	0.17	0.03	0.00	1.00
fed_sup	0.12	0.32	0.10	0.00	1.00
private_sup	0.04	0.19	0.04	0.00	1.00
watdist_sup	0.30	0.46	0.21	0.00	1.00
jan	0.13	0.34	0.11	0.00	1.00
mar	0.10	0.29	0.09	0.00	1.00
may	0.07	0.26	0.07	0.00	1.00
jun	0.08	0.28	0.08	0.00	1.00
jul	0.03	0.18	0.03	0.00	1.00
sep	0.16	0.37	0.13	0.00	1.00
oct	0.10	0.29	0.09	0.00	1.00
nov	0.07	0.25	0.06	0.00	1.00
dec	0.05	0.22	0.05	0.00	1.00
arizona	0.26	0.44	0.20	0.00	1.00
new_mexico	0.26	0.44	0.20	0.00	1.00
nevada	0.02	0.13	0.02	0.00	1.00
utah	0.10	0.29	0.09	0.00	1.00

REGRESSION RESULTS
SOUTHWEST QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	0.101	8.968	0.01	0.991
adj_alfalfa	0.003	0.009	0.32	0.7459
lnincome	0.453	0.463	0.98	0.3295
trans_per_year	-0.053	0.060	-0.88	0.3796
SPI24L6	0.118	0.168	0.7	0.4829
MEI6	-0.814	0.202	-4.04	<.0001
ag_sup	-0.775	1.273	-0.61	0.5439
city_sup	0.012	1.211	0.01	0.9924
state_sup	0.127	1.385	0.09	0.9272
county_sup	-0.259	1.469	-0.18	0.8604
fed_sup	-1.659	1.346	-1.23	0.2198
private_sup	-1.269	1.381	-0.92	0.3597
watdist_sup	1.048	1.285	0.82	0.4162
jan	0.027	0.614	0.04	0.9644
mar	-1.221	0.645	-1.89	0.0604
may	-0.489	0.720	-0.68	0.4975
jun	-0.775	0.691	-1.12	0.2644
jul	-2.085	0.926	-2.25	0.0258
sep	-1.286	0.610	-2.11	0.0368
oct	-1.529	0.688	-2.22	0.0278
nov	-1.762	0.755	-2.33	0.021
dec	-1.009	0.810	-1.25	0.2148
arizona	1.067	0.657	1.63	0.1062
new_mexico	0.992	0.847	1.17	0.2436
nevada	0.733	1.490	0.49	0.6236
utah	0.704	0.915	0.77	0.443
Observations	178			
R^2	0.50			

*Dependent variable is natural log of AF

A.1.6 West-wide

DESCRIPT ION OF VARIABLES
WEST QUANTITY MODEL

Name	Description
lnaf	Natural log of acre-feet.
adj_alfalfa	The real three month average price of alfalfa at the state level.
lnincome	Natural log of real, annual personal income at the state level.
SPI12L6	24-month MEI lagged six months.
Indust_OrigUse	Binary variable equal to one if the water was originally used in industry.
munic_OrigUse	Binary variable equal to one if the water was originally used by a city.
storage_OrigUse	Binary variable equal to one if the water was originally in storage.
reclaim_OrigUse	Binary variable equal to one if the water was originally reclaimed water.
other_origuse	Binary variable equal to one if the water had some other original use.
jan - dec	Indicates the month in which the transaction was reported.
lnpopulation	Natural log of the annual population for each state.
arizona	Binary variable equal to one if the transaction took place in Arizona.
california	Binary variable equal to one if the transaction took place in California.
idaho	Binary variable equal to one if the transaction took place in Idaho.
montana	Binary variable equal to one if the transaction took place in Montana.
nevada	Binary variable equal to one if the transaction took place in Nevada.
new_mexico	Binary variable equal to one if the transaction took place in New Mexico.
texas	Binary variable equal to one if the transaction took place in Texas.
utah	Binary variable equal to one if the transaction took place in Utah.
washington	Binary variable equal to one if the transaction took place in Washington.
wyoming	Binary variable equal to one if the transaction took place in Wyoming.

SUMMARY STATISTICS
WEST-WIDE QUANTITY MODEL

Variable Name	Mean	Std. Dev.	Variance	Min	Max
lnaf	8.02	2.41	5.80	0.43	13.12
adj_alfalfa	128.63	26.71	713.38	71.82	201.57
lnincome	19.40	1.41	2.00	14.99	21.01
SPI12L6	0.12	1.00	1.00	-3.44	2.79
Indust_OrigUse	0.02	0.12	0.01	0.00	1.00
munic_OrigUse	0.12	0.32	0.10	0.00	1.00
storage_OrigUse	0.39	0.49	0.24	0.00	1.00
reclaim_OrigUse	0.03	0.17	0.03	0.00	1.00
other_origuse	0.07	0.25	0.06	0.00	1.00
jan	0.10	0.30	0.09	0.00	1.00
mar	0.07	0.26	0.07	0.00	1.00
may	0.05	0.22	0.05	0.00	1.00
jun	0.11	0.31	0.09	0.00	1.00
jul	0.09	0.29	0.08	0.00	1.00
sep	0.12	0.32	0.10	0.00	1.00
oct	0.10	0.30	0.09	0.00	1.00
nov	0.07	0.26	0.07	0.00	1.00
dec	0.08	0.27	0.07	0.00	1.00
lnpopulation	15.98	1.31	1.72	13.08	17.40
arizona	0.07	0.26	0.07	0.00	1.00
california	0.32	0.47	0.22	0.00	1.00
idaho	0.05	0.22	0.05	0.00	1.00
montana	0.01	0.12	0.01	0.00	1.00
nevada	0.00	0.07	0.00	0.00	1.00
new_mexico	0.07	0.26	0.07	0.00	1.00
texas	0.20	0.40	0.16	0.00	1.00
utah	0.03	0.16	0.03	0.00	1.00
washington	0.04	0.20	0.04	0.00	1.00
wyoming	0.04	0.19	0.04	0.00	1.00

REGRESSION RESULTS
WEST-WIDE QUANTITY MODEL*

Variable Name	Parameter Estimate	Stand. Error	T-Stat	Pr > |t|
Intercept	48.722	15.723	3.1	0.002
adj_alfalfa	-0.010	0.005	-2.05	0.041
lnincome	1.245	0.518	2.4	0.0166
SPI12L6	0.042	0.085	0.5	0.6193
Indust_OrigUse	-0.280	0.693	-0.4	0.6869
munic_OrigUse	-0.488	0.286	-1.7	0.0889
storage_OrigUse	0.331	0.222	1.49	0.1368
reclaim_OrigUse	-0.227	0.531	-0.43	0.6686
other_origuse	-0.473	0.364	-1.3	0.1938
jan	-0.225	0.329	-0.68	0.494
mar	-0.347	0.364	-0.95	0.3411
may	0.014	0.409	0.03	0.9723
jun	-0.103	0.327	-0.32	0.7527
jul	-0.561	0.335	-1.67	0.0952
sep	-0.407	0.323	-1.26	0.2076
oct	-0.490	0.324	-1.51	0.1308
nov	-0.033	0.370	-0.09	0.9291
dec	0.213	0.351	0.61	0.5446
lnpopulation	-4.205	1.336	-3.15	0.0017
arizona	3.354	0.458	7.33	<.0001
california	8.915	2.319	3.85	0.0001
idaho	-1.102	1.209	-0.91	0.3623
montana	-4.099	1.728	-2.37	0.018
nevada	-2.389	1.720	-1.39	0.1653
new_mexico	-1.011	0.839	-1.21	0.2285
texas	5.819	1.904	3.06	0.0023
utah	-0.211	0.850	-0.25	0.8036
washington	0.945	0.641	1.47	0.1413
wyoming	-7.675	2.238	-3.43	0.0006
Observations	0.27			
R^2	660			

*Dependent variable is natural log of AF

MARGINAL IMPLICIT PRICES ACROSS STATE MODELS*							
	Trend	lnAF	SPI	MEI	ag_NewUse	muni_NewUse	enviro_NewUse
AZ	-$3.53		-$38.61	$53.42			
CA			-$11.72		-$54.39		-$40.76
CO		-$19.26	-$62.26				
ID		-$11.20	-$15.68				$297.37
NM	$3.04	$6.77	-$21.83	$20.90			-$45.88
OR	-$2.72		-$7.88	$10.00			$162.45
TX			-$15.30		-$28.81		

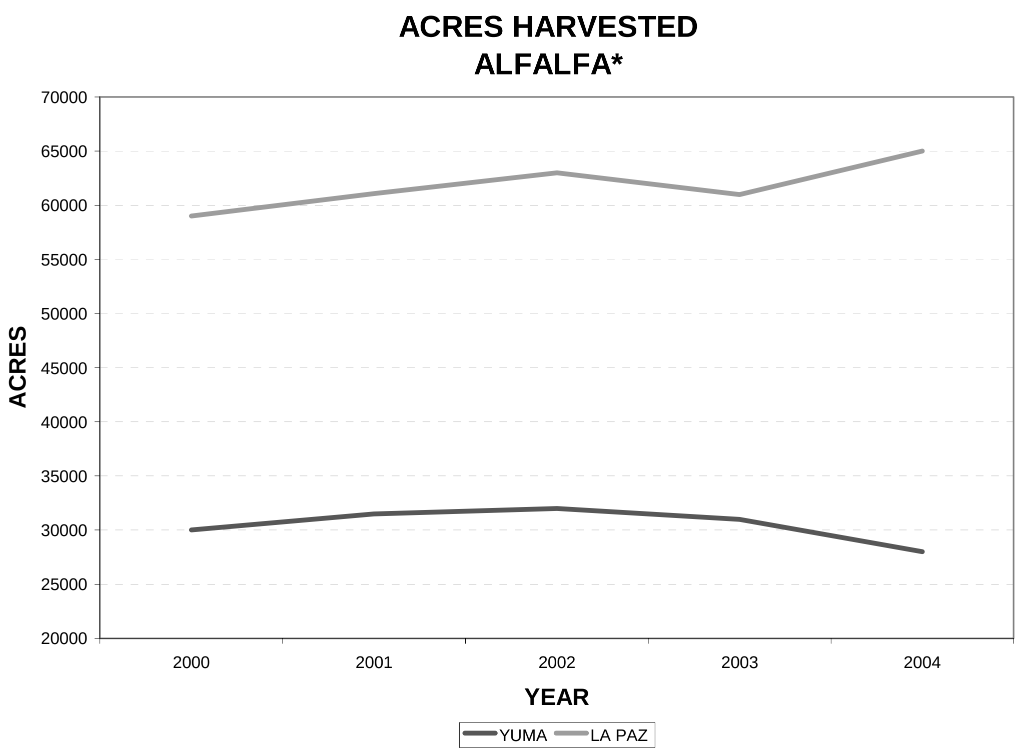
*Marginal implicit price is calculated for significant variables using elasticity values as reported in table 4.26 and applying these to the mean price. For non-binary variables, marginal implicit price indicates the dollar change in price per acre-foot of leased water due to a one percent change in the independent variable. For binary variables, the marginal implicit price indicates the difference in price when the binary variable takes on the value of zero and one.

APPENDIX 2

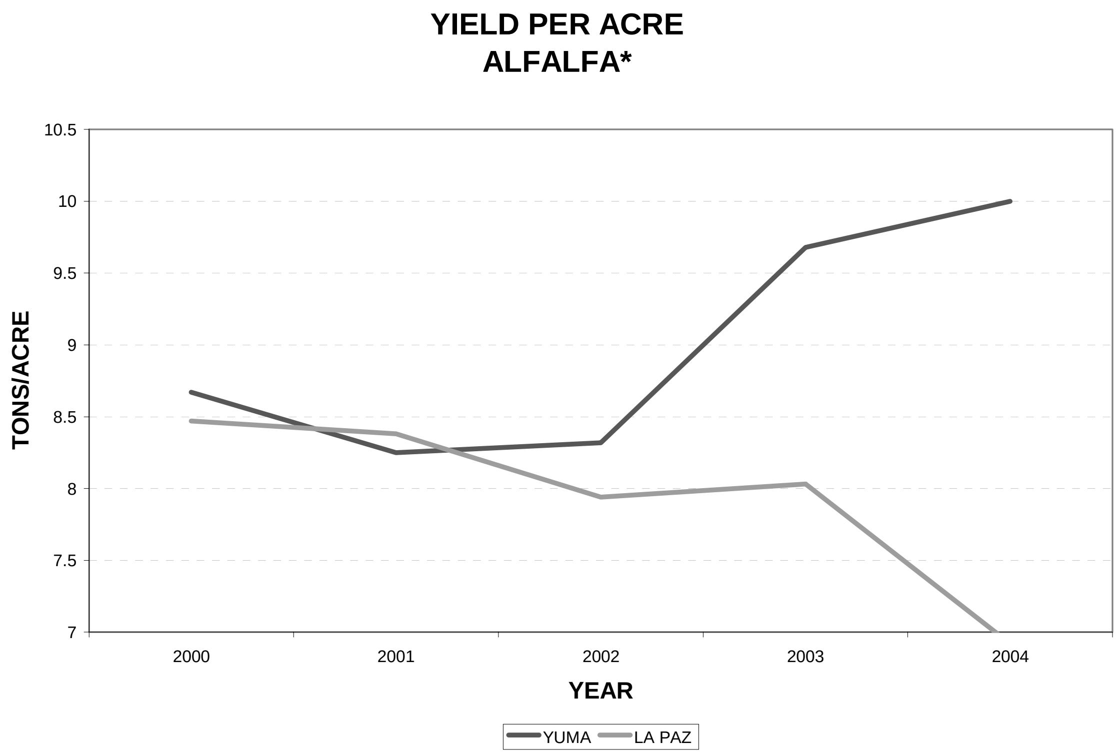
A.2 FARM BUDGET ANALYSIS

A.2.1 5-YEAR TRENDS

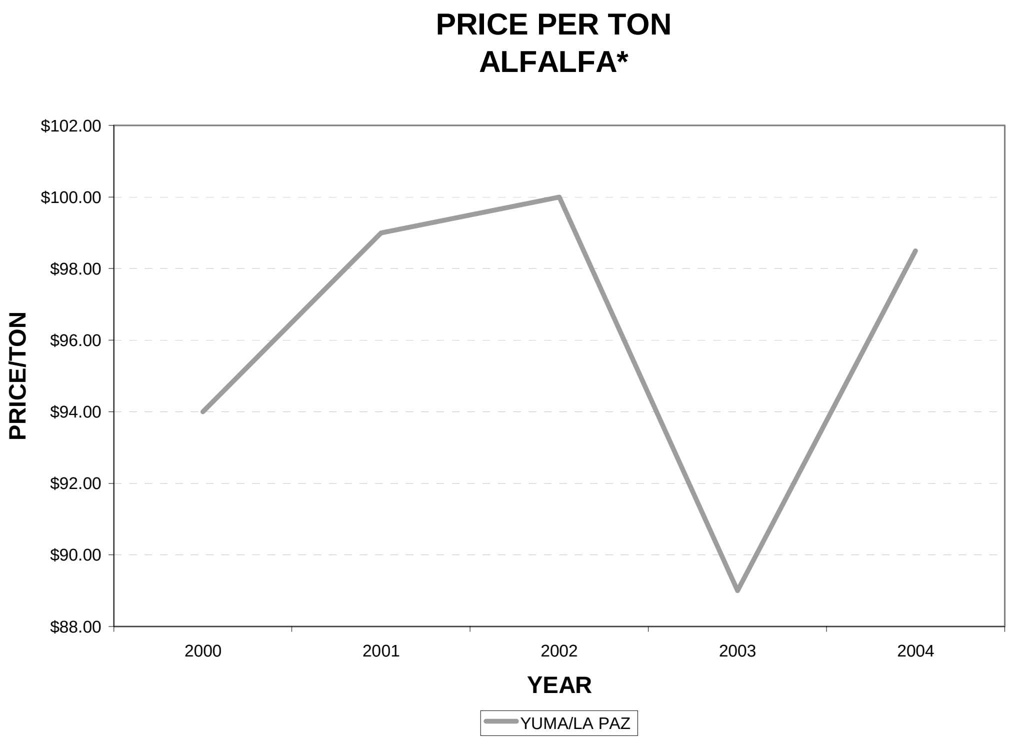
A.2.1.1 ALFALFA



*Note: Scale of y-axis does not begin at zero.

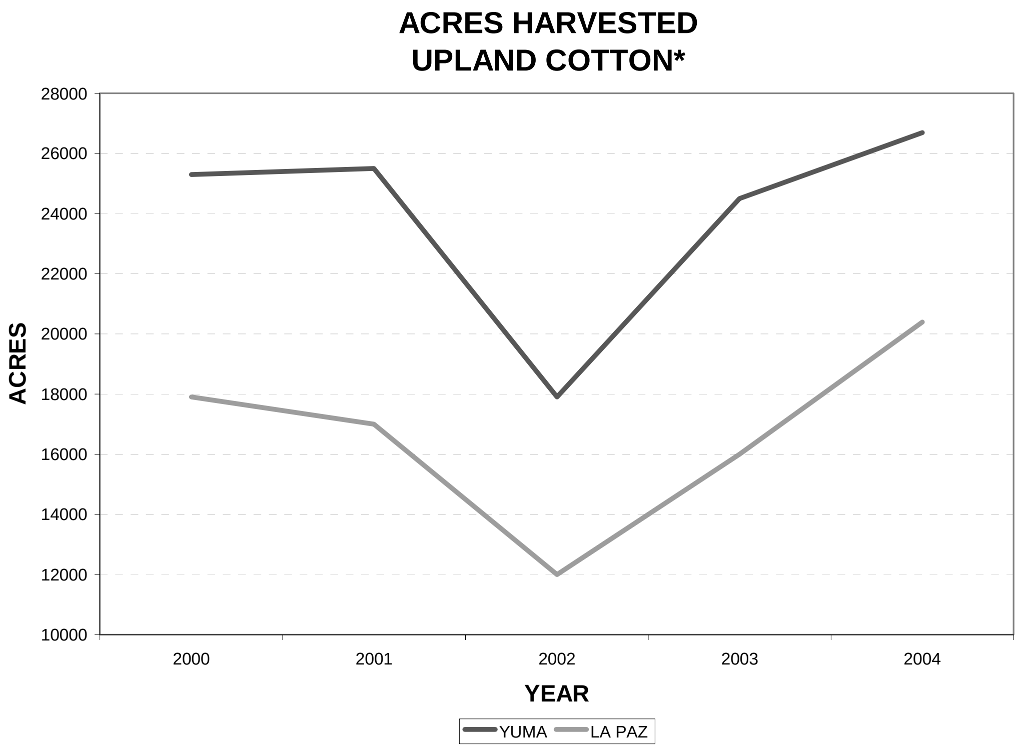


*Note: Scale of y-axis does not begin at zero.

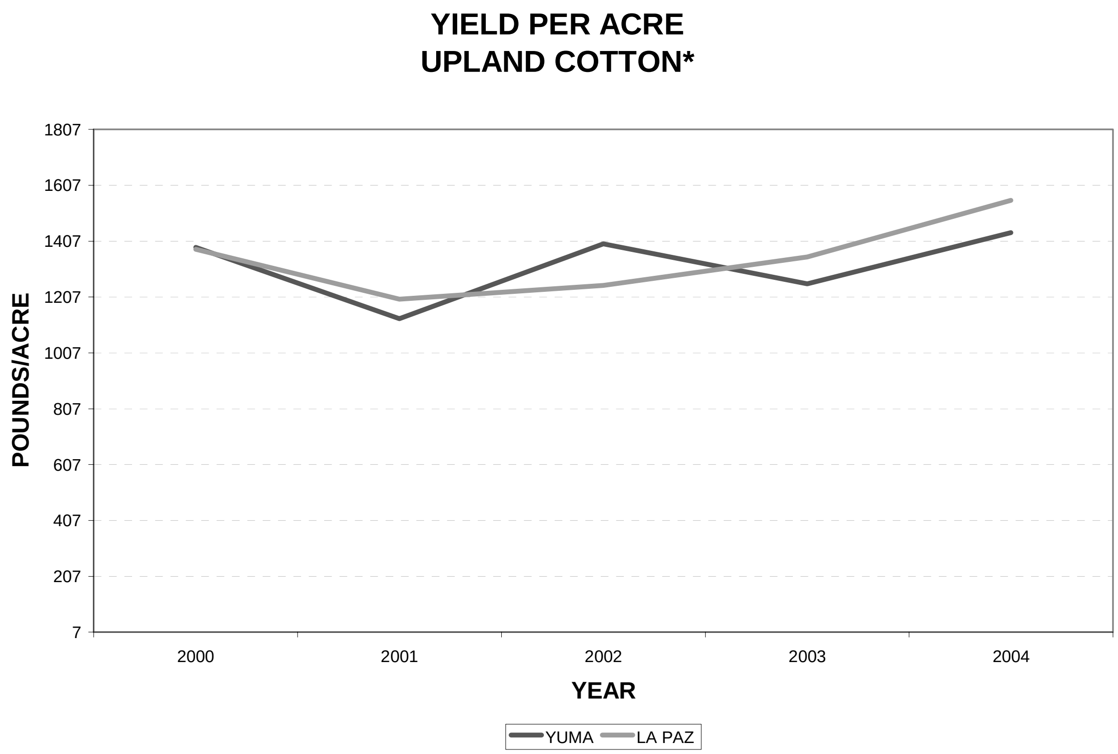


*Note: Scale of y-axis does not begin at zero.

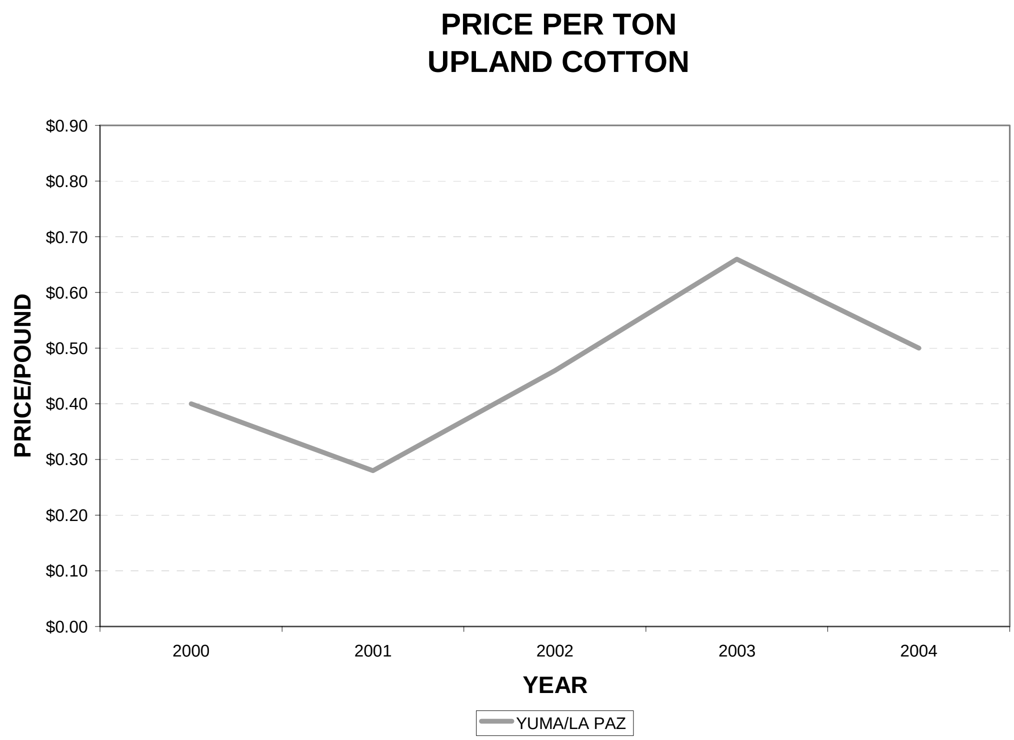
A.2.1.2 UPLAND COTTON



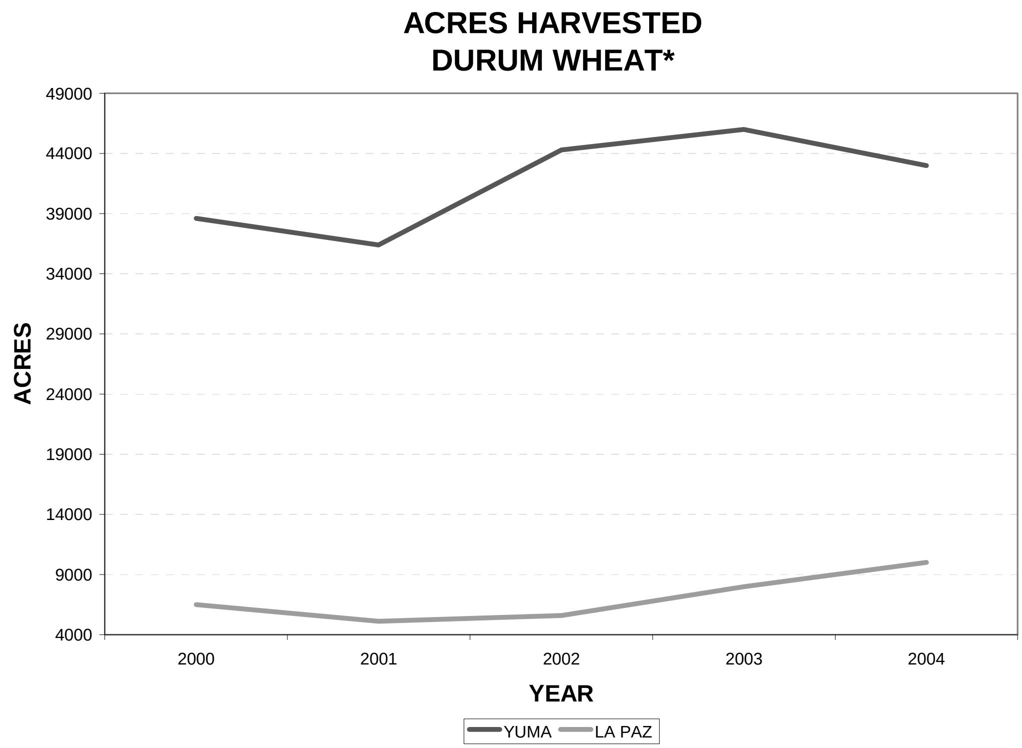
*Note: Scale of y-axis does not begin at zero.



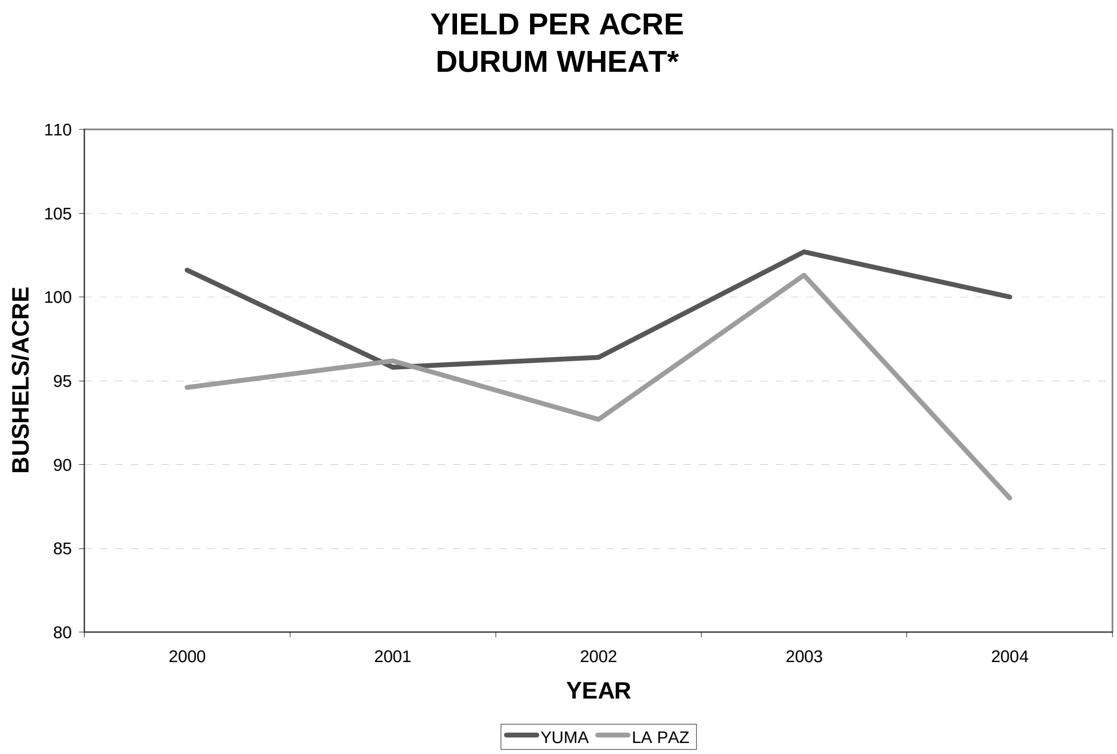
*Note: Scale of y-axis does not begin at zero.


PRICE PER TON
UPLAND COTTON
PRICE/POUND
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
2000
2001
2002
2003
2004
YEAR
YUMA/LA PAZ

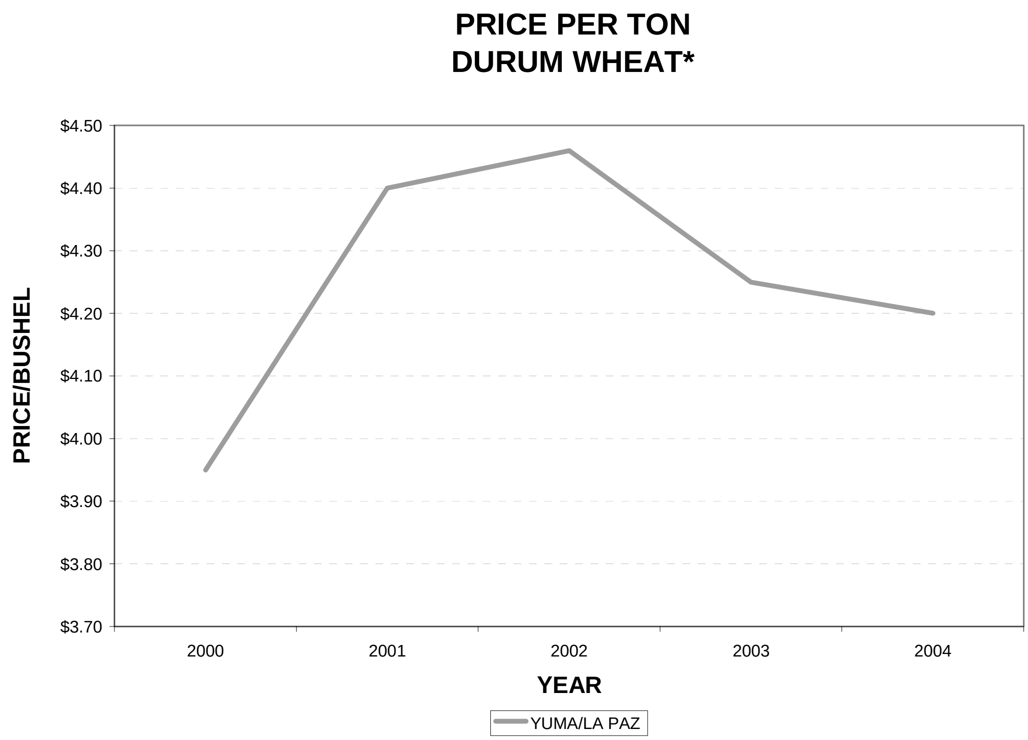
A.2.1.3 DURUM WHEAT



*Note: Scale of y-axis does not begin at zero.

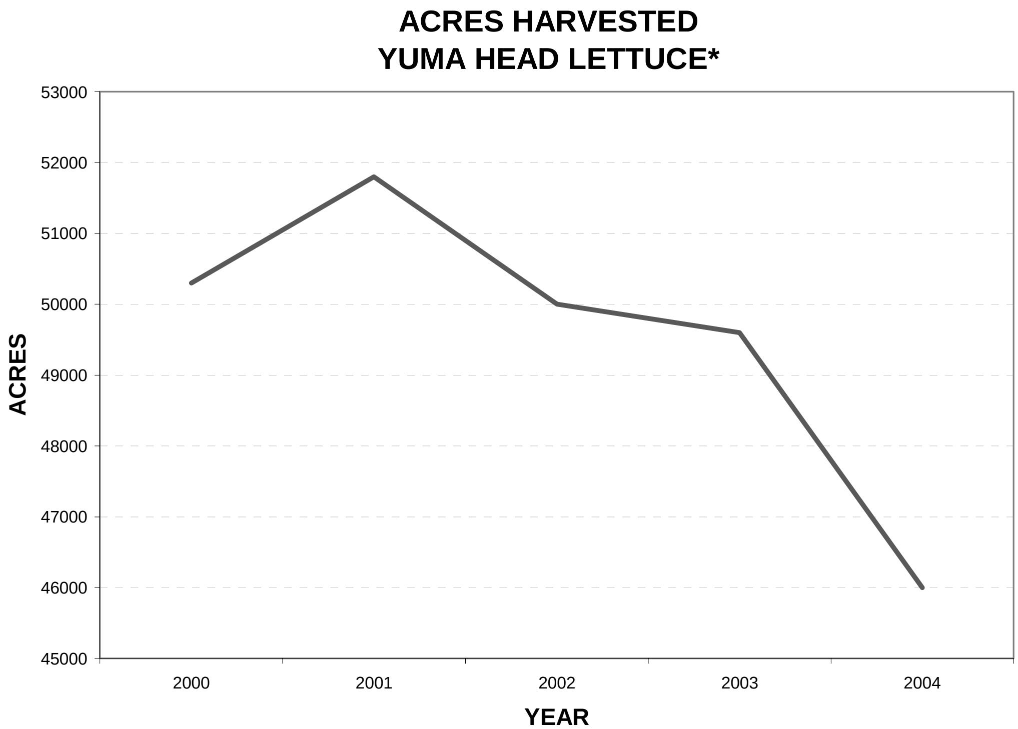


*Note: Scale of y-axis does not begin at zero.

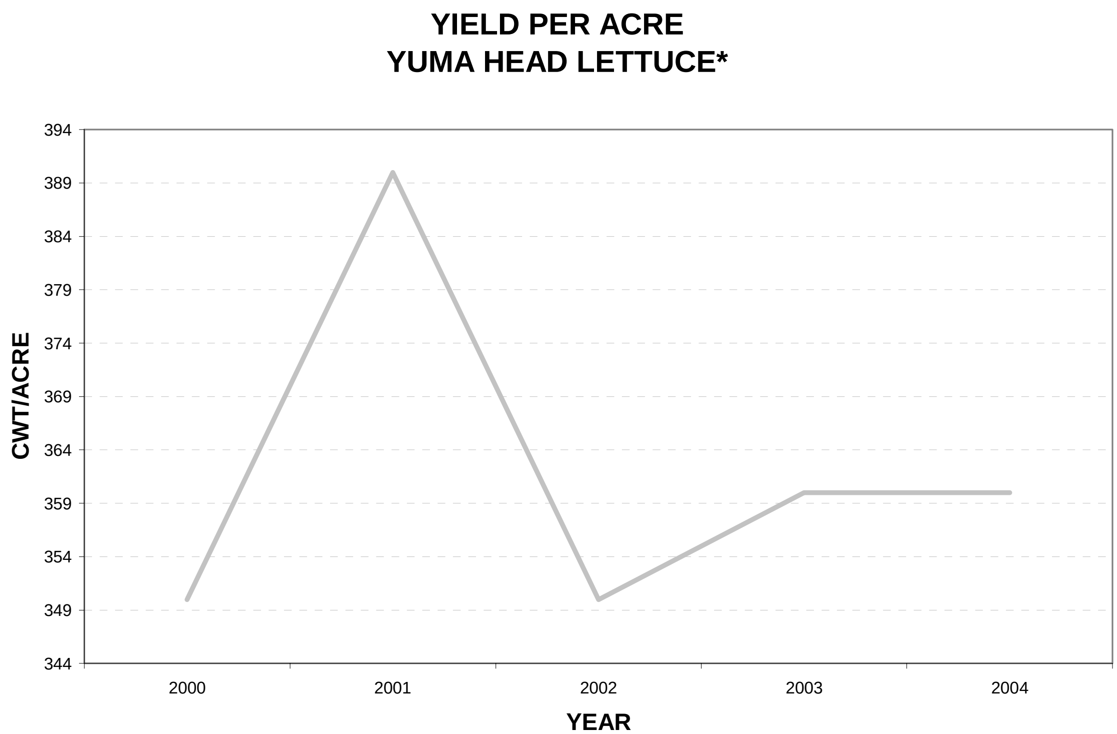


*Note: Scale of y-axis does not begin at zero.

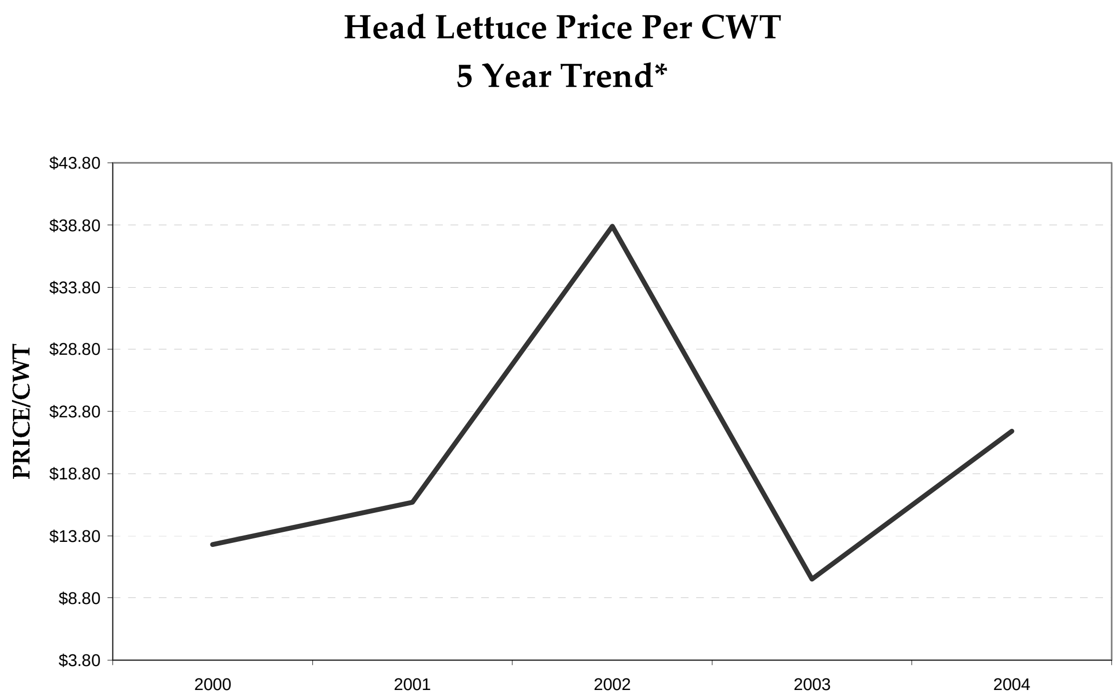
A.2.1.4 HEAD LETTUCE



*Note: Scale of y-axis does not begin at zero.



*Note: Scale of y-axis does not begin at zero.



*Note: Scale of y-axis does not begin at zero.

A.2.2 NROVC

Yuma Alfalfa Production	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre	10	9.044	10	8.25
Price/unit	98.5	96.2	100	98.5
LDP Rate	0	0	0	0
Price Plus LDP per unit	98.5	96.2	100	98.5
Gross Revenue ($/Acre)	985	870.0328	1000	812.625
Total Variable Costs per Acre	506.81	506.81	506.81	506.81
Net Returns Over Variable Costs Per Acre	478.19	363.2228	493.19	305.815
A/F of water applied per acre	5.8	5.8	5.8	5.8
Net Returns Over Variable Costs Per Acre-foot of water applied	82.45	62.62	85.03	52.73

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

Yuma Upland Cotton	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre (lint)	1438	1438	1438	1438
Price/unit (lint)	0.5	0.46	0.664	0.284
Yield/acre (seed)	1.69	1.69	1.69	1.69
Price/unit (seed)	140	140	140	140
LDP Rate	0.15	0.06	0.15	0
Price Plus LDP per unit	0.65	0.52	0.814	0.284
Gross Revenue ($/Acre)	1171.3	984.36	1407.132	644.992
Total Variable Costs per Acre	1194.37	1194.37	1194.37	1194.37
Net Returns Over Variable Costs Per Acre	-23.07	-210.01	212.762	-549.378
A/F of water applied per acre	4.2	4.2	4.2	4.2
Net Returns Over Variable Costs Per Acre-foot of water applied	-5.49	-50.00	50.66	-130.80

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

Yuma Durum Wheat	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre	100	99.3	102.7	95.8
Price/unit	4.25	4.15	4.65	3.5
LDP Rate	0	0	0	0
Price Plus LDP per unit	4.25	4.15	4.65	3.5
Gross Revenue ($/Acre)	425	412.095	477.555	335.3
Total Variable Costs per Acre	441.87	441.87	441.87	441.87
Net Returns Over Variable Costs Per Acre	-16.87	-29.775	35.685	-106.57
A/F of water applied per acre	3.5	3.5	3.5	3.5
Net Returns Over Variable Costs Per Acre-foot of water applied	-4.82	-8.51	10.20	-30.45

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

YUMA Head Lettuce	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	360	362	390	350
Price/unit	22.2	20.16	38.7	13.1
LDP Rate	0	0	0	0
Price Plus LDP per unit	22.2	20.16	38.7	13.1
Gross Revenue ($/Acre)	7992	7297.92	15093	4585
Total Variable Costs per Acre	2167.2	2167.2	2167.2	2167.2
Net Returns Over Variable Costs Per Acre	5824.8	5130.72	12925.8	2417.8
A/F water applied per acre	3.6	3.6	3.6	3.6
Net Returns Over Variable Costs Per Acre-foot of Water Applied	1618.00	1425.20	3590.50	671.61

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

LA PAZ Alfalfa Production	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	6.92	7.888	8.47	6.92
Price/unit	98.5	96.2	100	89.5
Sheep Grazing Head Days	200	200	200	200
Price/unit	0.09	0.09	0.09	0.09
LDP Rate	0	0	0	0
Price Plus LDP per unit	98.5	96.2	100	89.5
Gross Revenue ($/Acre)	699.62	776.8256	865	637.34
Total Variable Costs per Acre	386.09	386.09	386.09	386.09
Net Returns Over Variable Costs Per Acre	313.53	390.7356	478.91	251.25
A/F water applied per acre	5.8	5.8	5.8	5.8
Net Returns Over Variable Costs Per Acre-foot of Water Applied	54.06	67.37	82.57	43.32

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

LA PAZ Upland Cotton	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	1553	1345.8	1553	1200
Price/unit	0.5	0.46	0.664	0.284
Yield/acre (seed)	1.2	1.2	1.2	1.2
Price/unit (seed)	140	140	140	140
LDP Rate	0.15	0.06	0.15	0
Price Plus LDP per unit	0.65	0.52	0.814	0.284
Gross Revenue ($/Acre)	1177.45	867.816	1432.142	508.8
Total Variable Costs per Acre	1060.78	1060.78	1060.78	1060.78
Net Returns Over Variable Costs Per Acre	116.67	-192.964	371.362	-551.98
A/F water applied per acre	4.2	4.2	4.2	4.2
Net Returns Over Variable Costs Per Acre-foot of Water Applied	27.78	-45.94	88.42	-131.42

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

LA PAZ Durum Wheat	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	88	94.56	101.3	88
Price/unit	4.25	4.15	4.65	3.5
LDP Rate	0	0	0	0
Price Plus LDP per unit	4.25	4.15	4.65	3.5
Gross Revenue ($/Acre)	374	392.424	471.045	308
Total Variable Costs per Acre	292.89	292.89	292.89	292.89
Net Returns Over Variable Costs Per Acre	81.11	99.534	178.155	15.11
A/F water applied per acre	3.5	3.5	3.5	3.5
Net Returns Over Variable Costs Per Acre-foot of Water Applied	23.17	28.44	50.90	4.32

1 Avg AZ market price and crop yield in 2004
2 2000 – 2004 avg AZ market price and crop yield
3 Combined 2000 – 2004 high AZ market price and high crop yield
4 Combined 2000-2004 low AZ market price and low crop yield

A.3.3 Operations

County:		**Yuma**				
Crop:		**Alfalfa**				
Tot. Variable Cost:		**$541.11**				
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Variable Cost**	**Running Total (%)**
Jan	Irrigate	Growing	58.98	58.98	10.90	10.90
Jan	Swathing	Harvest	66.87	125.85	12.36	23.26
Jan	Raking	Harvest	27.90	153.75	5.16	28.41
Jan	Bailing	Harvest	141.48	295.23	26.15	54.56
Jan	Roadsiding	Harvest	81.76	376.99	15.11	69.67
Feb	Rerun Borders	Growing	10.68	387.67	1.97	71.64
Feb	Apply Herbicide/Ground	Growing	32.26	419.93	5.96	77.61
Mar	Apply Insecticide/Air	Growing	32.26	452.19	5.96	83.57
Sep	Irrigate/Run Fertilizer	Growing	22.93	475.12	4.24	87.80
Oct	Renovate	Growing	1.72	476.84	0.32	88.12
Oct	Plant	Land Prep	17.64	494.48	3.26	91.38
Misc.	Pickup Use		21.04	515.52	3.89	95.27
	Operating Interest		25.59	541.11	4.73	100.00
TOTAL			541.11	541.11	100.00	100.00

County:		Yuma				
Crop:		Upland Cotton				
Tot. Variable Cost:		$1,194.36				
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Variable Cost**	**Running Total (%)**
Dec	Rip	Land Prep	10.10	10.10	0.85	0.85
Dec	Disk	Land Prep	12.48	22.58	1.04	1.89
Jan	Laser Level	Land Prep	52.46	75.04	4.39	6.28
Jan	Roll Beds	Growing	2.38	77.42	0.20	6.48
Jan	List	Land Prep	6.97	84.39	0.58	7.07
Feb	Preirrigate	Growing	6.39	90.78	0.54	7.60
Mar	Mulch	Land Prep	5.52	96.30	0.46	8.06
Mar	Plant	Land Prep	8.30	104.60	0.69	8.76
Mar	Remove Cap	Growing	4.46	109.06	0.37	9.13
Apr	Cultivate	Growing	20.70	129.76	1.73	10.86
Apr	Soil Fertility	Growing	3.00	132.76	0.25	11.12
May	Irrigate/Run Fertilizer	Growing	56.02	188.78	4.69	15.81
Jun	Irrigate	Growing	6.39	195.17	0.54	16.34
Jun	Hand Weeding	Growing	100.00	295.17	8.37	24.71
Jun	Apply Insecticide/Ground	Growing	43.43	338.60	3.64	28.35
Jun	Apply Herbicide/Ground	Growing	10.49	349.09	0.88	29.23
Jul	Apply Insecticide/Ground	Growing	198.40	547.49	16.61	45.84
Jul	Apply Insecticide/Ground	Growing	15.57	563.06	1.30	47.14
Jul	Hand Weeding	Growing	100.00	663.06	8.37	55.52
Jul	Apply Insecticide/Air	Growing	14.89	677.95	1.25	56.76
Aug	Apply Insecticide/Air	Growing	10.95	688.90	0.92	57.68
Aug	Apply Insecticide/Air	Growing	16.17	705.07	1.35	59.03
Aug	Irrigate/Run Fertilizer	Growing	48.97	754.04	4.10	63.13
Sep	Apply Insecticide/Air	Growing	15.70	769.74	1.31	64.45
Sep	Apply Defoliant/Air	Harvest	43.59	813.33	3.65	68.10
Sep	Apply Defoliant/Air	Harvest	25.71	839.04	2.15	70.25
Sep	Dust Control	Growing	24.97	864.01	2.09	72.34
Sep	Prepare Ends	Harvest	1.22	865.23	0.10	72.44
Sep	Cotton, First Pick	Harvest	67.46	932.69	5.65	78.09
Sep	Cotton, Make Mounds	Harvest	13.60	946.29	1.14	79.23
Sep	Cotton, Rood	Harvest	43.33	989.62	3.63	82.86
Sep	Haul	Harvest	6.80	996.42	0.57	83.43
Sep	Cotton Ginning	Post Harvest	112.67	1109.09	9.43	92.86
Dec	Cotton Classing	Marketing	3.30	1112.39	0.28	93.14
Dec	Crop Assessment	Marketing	9.38	1121.77	0.79	93.92
Dec	Cut Stalks	Post Harvest	4.69	1126.46	0.39	94.31
Dec	Disk Residue	Land Prep	12.82	1139.28	1.07	95.39
Misc.	Pickup Use		25.24	1164.52	2.11	97.50

	Operating Inerest 6%		29.84	1194.36	2.50	100.00
	TOTAL		1194.36	1194.36	100.00	100.00

County:	Yuma					
Crop:	Durum Wheat					
Total Variable Cost:	$441.88					

Month	Operations	Class	Cost	Running Total ($)	% of Total Variable Cost	Running Total (%)
Dec	Disk	Land Prep.	19.87	19.87	4.50	4.50
Dec	Roll Beds	Land Prep.	2.38	22.25	0.54	5.04
Dec	Laser Level	Land Prep.	42.88	65.13	9.70	14.74
Dec	Apply Fert/Ground	Growing	63.34	128.47	14.33	29.07
Dec	Plant	Land Prep.	34.02	162.49	7.70	36.77
Jan	Make Borders	Growing	2.42	164.91	0.55	37.32
Jan	Irrigate	Growing	5.12	170.03	1.16	38.48
Feb	Apply Herb/Ground	Growing	27.58	197.61	6.24	44.72
Feb	Irrigate/Run Fert	Growing	85.72	283.33	19.40	64.12
Feb	Apply Herb/Ground	Growing	24.21	307.54	5.48	69.60
Mar	Apply Insect/Air	Growing	17.34	324.88	3.92	73.52
Mar	Irrigate	Growing	10.23	335.11	2.32	75.84
Jun	Combine Harvest	Harvest	57.68	392.79	13.05	88.89
Jun	Haul	Harvest	15.75	408.54	3.56	92.45
Jun	Disk Residue	Land Prep.	12.82	421.36	2.90	95.36
Misc.	Pickup Use		12.62	433.98	2.86	98.21
Misc.	Op. Interest 6%		7.90	441.88	1.79	100.00
	TOTAL		441.88	441.88	100.00	100.00

County:	La Paz					
Crop:	Hay Alfalfa (w/ Grazing)					
Tot. Variable Cost:	$438.44					
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Variable Cost**	**Running Total (%)**
Jan	Irrigate	Growing	40.76	40.76	9.30	9.30
Mar	Swathing	Harvest	12.27	53.03	2.80	12.10
Mar	Raking	Harvest	42.06	95.09	9.59	21.69
Mar	Bailing	Harvest	78.79	173.88	17.97	39.66
Mar	Roadsiding	Harvest	68.85	242.73	15.70	55.36
Mar	Irrigate/Run Fertilizer	Growing	55.64	298.37	12.69	68.05
Apr	Apply Herbicide/Air	Growing	13.59	311.96	3.10	71.15
Apr	Apply Insecticide/Air	Growing	14.42	326.38	3.29	74.44
May	Apply Insecticide/Air	Growing	56.93	383.31	12.98	87.43
Oct	Scratch	Growing	4.54	387.85	1.04	88.46
Oct	Plant	Land Prep	12.44	400.29	2.84	91.30
Misc.	Pickup Use		16.92	417.21	3.86	95.16
	Operating Interest		21.23	438.44	4.84	100.00
TOTAL			438.44	438.44	100.00	100.00

County:			**La Paz**			
Crop:			**Upland Cotton**			
Tot. Variable Cost:			**$1,151.62**			
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Variable Cost**	**Running Total (%)**
Dec	Disk	Land Prep	13.03	13.03	1.13	1.13
Dec	Rip	Land Prep	38.84	51.87	3.37	4.50
Dec	Laser Level	Land Prep	42.88	94.75	3.72	8.23
Jan	Soil Fertility	Growing	12.00	106.75	1.04	9.27
Jan	Apply Herbicide/Ground	Growing	19.11	125.86	1.66	10.93
Jan	Apply Fertilizer/Ground	Growing	18.66	144.52	1.62	12.55
Feb	List	Land Prep	6.49	151.01	0.56	13.11
Feb	Buck Rows	Growing	3.32	154.33	0.29	13.40
Feb	Preirrigate	Growing	3.83	158.16	0.33	13.73
Feb	Disk Ends	Growing	1.88	160.04	0.16	13.90
Feb	Mulch	Land Prep	6.87	166.91	0.60	14.49
Mar	Plant	Growing	7.11	174.02	0.62	15.11
Apr	Remove Cap	Growing	3.31	177.33	0.29	15.40
Apr	Cultivate	Growing	15.62	192.95	1.36	16.75
Apr	Apply Fertilizer/Inject	Growing	92.28	285.23	8.01	24.77
Apr	Apply Herbicide/Ground	Growing	22.94	308.17	1.99	26.76
May	Irrigate	Growing	17.88	326.05	1.55	28.31
Jun	Irrigate/Run Fertilizer	Growing	18.67	344.72	1.62	29.93
Jun	Field Scouting	Growing	6.50	351.22	0.56	30.50
Jun	Apply Growth Regulator	Growing	47.12	398.34	4.09	34.59
Jun	Apply Insecticide/Air	Growing	144.38	542.72	12.54	47.13
Jul	Hand Weeding	Growing	30.68	573.40	2.66	49.79
Jul	Apply Insecticide/Air	Growing	22.68	596.08	1.97	51.76
Jul	Apply Insecticide/Air	Growing	22.83	618.91	1.98	53.74
Jul	Apply Insecticide/Air	Growing	25.38	644.29	2.20	55.95
Jul	Apply Insecticide/Air	Growing	25.81	670.10	2.24	58.19
Aug	Apply Insecticide/Air	Growing	32.11	702.21	2.79	60.98
Aug	Apply Insecticide/Air	Growing	20.86	723.07	1.81	62.79
Aug	Apply Insecticide/Air	Growing	20.61	743.68	1.79	64.58
Sep	Apply Growth Regulator	Growing	21.29	764.97	1.85	66.43
Sep	Apply Defoliant/Air	Harvest	30.71	795.68	2.67	69.09
Sep	Apply Defoliant/Air	Harvest	28.73	824.41	2.49	71.59
Oct	Prepare Ends	Harvest	0.74	825.15	0.06	71.65
Nov	Cotton, First Pick	Harvest	79.87	905.02	6.94	78.59
Nov	Cotton, Make Modules	Harvest	17.72	922.74	1.54	80.13
Nov	Haul, Custom	Harvest	0.00	922.74	0.00	80.13
Dec	Cotton Ginning	Post Harvest	108.87	1031.61	9.45	89.58
Dec	Cotton Classing	Marketing	3.36	1034.97	0.29	89.87

Dec	Cotton, Second Pick	Harvest	35.05	1070.02	3.04	92.91
Dec	Crop Assessment	Marketing	9.56	1079.58	0.83	93.74
Dec	Cut Stalks	Post Harvest	6.95	1086.53	0.60	94.35
Dec	Disk Residue	Land Prep	9.19	1095.72	0.80	95.15
Misc.	Pickup Use		25.38	1121.10	2.20	97.35
	Operating Interest 6%		30.52	1151.62	2.65	100.00
	TOTAL		1151.62	1151.62	100.00	100.00

County:		La Paz				
Crop:		Durum Wheat				
Tot. Variable Cost:		$292.70				
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Tot Variable Cost**	**Running Total (%)**
Dec	Disk	Land Prep.	9.66	9.66	3.30	3.30
Dec	Apply Fert/Ground	Growing	49.39	59.05	16.87	20.17
Dec	Landplane	Land Prep.	10.29	69.34	3.52	23.69
Dec	Plant	Land Prep.	41.46	110.80	14.16	37.85
Dec	Make Borders	Growing	2.88	113.68	0.98	38.84
Dec	Preirrigate	Growing	3.83	117.51	1.31	40.15
Feb	Irrigate	Growing	10.21	127.72	3.49	43.64
Mar	Apply Herb/Ground	Growing	25.27	152.99	8.63	52.27
Mar	Irrigate/Run Fert	Growing	34.50	187.49	11.79	64.06
Mar	Apply Insect/Air	Growing	8.44	195.93	2.88	66.94
May	Knock Borders	Growing	2.86	198.79	0.98	67.92
Jun	Combine Harvest	Harvest	53.33	252.12	18.22	86.14
Jun	Haul	Harvest	14.25	266.37	4.87	91.00
Jun	Cut Stalks	Post Harvest	6.61	272.98	2.26	93.26
Misc.	Pickup Use		12.69	285.67	4.34	97.60
	Operating Interest 6%		7.03	292.70	2.40	100.00
	TOTAL		292.70	292.70	100.00	100.00

County:		Yuma				
Crop:		Head Lettuce				
Tot. Variable Cost:		$3,423.49				
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Var. Cost**	**Running Total (%)**
July	Rip	Lnd Prep	18.54	18.54	0.54	0.54
July	Disk	Lnd Prep	13.15	31.69	0.38	0.93
July	Laser Level	Lnd Prep	17.87	49.56	0.52	1.45
July	Make Borders	Growing	0.48	50.04	0.01	1.46
July	Preirrigate	Growing	6.39	56.43	0.19	1.65
July	Soil Fertility	Growing	3.00	59.43	0.09	1.74
July	Dust Control	Growing	4.91	64.34	0.14	1.88
Aug	Apply Fert/Ground	Growing	114.91	179.25	3.36	5.24
Aug	Apply Herbicide/Ground	Growing	129.43	308.68	3.78	9.02
Sep	List	Lnd Prep	5.34	314.02	0.16	9.17
Aug	Pre-Shape	Lnd Prep	7.56	321.58	0.22	9.39
Aug	Shape Beds	Lnd Prep	66.46	388.04	1.94	11.33
Sep	Plant	Lnd Prep	130.12	518.16	3.80	15.14
Sep	Bird Control	Growing	6.10	524.26	0.18	15.31
Sep	Set Sprinklers	Growing	5.02	529.28	0.15	15.46
Sep	Irrigate/Sec Sys	Growing	6.97	536.25	0.20	15.66
Sep	Apply Insecticide/Air	Growing	32.51	568.76	0.95	16.61
Sep	Field Scouting	Growing	90.00	658.76	2.63	19.24
Oct	Apply Insecticide/Ground	Growing	33.82	692.58	0.99	20.23
Oct	Apply Insecticide/Ground	Growing	54.94	747.52	1.60	21.84
Sep	Irrigate/Run Fertilizer	Growing	13.75	761.27	0.40	22.24
Sep	Remove Sprinklers	Growing	5.02	766.29	0.15	22.38
Sep	Make Ditches	Growing	2.39	768.68	0.07	22.45
Oct	Irrigate/Run Fertilizer	Growing	71.74	840.42	2.10	24.55
Oct	Thinning	Growing	100.00	940.42	2.92	27.47
Oct	Cultivate	Growing	22.53	962.95	0.66	28.13
Oct	Apply Fungicide/Ground	Growing	52.38	1015.33	1.53	29.66
Oct	Apply Insect/Ground	Growing	11.21	1026.54	0.33	29.99
Oct	Apply Insect/Air	Growing	33.57	1060.11	0.98	30.97
Oct	Irrigate/Run Fertilizer	Growing	21.94	1082.05	0.64	31.61
Oct	Hand Weeding	Growing	100.00	1182.05	2.92	34.53
Oct	Apply Insect/Ground	Growing	26.60	1208.65	0.78	35.30
Nov	Knock Borders	Growing	0.48	1209.13	0.01	35.32
Nov	Knock Ditches	Growing	0.80	1209.93	0.02	35.34
Nov	Harvest, Load and Haul	Harvest	2167.20	3377.13	63.30	98.65
Dec	Disk Residue	Lnd Prep	6.57	3383.70	0.19	98.84
Misc.	Pickup Use		21.04	3404.74	0.61	99.45
	Operating Interest 6%		18.75	3423.49	0.55	100.00

	TOTAL		3423.49	3423.49	100.00	100.00

WORKS CITED

Agudelo, J.I. "The Economic Valuation of Water: Principles and Methods." Value of Water Research Report No. 5. Aug. 2001. http://www.unesco-ihe.org/downloads/projects/value_of_water/05.pdf. Accessed Dec. 2, 2005.

Amerigas Propane, Parker, Arizona. Telephone interview. Jan. 2006.

Arizona Agricultural Statistics. "2004 Arizona Agricultural Statistical Bulletin." Sept. 2005. Phoenix, AZ.

Arizona Water Banking Authority. "Executive Summary." http://www.awba.state.az.us/backgrnd/exec_sum.html. Accessed April 14, 2006.

Barkley Seed Inc., Yuma, Arizona. Telephone Interview. 6 Feb. 2006.

Beattie, Bruce R., and C. Robert Taylor. *The Economics of Production*. Malabar, Florida: Kreiger Publishing Company, 1985.

Bequette, Barry, Barry Tickes, and Mohammed Zerkoune. "2001 Yuma County Agricultural Statistics." University of Arizona Cooperative Extension, 2001. http://ag.arizona.edu/crops/counties/yuma/agstats2001.html. Accessed Aug 5, 2005.

Boriss, Hayley and Henrich Brunke. "Commodity Profile: Head Lettuce." Agricultural Issues Center. University of California. 2005. http://aic.ucdavis.edu/profiles/lettuce-2005.pdf. Accessed April 15, 2006.

Brookshire, David S., Bonnie Colby, Mary Ewers, and Philip T. Ganderton. "Market prices for water in the semiarid West of the United States." *Water Resources Research.* (2004) 40. W09S01. doi:10.1029/2004WR003394.

Brozovic, Nicholas, Janis M. Carey, and David L. Sunding. "Trading Activity in an Informal Agricultural Water Market: An Example from California." *Water Resources Update.* 121(2002): 3-16.

Bureau of Economic Analysis. "Glossary." http://www.bea.gov/bea/glossary/glossary_p.htm. Accessed March 3, 2006.

Bureau of Land Management. "Arizona Water Rights Fact Sheet." *Western States Water Laws.* 2001a. http://www.blm.gov/nstc/WaterLaws/arizona.html. Accessed April 15, 2006.

Bureau of Land Management. "California Water Rights Fact Sheet." *Western States Water Laws.* 2001b. http://www.blm.gov/nstc/WaterLaws/california.html. Accessed April 15, 2006.

Bureau of Land Management. "Colorado Water Rights Fact Sheet." *Western States Water Laws.* 2001c. http://www.blm.gov/nstc/WaterLaws/colorado.html. Accessed April 15, 2006.

Bureau of Land Management. "Oregon Water Rights Fact Sheet." *Western States Water Laws.* 2001d. http://www.blm.gov/nstc/WaterLaws/oregon.html. Accessed April 15, 2006.

Bureau of Reclamation. "Development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead, Particularly Under Low Reservoir Conditions." March 2006a. http://www.usbr.gov/lc/region/programs/strategies.html. Accessed March 28, 2006.

Bureau of Reclamation. "Policy Establishing a Demonstration Program for System Conservation of Colorado River Water." Draft Proposal, June 2006.

Bureau of Reclamation. "Scoping Summary Report: Development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead, Particularly Under Low Reservoir Conditions." March 2006b. http://www.usbr.gov/lc/region/programs/strategies/scopingreport/report.pdf. Accessed March 28, 2006.

Bureau of Reclamation. "Lake Powell – Glenn Canyon Dam – Current Status." April 2006. http://www.usbr.gov/uc/water/crsp/cs/gcd.html. Accessed April 30, 2006.

Bureau of Reclamation. "Seven Basin States' Preliminary Proposal Regarding Colorado River Interim Operations." Feb 2006. http://www.usbr.gov/lc/region/programs/strategies/consultation/Feb06SevenBasinStatesPreliminaryProposal.pdf. Accessed March 28, 2006.

Carr Seed Company, Yuma, Arizona. Telephone Interview. 6 Feb. 2006.

Center for Agricultural and Rural Development. Iowa State University. 2005. http://cardsrv7.card.iastate.edu/LDPHome.aspx. Accessed March 15, 2006.

Central Arizona Project. "Management – Revenue." 1997. http://www.cap-az.com/management/index.cfm?action=revenue&subSection=12. Accessed March 15, 2006.

Clifford, Peggy, Clay Landry, and Andrea Larsen-Hayden. "Analysis of Water Banks in the Western States." July 2004. Prepared by Washington State Department of Ecology and WestWater Research.

Colby, Bonnie G. "Transactions Costs and Efficiency in Western Water Allocation." *American Journal of Agricultural Economics.* 72.5(1990): 1184-1192.

Colby, Bonnie G., Dana R. Smith and Katherine Pittenger. "Water Transactions and Flexibility During Drought." *Arizona Water Policy: Management Innovations in an Urbanizing, Arid Region.* Resources for the Future Press, Forthcoming.

Colby B.G. *et al.* "Water Transfers and Transactions Costs: Case Studies in Colorado, New Mexico, Utah, and Nevada." Department of Agricultural Economics. University of Arizona. 1989.

Conservation Before Shortage: Proposed Shortage Criteria for Colorado River Operations. July, 2005. http://www.environmentaldefense.org/documents/4601_CBSshortageproposal2.pdf. Accessed Aug. 15, 2006.

Crouter, Jan P. "Hedonic Estimation Applied to a Water Rights Market." *Land Economics.* 63.3(1987): 259-271.

Edwards Aquifer Authority. 2006. http://edwardsaquifer.org/ Accessed April 17, 2006.

Ferrel Gas, Yuma, Arizona . Telephone interview. Jan. 2006.

Frisvold, George. "Arizona Cropland: A Background Paper." April 28, 2004. http://ag.arizona.edu/AZWATER/postconf/background/Frisvold.AZ.land.use.pdf. Accessed Aug. 11, 2005.

Gollehon, Noel R. "Water Markets: Implications for Rural Areas of the West." *Rural Development Perspectives.* 14.2(1999): 57-63.

Gollehon, Noel, and William Quinby. "Irrigation in the American West: Area, Water and Economic Activity." *Water Resource Development.* 16.2(2000): 187-195.

Governor's Drought Task Force Irrigated Agriculture Work Group. Sept. 28, 2004.

Gibbons, D.C. *The Economic Value of Water.* Washington D.C.: Resources for the Future, Inc., 1986.

Greene, William H. *Econometric Analysis*. Fifth Edition. Upper Saddle River, NJ: Prentice-Hall, 2003.

Griffin, Ronald C. *Water Resource Economics: The Analysis of Scarcity, Policies, and Projects.* Cambridge, MA: The MIT Press, 2006.

Griffin, R. C. and G. W. Characklis. "Issues and Trends in Texas Water Marketing", *Water Resources Update*, 121(2002): 29-33.

H & H Seed Company, Yuma, Arizona. Telephone Interview. 6 Feb. 2006.

Hanak, Ellen. "California's Water Market, By the Numbers." Occasional Papers prepared for presentation to the Department of Water Resources. Public Policy Institute of California: San Francisco, CA, 2002.

Howe, Charles W. and Christopher Goemans. "Economic Efficiency and Equity Considerations in Regional Water Transfers: A Comparative Analysis of Two Basins in Colorado." 2003. http://www.economics.hawaii.edu/research/seminars/02-03/01-17.pdf. Accessed April 15, 2006.

Howitt, Richard E. "Spot Prices, Option Prices, and Water Markets: An Analysis of Emerging Markets in California." *Markets for Water: Potential and Performance*. Eds. Easter, K.W., Rosegrant, M., Dinar. Kluwer Academic Publishers: New York, 1998.

Howitt, Richard E. and Ellen Hanak. "Incremental Water Market Development: The California Water Sector 1985-2004." *Canadian Water Resource Journal.* 30.1(2005): 73-82.

Howitt, Richard and Kristiana Hansen. "The Evolving Western Water Markets." *Choices Magazine.* 20.1(2005).

Hutson, S., N. L. Barber, J. F. Kenny, K. S. Linsey, D. S. Lumia, and M. A. Maupin. *Estimated use of water in the United States in 2000.* U.S. Geological Survey Circular 1268. U.S. Department of the Interior, 2004.

Idaho Department of Water Resources. "Idaho Water Supply Bank." http://www.idwr.idaho.gov/waterboard/water%20bank/waterbank.htm. Accessed April 1, 2006.

Idaho Department of Water Resources. "What is a Water Right?" http://www.idwr.state.id.us/water/rights/definition.htm. Accessed April 1, 2006.

Inter Tribal Council of Arizona. "Colorado River Indian Tribes." 2003. http://www.itcaonline.com/tribes_coriver.html. Accessed April 1, 2006.

Kennedy, Peter. *A Guide to Econometrics*. Fifth Edition. Cambridge, MA: The MIT Press, 2003.

Keplinger, Keith O., and Bruce McCarl. "An Evaluation of the 1997 Edwards Aquifer Irrigation Suspension." *Journal of the American Water Resources Association.* 36.4(2000): 889-901. Accessed July 20, 2005.

Kerns, David, Michael Marheron, John Palumbo, Charles Sanchez, David W. Still, Barry Tickes, Kai Umeda, and Mark Wilcox. "Guidelines for Head Lettuce Production in Arizona." IPM Series, Number 12. 1999. http://ag.arizona.edu/pubs/crops/az1099/. Accessed April 20, 2006.

Klaus, Wolter. "Multivariate ENSO Index (MEI)." 2006. http://www.cdc.noaa.gov/people/klaus.wolteer/MEI/mei.html. Accessed April 30, 2006.

Klaus, Wolter. "Multivariate ENSO Index." 2004. http://www.cdc.noaa.gov/ENSO/enso.mei_index.html. Accessed April 30, 2006.

Landry, Clay J. "Instream Flow Marketing in the Pacific Northwest." Political Economy Research Center. 1998. http://www.pnrec.org/1998/papers/clandry.pdf. Accessed Aug. 15, 2005.

Landry, Clay J., and Clint Peck. "Western States are Creating Water Markets without Compromising the Prior Appropriation Doctrine." 1998. *West Water Research.* http://www.waterexchange.com/market_research/dealing/. Accessed Aug. 15, 2005.

Landry, Clay J., and Terry L. Anderson. "The Rising Tide of Water Markets." ITT Industries Guidebook to Global Water Issues. 1999. http://www.itt.com/waterbook/page71.pdf. Accessed Aug. 15, 2005.

Loomis, J., K. Quattlebaum, T.C. Brown, and S.J. Alexander. "Expanding Institutional Arrangement for Acquiring Water for Environmental Purposes: Transaction Evidence from the Western United States." *International Journal of Water Resources Development.* (March 2003): 21-28.

Lund, Jay R., and Morris S. Israel. "Water Transfers in Water Resource Systems." *Journal of Water Resources Planning.* 121.2(1995): 193-205.

Lund, J. R., Israel, M., and Kanazawa, R. *Recent California Water Transfers: Emerging Options in Water Management*, Center for Environmental and Water Resources Engineering. 1992. University of California, Davis.

MacDonnell, L. “The Water Transfer Process as a Management Option for Meeting Changing Water Demands.” Natural Resource Law Center Rep., University of Colorado, 1990.

Maas, A. and R Anderson. *And the Deserts Shall Rejoice: Conflict, Growth and Justice in Arid Environments.* MIT Press: Cambridge, Massachusetts, 1978.

Meko, David, Charles W. Stockton, and W.R. Boggess. “The Tree-Ring Record of Severe Sustained Drought.” *Water Resources Bulletin.* (Oct. 1995): 789-801.

Metropolitan Water District of Southern California. “Metropolitan Calls on Water Transfer Options from Sacramento Valley Rice Farmers.” (2003). http://www.mwdh2o.com/mwdh2o/pages/news/press_releases/2003-02/Options_Exercised.htm. Accessed Aug. 15, 2005.

Michelsen, A. R. and Young, R. A. Optioning Agricultural Water Rights for Urban Water Supplies During Drought. *American Journal of Agricultural Economics.* 75(November 1993):1010-20.

Naeser, Robert Benjamin and Lynne Lewis Bennett. “The Cost of Noncompliance: The Economic Value of Water in the Middle Arkansas River Valley.” *Natural Resources Journal*. 38(1998): 445-463.

National Oceanic and Atmospheric Administration (NOAA). “Economic Impacts of Drought and Benefits of NOAA’s Drought Forecasting Services.” *NOAA Magazine.* (Sept. 2002). http://www.magazine.noaa.gov/stories/mag51.htm. Accessed March 3, 2006.

National Oceanic and Atmospheric Administration (NOAA). “Standard Precipitation Index.” http://www.ncdc.noaa.gov/paleo/drought/drght_spi.html. Accessed March 3, 2006.

National Research Council. *Water Transfers in the West*. National Academy Press: Washington D.C., 1992.

Nolte, Kurt. Yuma County Agricultural Extension. Email communication. Dec 20, 2005.

Nolte, Kurt. Yuma County Agricultural Extension. Telephone interview. April 17, 2006.

Oregon Water Trust. http://www.owt.org/. Accessed April 15, 2006.

Osborn, Dennis. Fertizona, Casa Grande, Arizona. Email communication. Sept. 9, 2005.

Osborn, Dennis. Fertizona, Casa Grande, Arizona. Email communication. Feb. 3, 2006.

Osborn, Dennis. Fertizona, Casa Grande, Arizona. Email communication. April 19, 2006.

Parker Oil, La Paz, Arizona. Telephone interview. Jan. 2006.

Pontius, Dale. "The Colorado River Basin Study." Report to the Western Water Policy Review Advisory Commission. August 1997.

Pulwarty, Roger S., Katharine L. Jacobs, and Randall M. Dole. "The Hardest Working River: Drought and Critical Water Problems in the Colorado Rive Basin." *Drought and Water Crises: Science, Technology, and Management Issues.* Ed. Donald A. White. Taylor & Francis: Boca Raton, FL, 2005. 249-286.

Reinerston, Jim. County Executive Director, Arizona Farm Service Agency, Yuma/La Paz County office. Telephone interview. May 1, 2006.

SAS Help and Documentation. SAS System for Windows Version 9.0, 2002.

Southern Nevada Water Authority. "Arizona Water Bank." 2006. http://www.snwa.com/html/wr_colrvr_azbank.html. Accessed April 15, 2006.

Stockton, Charles W., and Gordon C. Jacoby. "Long-Term Surface Water Supply and Streamflow Trends in the Upper Colorado River Basin Based on Tree-Ring Analysis." Lake Powell Research Project Bulletin Number 18. March, 1976.

Tadayon, Saeid. "Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of active management areas, 1991-2000." USGS Scientific Investigations Report Number 2004-5293. 2005.

Teegerstrom, Trent and Timothy Knowles. "Arizon Field Crop Budgets 1999-2000: La Paz County." March 1999. Cooperative Extension, University of Arizona. http://ag.arizona.edu/arec/ext/budgets/LaPaz-map.html. Accessed Aug. 15, 2005.

Teegerstrom, Trent and Barry Tickes. "Arizon Field Crop Budgets 1999-2000: Yuma County." March 1999. Cooperative Extension, University of Arizona. http://ag.arizona.edu/arec/ext/budgets/Yuma-map.html. Accessed Aug. 15, 2005.

Teegerstrom, Trent, John Palumbo, and Mohammed Zerkoune. "2000-2001 Arizona Vegetable Crop Budgets: Western Arizona." 2001. Cooperative Extension, University of Arizona. http://ag.arizona.edu/arec/ext/budgets/western.html. Accessed Aug. 15, 2005.

Teegerstrom, Trent. University of Arizona Research Specialist. Personal Interview. May 8, 2006.

Texas Commission on Environmental Quality. "Rio Grande Watermaster Program." http://www.tceq.state.tx.us/compliance/field_ops/wmaster/rgwr/riogrande.html. Accessed April 15, 2006.

Thobani, Mateen. "Meeting Water Needs in Developing Countries: Resolving Issues in Establishing Tradable Water Rights." In *Markets for Water: Potential and Performance*. Easter, K. William, Mark Rosengrant, and Ariel Dinar. Kluwer Academic Press, 1998.

Tronstad, Russell. University of Arizona Extension Economist. Personal Interview. May 1, 2006.

Union Oil, Yuma, Arizona. Telephone interview. Jan. 2006.

USDA, National Agricultural Statistical Service (NASS). "Estimated Quantity of Water Applied and Method of Distribution by Selected Crops Harvested: 2003 and 1998." *2003 Farm and Ranch Irrigation Survey Census of Agriculture*. http://www.nass.usda.gov/census/census02/fris/tables/fris03_28.pdf. Accessed Aug. 15, 2005.

USDA-NASS 2002 Census of Agriculture. "2002 Census of Agriculture - Volume 1 Geographic Area Series Census, State - County Data." http://151.121.3.33:8080/Census/Create_Census_US_CNTY.jsp. Accessed Feb. 15, 2006.

U.S. Census Bureau. "Arizona State and County Quickfacts." http://quickfacts.census.gov/qfd/states/04000.html. Accessed Feb. 15, 2006.

Vaux, H.J. and Richard E. Howitt. "Managing Water Scarcity: An Evaluation of Interregional Transfers." *Water Resources Research.* 20.7(1984): 785-792.

Weinberg, Marca. "Assessing a Policy Grab Bag: Federal Water Policy Reform." *American Journal of Agricultural Economics.* 84.3(Aug 2002): 541-556.

Western Regional Climate Center. "Explanation of Terms." http://www.wrcc.dri.edu/spi/explanation.html. Accessed April 15, 2006.

Wilson, P.N. "Economic Science and the Central Arizona Project: Lessons Learned." *Water Resources Update* 123. (June 2002): 30–37.

Wilson, Paul. University of Arizona Agricultural and Resource Economics Professor. Personal Interview. May 12, 2006.

Wooldridge, Jeffrey M. *Introductory Econometrics: A Modern Approach.* Second Edition. Mason, OH: South-Western, 2003.

Yolles, Peter L. 2000. "Update 2000: Progress and Limitations in Developing a Water Market in California." Western Water Company: Point Richmond, CA.

Young, Robert A. *Determining the Economic Value of Water.* Washington, D.C.: Resources for the Future, 2005.

Yuma Desalting Plant/Cienega de Santa Clara Workgroup. 2005. "Balancing Water Needs on the Lower Colorado River: Recommendations of the Yuma Desalting Plant/Cienega de Santa Clara Workgroup." http://ag.arizona.edu/AZWATER/publications/YDP%20report%20042205.pdf. Accessed Feb. 1, 2006.