VOLUNTARY IRRIGATION FORBEARANCE TO MITIGATE DROUGHT IMPACTS: ECONOMIC CONSIDERATIONS[1]

Bonnie Colby, Professor
Katie Pittenger, Graduate Research Assistant
Lana Jones, Graduate Research Assistant
Department of Agricultural and Resource Economics
The University of Arizona

March 30, 2007
Comments to: bcolby@email.arizona.edu

INTRODUCTION

The balance between limited and variable water supplies and growing demands in the Colorado River Basin means that costs of drought-induced supply variability have the potential to be widespread and acute, affecting many different sectors of the economy. Regional water management strategies to enhance dry-year supply reliability are essential to minimizing susceptibility to drought-induced shortage. This report examines voluntary, temporary dry-year irrigation forbearance as a mechanism to mitigate drought impacts for water users susceptible to dry-year water supply shortfalls. Many other fields of expertise are essential to designing a well accepted and cost effective forbearance program. This report focuses on economic considerations as a complement to work being conducted in other disciplines.

This report provides analyses of on-farm irrigation water values in La Paz and Yuma Counties in western Arizona based on crop-specific net returns over variable costs (NROVC). NROVC indicates the ***minimum*** payment offer an irrigator would need in order to consider refraining from irrigating a specific crop. This can be a useful benchmark in negotiations over dry-year forbearance agreements. This calculation is straightforward, transparent and easily modified to reflect changes in input and output prices and federal farm program payments. The basic methodology established in this report can be applied to other locations and crops beyond those investigated for this research.

The Lower Colorado River Basin In Context

In Arizona, the construction of the Central Arizona Project (CAP) fundamentally changed the nature of Arizona's water supply. The CAP delivers approximately 1.5 million acre-feet of Colorado River water to municipal, agricultural, and Native American interests in central Arizona. The CAP was constructed to

---

[1] This report represents one facet of a multi-pronged project (Enhancing Water Supply Reliability Through Improved Predictive Capacity And Response) which examines ways to enhance Arizona's water supply reliability from the Colorado River. The Principal Investigators on this project include, in addition to Colby, Kathy Jacobs, Arizona Water Institute; David Meko, Laboratory Of Tree Ring Research and Bart Nijssen, formerly with the Departments of Hydrology and Water Resources and Civil Engineering. at The University Of Arizona.
Acknowledgements and disclaimer. The research team appreciates support for this work provided by the U.S. Bureau of Reclamation and the Arizona Water Sustainability Program. While this report has benefited significantly from conversations with Bureau staff, Lower Basin stakeholders, faculty colleagues and Cooperative Extension personnel, report contents represent the professional expertise and research findings of the authors and do not purport to represent the views of project sponsors.

provide an additional source of surface water to offset groundwater overdraft in central Arizona. California's eventual support of the CAP was contingent on Arizona accepting a junior CAP priority status, meaning CAP water users would be among the first to experience reduced deliveries in the event of shortage on the Colorado River system. Uncertainty surrounding Upper Basin development, shortage sharing criteria, and tribal reserved rights has created concern over the CAP's junior priority.

The Arizona Water Banking Authority (AWBA) was established in 1996 with several objectives: to protect Arizona against Colorado River shortage or CAP supply disruptions by storing any unused apportionment in underground aquifers within the state; 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 through facilitating interstate water banking with water stored in Arizona (Arizona Water Banking Authority).

Temporary water transfers are not new to Arizona but have generally involved transfers of surplus CAP water and transfers of agricultural water to meet municipal needs. Since 1987, almost 4.5 million acre-feet of water have been temporarily reallocated in the State via lease transactions. Approximately 87% of these temporary transactions involved CAP water (Pittenger, 2006).

Nevada's 300,000 AF/year allocation of Colorado River water, which once seemed plentiful to support southern Nevada's needs, is no longer perceived as adequate given southern Nevada's urban population explosion. Unlike the other Lower Basin states, southern Nevada has a small amount of irrigated acreage (Virgin and Muddy River Basins), which limits the potential for transferring water out of local irrigated agriculture to municipal use. Nevada has explored a number of options to increase its access to Colorado River water. 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.

The Lower Colorado River Basin periodically experiences consecutive years of serious drought, characterized by low rainfall and snowpack, reduced runoff and streamflows, and drawdown of storage reservoirs. For instance, between 2000 and 2004, inflows into Lake Powell 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). Although 2005 was wetter than the previous years, inflows into Lake Powell are expected to be below average again in water year 2006 with storage in Lake Powell likely to decline.[2]

[2] This research project also considers tree-ring reconstructions which give a much longer perspective and affirm the potential for a drought in the Colorado River Basin more extreme and sustained than any in recorded history (Meko, 1995; Woodhouse et al 2006).

Managing water supplies to minimize potential damages of climate-related supply shortages is a critical challenge facing Arizona. Temporary and voluntary dry-year water transfers represent one viable mechanism to reallocate water during drought and to avert dry-year shortages in vulnerable locations and water use sectors.

Economic Rationale for Dry-Year Transfers

Temporary water transfers to mitigate drought impacts will typically involve irrigation water because agriculture accounts for such a substantial proportion of water use in the Southwest. Low financial returns to irrigating various field crops, and the relative seniority of some agricultural water allocations, make transfers out of agriculture attractive to those urban and industrial users which would face high costs if their supplies were curtailed. In addition, public programs to protect and restore water-dependent habitat may be potential lessees of irrigation water during dry periods.

Many water rights in the western states are governed by prior appropriation, a "first-in-time, first-in-right" system. Irrigators across the West hold senior water rights while municipalities and newer uses such as environmental flows or recreation have a junior priority. In the event of shortage, irrigators with senior water rights will receive their full allocation, while junior right holders may be shorted. Lower priority water users face high economic and political costs during water shortages. However, these losses can be mitigated through voluntary negotiated transfers. Such transfers can be financially feasible when the marginal value of the water used to irrigate low-value crops is markedly lower than the marginal value of additional supplies to the user who faces losses when supplies are short. When different types of users have differential marginal values for water during drought, then the water can be voluntarily re-allocated to ameliorate high cost drought impacts while still paying farmers more than they would have earned irrigating crops. However, other costs of implementing the transfer must not be so high as to make the dry-year lease unattractive to those seeking to augment their dry-year supplies. To summarize, a necessary condition for voluntary irrigation forbearance arrangements is: those parties wishing to enhance their own dry-year supply reliability must be willing and able to pay an amount that, at minimum, exceeds irrigators' foregone NROVC plus program administrative and implementation costs. This implies that forbearance programs are more affordable to the extent that they target irrigation forbearance for low profitability crops and that program implementation costs are kept low.

The temporary nature of such transfers has several advantages. While effective in mitigating the costs of drought-induced supply variability, dry-year transfers are not suitable to provide long term supplies for population growth (as a temporary "borrowing" of water from an established user). This means they cannot be dedicated to support growth once drought has ended, which would make them unavailable as a buffer in future dry periods. Further, they are less costly in both financial and political terms than permanent acquisitions of agricultural land and water, and they generally engender less heated opposition over potential third party impacts.

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 drawdown of the Colorado River system's two main storage reservoirs (Lake Powell and Lake Mead) have prompted the development of guidelines on how shortage conditions would be declared, managed, and shared among the Basin States.

In 2005, a formal process began to develop 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 environmental impacts of the shortage sharing and coordinated management guidelines, the Department of the Interior 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, represents 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, March 2006b). They are:

(1) Develop criteria 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.

New shortage guidelines will also be interim, persisting until 2025, so that modifications can be made based on 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.

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 Intentionally Created Surplus (ICS) program provides a framework for Colorado River water users in the Lower Basin to generate ICS credits to be stored in Lake Mead by

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 are 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 can conserve up to 400,000 AF/year, Nevada is allowed 125,000 AF/year, and Arizona's maximum ICS credits are 100,000 AF/year. Each year when annual water orders are placed for the following year, states with ICS credits can request the recovery of those credits in addition to their water order for the year. ISC credits are also available, upon approval by the Bureau of Reclamation, in the case of extreme weather or water emergency situations (Bureau of Reclamation Feb 2006). Storage of ICS water in Lake Mead is related to adoption of proposed coordinated operations for Lakes Mead and Powell.

A demonstration ICS program is underway in 2006, under an agreement between the Metropolitan Water District of Southern California and the Bureau. The program is designed to create 50,000 acre-feet of ICS water through extraordinary conservation occurring under the Palo Verde Irrigation District (PVID) Land Management, Crop Rotation and Water Supply Program initiated by MWD and PVID in 2004. (For full details on the demonstration program see http://www.usbr.gov/lc/region/programs/AgreementwithMWD.pdf).

ECONOMIC CONSIDERATIONS IN DESIGNING DROUGHT RESPONSE POLICIES

The economic impacts of drought are diverse and can reach far beyond an area actually experiencing a 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 (NOAA, 2002).

The effects of drought in agriculture, the largest water user in the western U.S., can be acute. Agricultural costs associated with drought include crop failure, reduced crop productivity, increased susceptibility to disease and insects, and wind erosion. In response to such costs, there are a variety of federal programs to mitigate drought impacts on farmers. Droughts' effects on agriculture also affect related industries such as farm input suppliers, food processing, farm labor and financial institutions.

Drought can force municipalities and industrial users, who often hold junior water rights, to incur high costs of acquiring supplemental supplies or to incur losses due to the inability to use their customary quantities of water. Further, hot dry conditions stimulate greater residential and commercial demand for outdoor water use to maintain landscape investments and turf.

Drought can also have severe implications for energy production. The ability to produce hydropower is impaired when streamflow and reservoir storage levels decrease. Moreover, higher temperatures typically associated with drought simultaneously bring with them increased energy demand.

Balancing environmental needs with power production, which is always a challenge, becomes even more difficult during drought.

Drought also affects recreation and tourism industries. Opportunities for skiing, boating, rafting, fishing, hunting and bird watching can be diminished because of drought. And this affects those sectors of the economy that rely on business generated by recreation/tourist activity.

The economic implications of water supply variability in the western U.S. are harsher today than they were years ago. Traditional supply-side approaches to water resource development, such as reservoir construction, have become less economically and environmentally viable. Yet rapid population growth and environmental considerations place additional demand on the West's water supplies, resulting in more intense competition for water and higher costs across many water using sectors during drought-induced shortages. These circumstances have prompted efforts to explore other methods for minimizing vulnerability to supply variability, such as water transfers via voluntary negotiations.

Voluntary Drought-Responsive Water Transfers: Background

The following section provides a more in-depth look at various forms of water transfers which have been identified in the literature as promising means of addressing drought-induced supply variability. Colorado and California are home to some of the most established "water markets" in the world (Landry and Anderson, 1999). In Colorado, urban areas have a reliable supply of water partly because of the growing, active water market. California has supported ag-to-urban transfers through the establishment of emergency drought water banks, federal water acquisitions for environmental purposes, and a growing number of arrangements for short term water transfers.

Weinberg (2002) examines economic aspects of voluntary ag-to-urban transfers in central California. The Central Valley Project (CVP) in California provides irrigation water for over 2.5 million acres of cropland, producing crops worth over $3 billion annually. Weinberg develops an optimization model using agricultural and urban benefit functions to analyze the economic impact of various policy instruments, including voluntary water transfers. The dataset is a mixed panel with a time series of crop and water use for multiple 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. Voluntary water transfers are found to be a cost effective means to acquire water for urban needs, with results suggesting that CVP farmers would sell 342,000 acre-feet to urban users at $32/af. This 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 benefits would increase by $25 million. The model results are consistent with observed ag-to-urban transactions in California.

The agricultural sector in Spain has been engaged in water transactions since the 15th century (Maass and Anderson 1978), and voluntary water transfers have occurred for years within the agricultural sector in

the western U.S., typically among farmers within the same irrigation company or district. 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 drought resilient (Lund *et al.,* 1992).

Examples of developing western water markets include: an electronic trading board in the Westland Irrigation District in California where farmers buy and sell water; active water transactions in Utah and Nevada in response to rapid urban growth; and an irrigation forbearance program in Oregon aimed at enhancing streamflows to protect endangered fish. Water transactions also occur outside of the U.S. in countries such as Mexico, Australia, South Africa and Chile. In Chile, for example, dry-year options have been employed to avoid the costs of buying water rights that are only needed during dry years.

In every political jurisdiction, transfers are subject to public agency oversight with the intent of protecting other rights holders and public interests. The approval process, however, can be lengthy and costly and may discourage desirable transfers. States such as Oregon and Colorado have recognized that bureaucratic delays create costs and uncertainties, and have tried to mitigate the problem by assuring more rapid decisions on temporary water transfer applications (Landry and Anderson, 1999).

Water transfers can be permanent or temporary. When water right ownership actually changes, the transaction is considered as a permanent transfer and provides a long term supply augmentation. Historically, the majority of permanent transfers have occurred between agricultural users and urban buyers. When potential buyers are more concerned with enhancing supply reliability during drought or other shortage situations (e.g. flooding, contamination), temporary transfers may be more appropriate.

Temporary water transfers occur in many different forms. In "spot market" transfers, the price is often established by a bidding process. With water banks, lessors provide water to the water bank for a fixed price and lessees obtain water from the bank at a higher fixed price, set to cover the bank's administrative and technical costs. During drought, water banks can reduce urban suppliers' need to pursue more expensive and disruptive permanent acquisitions.

Contingent transfer agreements, or dry-year options, are another form of reallocation that may be useful to enhance dry-year supply reliability. These temporary transfers, which are implemented contingent on supply shortage, are contractual agreements that extend over a specific time period which can range from a few months to many decades. Contingent dry-year transfer contracts between senior and junior water rights can maintain supply reliability for juniors.

Challenges in Forbearance Program Design

The design of forbearance programs must account for legal procedures and policies for transferring water, which vary from state to state and within states. In instances where a transfer involves changes in place or purpose of use specified in a water right, state administrative requirements must be satisfied. While some states have enacted legislation to facilitate temporary transfers during drought or other emergency

supply situations, both short term and long term transfers can encounter significant legal and economic challenges.

Quantifying the amount of "wet" water that can actually be transferred to a new place and/or purpose of use can be a difficult task. The portion of a particular farm's customary water applications that is no longer consumptively used when land is fallowed or crop patterns are altered is often difficult to determine. Seepage, evaporation, and natural accretion also create uncertainty that surrounds the estimate of how much wet water is actually available for transfer. If this issue is not addressed by developing standards to estimate consumptive use, the amount of "paper water" transferred could exceed actual consumptive use. Allowing this larger quantity to be transferred can be detrimental to downstream surface water users, nearby groundwater pumpers and water-dependent habitat. Screening out "paper water" (that is, legal access to water that has not been exercised and, therefore, whose forbearance will not provide "conserved" water) is an important and controversial task in any forbearance program. Water acquired to improve dry-year reliability needs to be water that is physically available for use during dry periods and for which reduced consumptive use by the forbearing party can be verified.

As an example, in Nevada's Truckee-Carson Basin water was needed for dry-year endangered fish recovery programs and to buffer drought impacts on urban areas. Some agricultural water rights had not been consumptively used for years, meaning that water became "paper" water, not "wet" water. It became the task of the organization that arranged transfers for environmental needs to coordinate with the Nevada State Engineer's office to identify which agricultural water entitlements had regularly been consumptively used. This was necessary so that water acquisitions from irrigators actually would firm up dry-year supplies and improve fish flows. The process was politically charged, protracted and contested by irrigators.

In addition to issues over quantifying the amount to be transferred, conveyance, storage, and treatment of the transferred water can be significant considerations. In regions with extensive conveyance and storage systems, there is a higher likelihood of successful dry-year water leases. The price per acre-foot transferred influences the quantity demanded and supplied. Thus, the cost of dry-year water, whether set by negotiations, by a water bank, or by a public agency has important implications for the number and character of transfers. Conveyance, storage, and treatment costs need to be weighed, along with costs such as legal fees, public review processes, technical studies, and third-party compensation (Lund and Israel, 1995).

Forbearance programs are more readily negotiated and implemented when a sound working relationship exists between agricultural water districts and their member irrigators. Negotiating the division of proceeds from dry-year leases between the district and the growers (who forgo income from crop production) can be challenging. Irrigation districts often undertake management and oversight obligations associated with implementing forbearance agreements and the district may hold the water entitlement that is delivered to its member growers. Forbearance contracts often are negotiated between the parties seeking more reliable supplies and an irrigation district, with the district negotiating payment for forbearance with individual member irrigators. In the 1980s in Utah, for example, an electric power generating facility needed

45,000 acre-feet of water to operate its plant. The power facility was located in a rural, agricultural region of Utah, and the local communities were concerned about the effects of the plant on water supplies in their area. When the power company began seeking water rights, the communities involved set up an arrangement in which all members of the irrigation companies were invited to participate in making water available. The power company negotiated with the local irrigation districts and ultimately purchased a package of 45,000 acre-feet of water that was composed of water rights of relatively small quantities from many different irrigators (Saliba and Bush, 1987).

Major impediments to the development of successful forbearance programs are unfamiliarity with the process (by agencies, irrigators and water districts), lack of program momentum, and disagreements among growers and districts over distribution of forbearance payments. One approach to addressing lack of momentum is to offer an early response bonus to farmers who participate in the program in its opening stages. To partially address divisiveness over forbearance payments, each irrigator in a specific district can be given an option to lease 10% of their water in a given year so that negotiations and trades in these options can occur between farmers. That is, if one farmer wanted to lease out more than 10% of his water, he could buy an option from a farmer who did not wish to lease out any water. This means that even those farmers who did not choose to lease water would be involved in, become familiar with, and benefit from the program. This avoids a "divide and conquer" approach, which characterized some early water transactions between cities and agriculture. Each district member receives some form of benefit, and the revenues from the acquisition program are spread more broadly.

The overall costs of dry-year options must be evaluated and weighed against the additional reliability the options will provide to municipal supply and fish recovery programs. Dry-year options are more expensive on a per unit basis (per each acre-foot made available) than outright water purchases. The desire to avoid the third party impacts associated with permanent fallowing and to maintain a vigorous agricultural sector is the chief impetus for considering drought-triggered transactions.

Third Party Impacts

Third party impacts can generate significant controversy and opposition to water transfers, preventing some transfers altogether and making others more costly. Agriculturally-linked rural communities and local governments (such as irrigation districts and counties) often respond to proposed water transfers out of agriculture with suspicion and alarm, concerned that movement of water away from local agricultural uses will undermine the local economy by reducing business activity and property values.

Due to the wide variation in the local economic consequences of water transfers out of agriculture, each case must be examined on its own merits. A number of economic studies have examined actual transfers and have modeled the effects of proposed transactions. Studies of transfers out of agriculture find that local economic impacts are proportionally smaller than the amount of irrigated land that is fallowed, even when the water is moved to a new use away from the area-of-origin (Howe *et al.*, 1990; Checchio, 1988). For instance, fallowing 10% of the irrigated land in a county will NOT cause a 10% reduction in net

farm income from irrigated crop production. The consistent findings of economic impacts being proportionally smaller than the percent of irrigated acreage fallowed are due to several factors: a) farmers choose to fallow their lowest value crops and their least productive acreage, b) a portion of water payments received by farmers is generally spent in the county from which the water is exported, and c) income from crop sales is a small portion of county income in nearly every rural county in the West. In the entire Colorado River Basin, less than a handful of counties are classified by the USDA as ag-dependent (counties are classified as agriculturally dependent when 15% or more of county income comes from farming, USDA, 2004). Rural county households rely on income coming from off-farm employment and government payments more than on income from crop sales. Water transfers can stimulate off-farm jobs and income.

Even though water transfer impacts are small in the context of a region's economy, they may be significantly concentrated in certain businesses or specific agricultural communities (Howe *et al.*, 1990). The parties most affected by proposed transfers generally are not those who have water to sell, but rather are suppliers of inputs and labor (farm workers) to growers and post-harvest processing enterprises (such as cotton gins).

Several approaches can be used to address local impacts. Transactions can be designed in ways to help minimize negative third party effects and maintain agricultural activity in rural areas. Making transfers contingent on drought conditions is one approach to preserving an agricultural base, as farming will occur as usual in normal years and growers can be adequately compensated in dry years to allow them to remain in business. Changes in crop mix could be considered as a means to address impacts as well. A University of California Davis study found that alfalfa is water intensive but employs relatively little labor compared to fruit and vegetable crops, so that alfalfa fallowing would have different impacts on ag-linked jobs than fallowing more labor-intensive crops (Martin, 2003; Howitt, 2002). Other approaches include paying for on-farm water conservation practices and transferring only the water conserved, and rotating acreage fallowed (and water lease payments) among landowners to maintain the baseline agricultural economy. Lease payments can include incentives, such as bonus payments, to growers to reinvest their lease payments in local agriculture and to spend payments at local businesses.

A "rebuttable presumption" approach can be adopted in which standard local economic impact models are used to estimate the magnitude of impacts. Regional economic models are a standard type of economic analysis. As with any set of models, analysts can choose assumptions that amplify or diminish economics effects. Nevertheless, reliable estimates of impacts can be made and evaluated. A multi-person expert panel, nominated by transfer proponents and opponents, can be used to evaluate impacts and make recommendations. Clearly documented impacts ought to be compensated in an affected local economy, not just to reduce conflict but also to avoid costs of economic dislocation and unemployment. Rural and urban areas in the southwest are bound together in an inextricable web of mutuality. Their economies are interdependent, as are farm and non-farm businesses. El Centro, Yuma, and Mexicali areas share some common landowners and common labor pools.

Compensation for impacts imposes a modest tax on the drought relief benefits of temporary fallowing. Most households in rural counties do not depend on ag-linked jobs. In non-metro Arizona only 17% of jobs are linked to agriculture, including provision of farming inputs all the way up the chain to retail sales of local agriculture products. Similarly in California, Colorado, and New Mexico only 18%, 20%, and 17% of jobs are linked to agriculture. Rural county per capita income grew 30% from 1999-2003 and percent poverty in farm households is the lowest in U.S. history.

People whose way of life changes involuntarily are understandably unhappy about it. Money does not change that, but it can address practical impacts on employment and agricultural linked business. Dry-year land fallowing programs are intended to avert serious economic dislocation among junior water users by paying farmers to forbear use of senior water. While rural communities may also benefit from these averted drought impacts, their opposition to water transfers may stem from fundamental and well-founded concerns that transfers signal a change in society's priorities and values for how water is used.

Well structured voluntary land fallowing agreements are an important regional drought response tool. To summarize, from the perspective of local economic impacts dry year leases have important advantages: a) drought-triggered fallowing cannot be diverted to support urban growth like permanent acquisitions do, b) land fallowing can be constrained and rotated so that only 10% is fallowed in any one year, c) incentives can be created for growers to reinvest fallowing payments in local area (such as bonuses for local spending of payments), d) standard methodologies can be adopted for estimating local impacts with a rebuttable presumption approach, and e) only modest land fallowing is needed for M&I dry-year purposes.

Structuring Irrigation Forbearance Programs

Water Banks

Water banks now are established in almost every western state, and although there are functional differences among the banks, each share a common goal of facilitating water transfers, taking on the role of broker, clearing-house, or market-maker while 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 lessor who temporarily leases water from multiple sellers for a specific purpose, water banking involves interaction between multiple lessors and lessees 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 function is as an information clearinghouse. Here, participants declare their intent to transact and most commonly, prices are determined through repeated, bilateral negotiations

between a single lessor and a single lessee. While the clearinghouse function does not necessarily eliminate price dispersion in thinly traded markets, it does reduce the transactions costs of identifying potential trading partners.

A fixed price structure, in which the price is fixed by the bank, is another framework employed by water banks. The bank, however, may not possess sufficient information to correctly estimate a market clearing price or to account for differences in quality and reliability of water rights within the region. Although the fixed price structure creates a sense of fairness and reduces concerns about price gouging and speculation, such a structure is unable to respond quickly to changes in market and climactic conditions. This limitation becomes acute during dry years because lack of a price incentive to bank water during wet years leads to insufficient banked supplies during drought.

A more flexible option is for buyers and sellers to negotiate prices themselves, along with quantity of water to be transferred as well as timing and location of delivery. This is the “clearinghouse” approach discussed previously.

Despite their potential for easing drought impacts, transaction activity in most banking programs tends to be limited. Water banks in the West are a relatively new concept in most regions and potential banking participants have limited experience. Also, the number and type of participants is typically restricted along with the types of allowable transfers (Clifford *et al.,* 2004). The Snake River water bank is an exception, having operated for several decades providing flexibility in Idaho’s Snake River Basin.

Dry-Year Options

Agriculture represents over 80% of water consumption in the southwestern U.S., and much of what the hay and field crop acreage generate 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 cost effective 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, “dry-year options” or “water supply option contracts” (Michelson and Young, 1993) can meet municipal water demands during drought.

A dry-year option is a contract or agreement between a farmer, group of farmers, or agricultural district and an urban water user to transfer water temporarily from agriculture to urban use during occasional critical drought periods. Such agreements can secure a source of drought water supply for cities and other users (Michelsen and Young, 1993). Dry-year options are exercised in pre-specified drought/shortage conditions. Agricultural water rights are maintained and agricultural water supply during normal supply conditions is not affected. This approach to addressing dry-year shortages is likely to be more cost effective and entails less third-party economic impacts than permanent acquisitions. When an option is exercised, irrigators temporarily cease irrigating cropland 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.

Option contracts can be one-time, short-term arrangements or can extend over decades. An example of the former would be an agreement negotiated during a winter when snow pack and reservoir storage are below normal, to be exercised later that same year if the region indeed finds itself in a shortage situation that threatens urban water supplies or fish recovery flows. Long term contracts can span many decades, giving those paying for forbearance the right to exercise an option to use irrigation water under pre-specified trigger conditions.

Dry-year options address two fundamental sources of uncertainty in water transactions: supply uncertainty and price uncertainty (Howitt, 1998). Options markets are a middle ground between pure spot markets and water markets for the permanent acquisition of water. Through options markets, risk can be spread between the suppliers and demander of dry-year supplies.

In spot markets, uncertainty is borne 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 may be unacceptable for risk-averse potential transactors. Dry-year options contracts can 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 the supplier would remain in possession of his water rights which may increase in value over time.

In addition to spreading these risks innate in water markets, options contracts can reduce third-party impacts of water transfers. The permanent transfer of water can have 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. In years the options are exercised, the growers likely will continue participating in the local economy and spend some of the options payments locally. In comparison to spot markets, options markets also allow rural communities more time to plan for changes in local spending patterns and job opportunities that occur as a result of temporary water transfers, thus minimizing the impact of those changes.

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.

From the perspective of the party seeking more reliable dry-year supplies, the value of an option contract is a function of its cost (including approval and implementation costs) compared to both the cost of

the most likely dry-year supply alternative and the costs that would be imposed by a water shortage. By comparing option contract costs with alternative water supply costs and shortage costs, the present value net benefit of an option contract (PVNB) can be determined. A positive PVNB indicates an option contract is economically rationale; that is, the costs of the contract are less than that of other means of assuring dry-year supplies and are less than the costs that would be imposed by a supply shortfall.

The following provisions should be considered in structuring an option contract:

1. The exercise price, which is the payment to irrigators for the net value of forgone agricultural production each time the option is exercised, should be specified to change over time to account for differences in water values and market conditions. Changes can be tied to inflation measures, regional water or power costs or other indices acceptable to the parties. Such adjustment provisions make an agreement more stable over time and ensure that the parties share in the economic effects of changes in regional water values.
2. The quantity, location, infrastructure use (wheeling through a canal, for instance) and timing of water delivery need to be specified. The cost-sharing arrangements for using storage and delivery infrastructure should be specified, as well as the costs themselves.
3. Irrigators should retain the option of selling the water rights (or water project entitlements) that support the option contract before contract termination, but the option purchaser should likewise be guaranteed the chance to match a bona fide offer for water rights. This condition ensures supply security for the option holder, while maintaining the irrigator's ability to respond to attractive purchase offers over the life of the contract. Without such a provision, irrigators and irrigation districts may be reluctant to participate in an option contract.
4. Options contracts are most cost effective when they consider seasonal hydrologic and crop production patterns. For instance, in the fall a party seeking reliable supplies for the following year can pay an initial fee to secure an option to lease a specific quantity of water from an irrigator in the spring or summer months (Howitt and Hansen, 2005). Then, if the winter snowpack turns out to be poor and water supply shortfalls are expected, the option is exercised through growers ceasing irrigation of crops generating the lowest NROVC. Negotiating the contract ahead of need spreads the risks of drought-induced supply variability and reduces costs that may be associated with rapid negotiations to secure water in the spring.

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 north central Colorado. The area is characterized by urban growth and pressures to purchase agricultural water by cities as well as a desire to maintain agricultural communities. The region generally had sufficient water in normal years to meet the demands of urban and agricultural users. In the early 1990s, Michelson and Young estimated the annual offering price for agricultural water to be $85/AF/year. Under varying river flow conditions and crop price conditions, estimated exercise costs range from $39 - $135/AF/year.

The PVNB 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 rates. 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. Higher alternative water costs increase the option value significantly.

Long-term drought on the Colorado River has led to a growing recognition of the limits of the Colorado River storage system and the need to devise alternative strategies for coping with severe drought. Water supply option contracts represent a strategy for 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, infrastructure, and institutional framework in place to implement option contracts. Options contracts can be 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.

DRY-YEAR IRRIGATION FORBEARANCE IN PRACTICE

A review of past experience with dry-year temporary transfers provides practical guidance in structuring dry-year supply reliability strategies for the Lower Colorado River Basin.

There have been a number of dry-year transfer programs in California, as a result of drought in southern California, the Quantification Settlement Agreement, and low farm commodity prices (Howitt and Hanak, 2005). Metropolitan Water District of Southern California (MWD) has played a leading role in dry-year transfer arrangements to secure more reliable supplies in its extensive and highly urbanized service area. MWD secured the option to use water from Sacramento Valley irrigators with an upfront payment of $10/AF to the irrigation districts, and an additional $90/AF to growers who reduce their use of surface water for irrigation when the option is exercised. Participating irrigators have switched to less water-intensive crop production and use of groundwater in order to make surface water available to MWD. In 2003 almost 100,000 acre-feet of water were transferred via these options agreements involving the Sacramento Valley growers (Metropolitan Water District of Southern California, 2003).

An earlier example, also involving MWD, is a 1993 dry-year option arrangement whereby MWD secured option contracts from irrigators in the Palo Verde Irrigation District (PVID), located along the Colorado River in southern California. The agreement 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 water at approximately $136/AF (Water Strategist, 1994).

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

Dry-year options to secure urban supplies have occurred in other 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 value of the alfalfa the irrigator would have grown had the water not been transferred to urban use (National Research Council, 1992).

The Edwards Aquifer Region of Texas has also used dry-year irrigation forbearance to meet water demand in dry years. With the aim of raising aquifer levels, increasing spring flows, and ensuring drought relief for municipalities, the Pilot Irrigation Suspension Program (ISP) was initiated in 1997. 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, necessary due to federal court order to maintain spring flows to support endangered species (Keplinger and McCarl, 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 then summed. Per acre bids were divided by the sum to produce the final score, a lower score being more attractive.

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 and McCarl presents a number of interesting findings. First, at an average price of $234 per acre, the ISP obtained forbearance on 10,067 irrigable acres in the Edwards Aquifer region. This payment is higher than what regional lease rates and land prices would suggest. This may be attributed to the newness of the ISP, its timing, collusion among farmers, and/or the belief that lower might affect future water prices or offers.

Keplinger and McCarl 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 crop mix from water-intensive corn, cotton, and vegetables to more water efficient sorghum and wheat. Despite a moderate reduction in farmer purchases of fertilizer, seed, and labor, secondary effects on the local economy appeared minimal. Farmers willingly participated in the pilot ISP and regional municipalities willingly funded the program. Although some modifications to the selection criteria, bidding process, and timing of the program could reduce program costs, the 1997 ISP proved to be a feasible and timely response to meeting needs during drought. The ISP was initially planned to be structured as a dry-year option, but such long term contracts could not be implemented in 1997 because a structure of tradable pumping permits was not in place yet.

Irrigators in the San Luis Valley of southern Colorado are implementing a voluntary irrigation forbearance program to preserve groundwater levels and prevent state regulatory actions to reduce aquifer overdraft (Oad and King, 2005). In Montana's Big Hole River Valley, irrigators have been paid to forbear from use of water entitlements in order to enhance flows for endangered fish, with some irrigators agreeing to forbear without compensation payments. The USDA Natural Resources Conservation Service offered ranchers from $40 to $60 per acre not to irrigate their hay meadows and pastures during a critical low flow period (Oad and King, 2005)

Chile is one of the few countries outside the U.S. that actively utilizes voluntary water transfers to manage water resources. Chilean farmers have negotiated options agreements amongst themselves to minimize dry-year supply variability for high value crops (Thobani, 1998). Instead of purchasing permanent water rights, farmers growing more profitable perennial crops secure the option to lease water for a season from a neighboring farmer engaged in annual crop production. Similar arrangements have been implemented in the U.S. Pacific Northwest between orchard and vineyard owners and nearby field crop producers.

Proposals for Dry-Year Transfer in the Lower Colorado River Basin

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

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, criteria have not been adopted to guide the Secretary of the Interior in declaring a shortage, though a scoping process to develop shortage guidelines is being undertaken by the Department of the Interior. Other concerned parties have also developed proposals for shortage sharing.

One such proposal is "Conservation Before Shortage" (CBS), a document developed by several NGOs, released in summer 2005 and updated in summer 2006 to reflect negotiations among the seven states and the ICS program (update referred to as CBS II, see

http://www.usbr.gov/lc/region/programs/strategies/alternatives/CBS2.pdf). CBS II discusses strategies to implement the ICS program and advocates consideration of extraordinary conservation program in Mexican agriculture. The CBS proposals advocate 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 agricultural users is triggered. A fundamental element of the CBS strategy is voluntary forbearance agreements in the form of part-year forbearance programs, dry-year options, and other similar arrangements.

The CBS 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 2005 CBS document suggests water conserved through forbearance arrangements could be acquired for $20 - $100 per acre-foot. An economic study undertaken by Environmental Defense suggests 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). The 2006 CBS proposal is one of the alternatives being evaluated in the Bureau's ongoing EIS process (Development of Lower Colorado River Basin Shortage Guidelines & Coordinated Management Strategies for Lakes Powell and Mead Under Low Reservoir Conditions, see http://www.usbr.gov/lc/region/programs/strategies.html).

Yuma Desalting Plant Workgroup

A consumptive use reduction and forbearance program based on voluntary, temporary irrigation forbearance has also been suggested as one of the solutions to controversy surrounding future 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 Welton-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 is 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 intermittently through mechanisms such as dry-year options.

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 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.

ECONOMIC VALUES FOR 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 create economic pressure to transfer water across uses during drought. Data on the economic value of water in different uses help 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 drought impacts in other sectors can be reduced by voluntary 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 transfers. Young (2005) describes several widely-employed methods.

Water-Crop Production Functions

In this approach, on-farm economic value of irrigation water is based on a water-crop production function. A water-crop production function models the link between the application of water and crop yield. In other words, it defines a relationship between a specific level of input application (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 such as fertilizers, pest control, etc. Crop-production functions are typically estimated based on expert opinion but can also be approximated using field experiments and computer simulation. The application of this approach is limited to locations and crops for which accurate up-to-date water crop functions are available.

Market Price Comparison

Another method for valuing irrigation water is the direct observation of transactions prices in voluntary water transfers. Such observations provide insight into users' valuation of short-term leases of irrigation water or the permanent purchase of agricultural water rights. In theory, transactions negotiated in a well-functioning market will reflect the economic value of water, which would fluctuate with its level of scarcity. In dry years, for example, the equilibrium value of water would be higher than in comparably wetter years 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 inadequate transaction data and constrained water markets (Young, 2005). Application of

this approach is limited to regions with regular, voluntary transactions and access to price data, which is sometimes kept confidential by the parties to the transaction.

Residual (or Farm Budget) Approach

The most common method for valuing irrigation water is the residual or farm budget method, which involves crop production cost and return analysis. Statistically estimating the marginal physical productivity of irrigation water using a crop-production function based on field data would be a more accurate 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 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 farmers in a specific area. A table detailing operations and inputs for each crop is constructed based on the representative farm. Data on the steps in the production process, timing, required production resources, and resulting outputs are generally obtained from farmer and extension agent interview to produce a crop- and location-specific crop budget. This data is then used 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.

Although this approach can be fairly straightforward from an accounting perspective, biases that arise in the data gathering process can be nontrivial. Young (2005) warns that farm budget analyses are sensitive to the assumptions made about the nature of the production function, as well as input and output prices and quantities.

Arizona Agriculture: Background

Arizona's semi-arid to arid climate necessitates the application of irrigation water on almost all agricultural acreage in the state, and 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). Correspondingly, water withdrawal for municipal use has 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 section examines potential on farm costs of voluntary, temporary transfers of mainstem Colorado River surface during drought to support municipal and environmental water needs.

Over 60% of the West's total sales of 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 variation in acres irrigated and the contribution of various crops to farm revenues means irrigators have 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.

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. In western Arizona, 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).

Crop Acreage and Irrigation Water Use in Yuma and La Paz Counties

Because dry-year transfers out of agriculture are voluntary and temporary, they maintain the viability of 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 water. A majority of their irrigation withdrawals come from Colorado River water. Of the 875 million gallons/day (mgal/day) total irrigation withdrawals in La Paz County in 2000, 590 mgal/day were surface water (Hutson *et al.,* 2004). In Yuma County in 2000, surface water composed 1079 mgal/day of its total 1432 mgal/irrigation withdraw. 1.2 million acre-feet of Colorado River water are diverted annually in Yuma County (2001 Yuma County Agricultural Statistics). This represents over one-third of Arizona's total 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 has 98,245 acres of cropland, of which 91,347 (93%) are irrigated (USDA- NASS 2002 Census of Agriculture). Yuma County contains 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.

Cropland in Study Area*

	ARIZONA	LA PAZ COUNTY	YUMA COUNTY
Number of Farms			
2002	7294	101	531
1997	8507	122	580
Total Cropland (Acres)			
2002	1261894	98245	212995
1997	1354820	not available	228758
Irrigated Cropland (Acres)			
2002	931735	91347	197424
1997	1075336	116985	207573

*Data from NASS 2002 Census of Agriculture

Table 1 Cropland Summary

The dominant field crops, in acreage, 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. Cotton and wheat are typically rotated with vegetables (Nolte, 2006). Vegetable crops occupy less acreage than field crops but outweigh field crops in value of gross sales. 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.

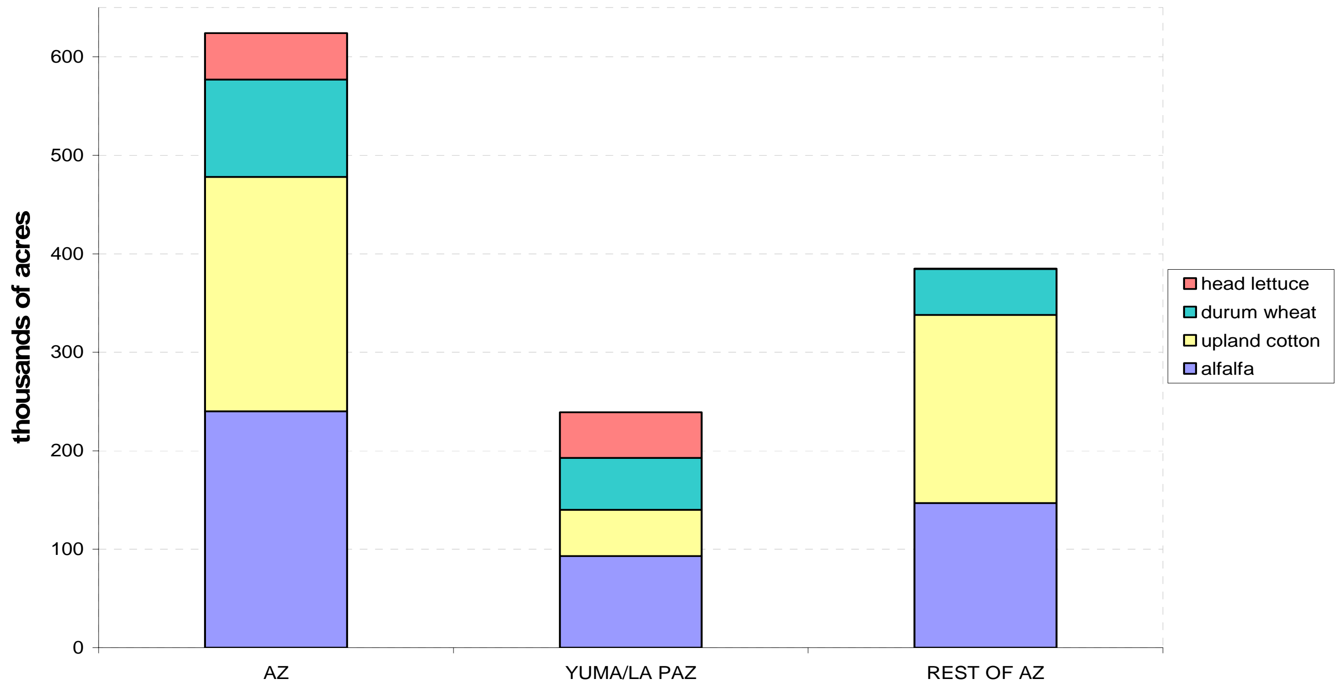


Figure 2 Summary of Harvested Acres, 2005 Arizona Agricultural Statistics Bulletin

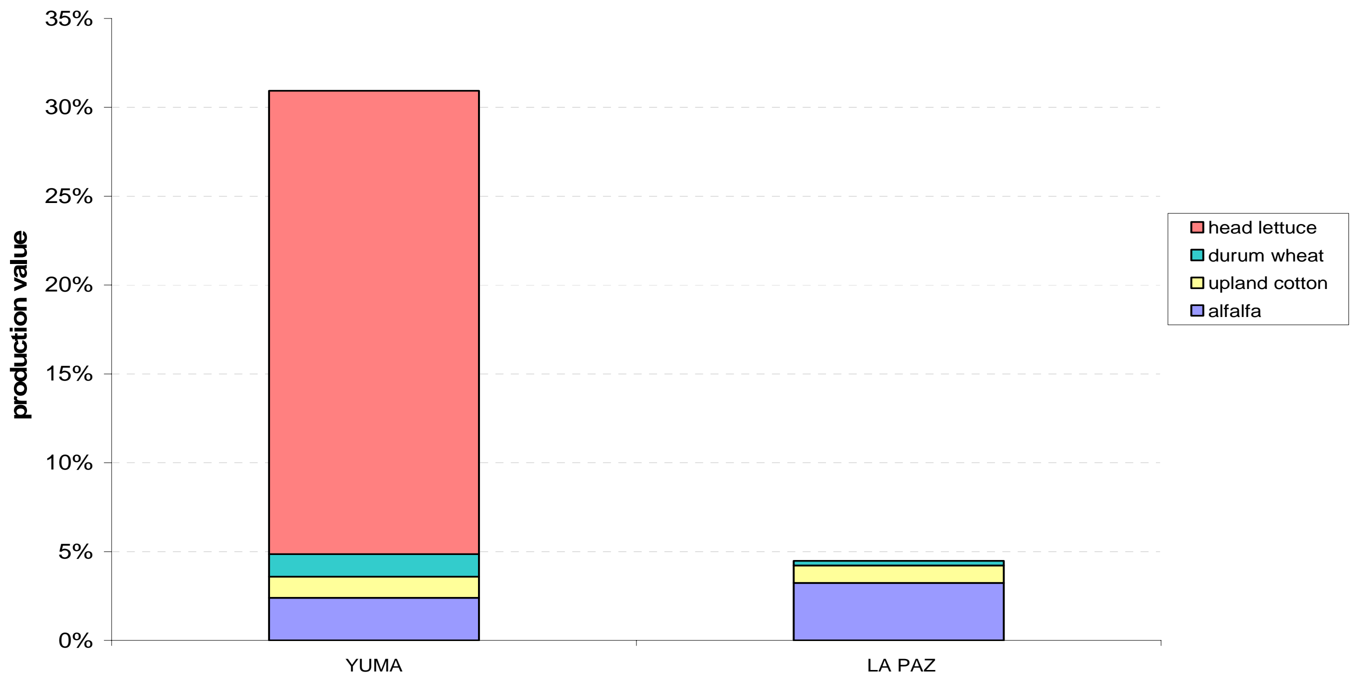


Figure 3 Percent of Arizona Crop Production Value, 2005 Arizona Agricultural Statistics Bulletin

Because dry-year forbearance programs can impact crop mix and crop rotations, head lettuce is also included in the crop budget for Yuma County. Due to its high net returns, lettuce is an unlikely candidate for irrigation forbearance, yet it needs to be considered as an important component of the seasonal crop mix. Other vegetable and fruit crops are also important. We focus on head lettuce here to illustrate issues forbearance programs may encounter with high-value crops.

The following tables illustrate the five-year movement (2000 to 2004) in the price and production for the field crops and head lettuces 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. Prices reported in the following two tables represent the market or spot value of the crops as reported by NASS. This price does not include federal farm program payments to producers.

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	8.62	9.68	10	9.044
Production (tons)	260000	260000	275700	300000	280000	275140
Price per Ton	$94.00	$99.00	$100.00	$89.50	$99.50	$96.40
Value of Production	$24,440,000	$25,740,000	$27,570,000	$26,850,000	$27,860,000	$26,492,000
Cotton, Upland	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	25400	26000	18200	24600	26800	24200
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	$0.44	$0.45
Value of Production	$13,911,079	$8,176,218	$11,577,917	$20,400,072	$17,047,202	$14,222,498
Wheat, Durum	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	38600	36800	44300	46000	43000	41740
Acres Harvested	38600	36400	44300	46000	42500	41560
Yield per Acre (bushels)	101.7	95.8	96.5	102.7	100	99.3
Production (bushels)	3923000	3488333.333	4272000	4724666.667	4250000	4131600
Price per Bushel	$3.50	$3.95	$4.40	$4.65	$4.25	$4.15
Value of Production	$13,734,423	$13,782,405	$18,801,072	$21,969,700	$18,066,750	$17,270,870
Lettuce, Head	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	50300	52000	51000	50000	47000	50060
Acres Harvested	50300	51800	50000	49600	46500	49640
Yield per Acre (cwt)	350	365	350	360	360	357
Production (thousand cwt)	17605	18907	17500	17856	16740	17721.6
Price per cwt	$13.10	$16.50	$38.70	$10.30	$22.20	$20.16
Value of Production	$230,625,500	$311,965,500	$677,250,000	$183,916,800	$371,628,000	$355,077,160

*Source: National Agricultural Statistics Service 2005 & 2004 Arizona Agricultural Statistics Bulletin

**Market price received by growers

Table 2 Yuma 5-Year Trends

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	$99.50	$96.40
Value of Production	$47,000,000	$50,688,000	$50,000,000	$43,855,000	$44,775,000	$47,263,600.00
Cotton, Upland	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	18000	17500	12200	16100	20500	16860
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	$0.44	$0.45
Value of Production	$9,792,481	$5,793,600	$6,933,888	$14,342,400	$14,066,453	$10,185,764
Wheat, Durum	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Acres Planted	6500	5100	5600	8000	10000	7040
Acres Harvested	6500	5100	5600	8000	10000	7040
Yield per Acre (bushels)	94.7	96.2	92.7	101.3	88.0	94.6
Production (bushels)	615000	490666.6667	519000	810000	880000	662933.3333
Price per Bushel	$3.50	$3.95	$4.40	$4.65	$4.25	$4.15
Value of Production	$2,153,115	$1,938,624	$2,284,119	$3,766,500	$3,740,880	$2,776,647.60

*Source: National Agricultural Statistics Service 2005 & 2004 Arizona Agricultural Statistics Bulletin

**Market price received by growers

Table 3 La Paz 5-Year Trends

Data and Procedures for Calculating Net Returns To Irrigation Water Use

The first step in crop-budget analysis is to obtain 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 used the county 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) as a model. The most recent published farm budgets (1999/2001) were substantially updated in the course of this research to reflect 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 rates 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 chemical 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.

Agricultural extension agents 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). Appendix Two provides detailed variable cost calculations, exclusive of water costs, for each location-specific crop in this analysis.

Because federal farm support payment can substantially improve the profitability of certain crops in certain locations, 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 from crop production. Consequently receipt of these payments would not be affected by irrigation forbearance (Reinertson, 2006) though such payments influence overall farm profitability.

Unit Crop Budget is assembled and used to calculate net returns over variable costs (NROVC) per acre for each crop. NROVC estimates 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 non-water input is attributed to be the return to irrigation water in crop production (Naeser and Bennett, 1998). This value is the maximum value an irrigator could pay for water and still cover the variable 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 not a chief consideration in yearly production decisions (Naeser and Bennett, 1998). A longer-run estimate of the on-farm value of irrigation water, however, would require the inclusion of the fixed costs of production. Moreover, attributing all of the NROVC to the water input ***overstates*** the on-farm economic value of irrigation water because farm budget data do not assign a cost per acre for management expertise and farm assets such as equipment.

Net Returns By County and Crop

The table below illustrates calculation of NROVC for cotton in Yuma County based on differing scenarios for crop prices and yields. These include five-year highs for both price and yield (High), five-year lows for both (Low), five-year averages for price and yield (2000 – 2004), and actual 2004 crop prices and yields per acre. Similar tables for other crops included in this analysis can be found in Appendix Three.

Yuma Upland Cotton	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre (lint)	1438	1320.6	1438	1129
Price/unit (lint)	0.5	0.4616	0.664	0.284
Yield/acre (seed)	1.24	1.06	1.24	0.87
Price/unit (seed)	160	139.2	160	124
LDP/Marketing Gain Rate	0.149	0.143	0.076	0.28
Price Plus LDP per unit	0.649	0.6046	0.74	0.564
Gross Revenue ($/Acre)	1131.662	945.98676	1262.52	744.636
Total Variable Costs per Acre	1194.37	1194.37	1194.37	1194.37
Net Returns Over Variable Costs Per Acre	-62.708	-248.38324	68.15	-449.734
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	-14.93	-59.14	16.23	-107.08

Table 4 NROVC, Upland Cotton. See Appendix Three for detailed citation.

NROVC for production of upland cotton in Yuma County is negative, except for the scenario that assumes five-year highs for both price and yield. The NROVC calculations do not, however, include federal price support payments that cotton producers receive in addition to the market price and the loan deficiency payment. These payments are not included because a grower's decision to cease irrigation does not affect their receipt (Reinertson, 2006). Thus, even if a grower refrains from irrigation for a season to lease out their water, they will still receive these payments and these federal programs do not affect calculations of NROVC.

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

YUMA COUNTY NROVC

CROP	NROVC/ACRE	AF WATER/ACRE	NROVC/AF
Alfalfa	$365.03	5.8	$62.94
Durum Wheat	-$29.78	3.5	-$8.51
Upland Cotton	-$248.38	4.2	-$59.14
Head Lettuce	$3823.56	3.6	$1062.10

Table 5 NROVC, Yuma Crops

LA PAZ COUNTY NROVC			
CROP	**NROVC/ACRE**	**AF WATER/ACRE**	**NROVC/AF**
Alfalfa	$398.10	5.8	$68.64
Durum Wheat	$99.53	3.5	$28.44
Upland Cotton	-$111.74	4.2	-$26.60

Table 6 NROVC, La Paz Crops

NROVC provide an objective baseline to inform negotiations over dry-year forbearance payments. The exercise payment in a voluntary program could not lie below NROVC for a specific crop, since in that case the farmer would be better off producing crops. Exercise payments may be larger than NROVC to provide an incentive for farmers to participate in a forbearance program and to cover other costs. On the other hand, a grower weighing various risks of crop production and marketing may choose a certain forbearance payment over an uncertain net return to crop production.

Issues Related to Higher and Lower Value Crops

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 a potential for significant financial benefits for producers who participate in dry-year options arrangements instead of irrigating these specific crops. Second, the high value of NROVC for head lettuce highlights the point that cost effective dry-year option arrangements must be structured so that low-value crops can temporarily be taken out of production while seasonal high-value vegetables continue to be produced. In western Arizona, vegetables are typically planted in November and harvested through March, after which time irrigators switch to production of field crops for late spring and 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 focus on fallowing low-value crops.

In reviewing and comparing the NROVC for crops in Yuma and La Paz counties, the question naturally arises as to why growers do not plant more acreage in 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 carefully 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 well established marketing networks (Teegerstrom, 2006). For any chance of financial success, the decision to produce and sell 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 or plow under the lettuce that cannot be profitably sold.

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 two 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 weekly fluctuation in prices received by Arizona growers for the first six months of 2006. Price fluctuations occur due to weather and other factors affecting yield and harvest dates in the numerous lettuce growing microclimates.

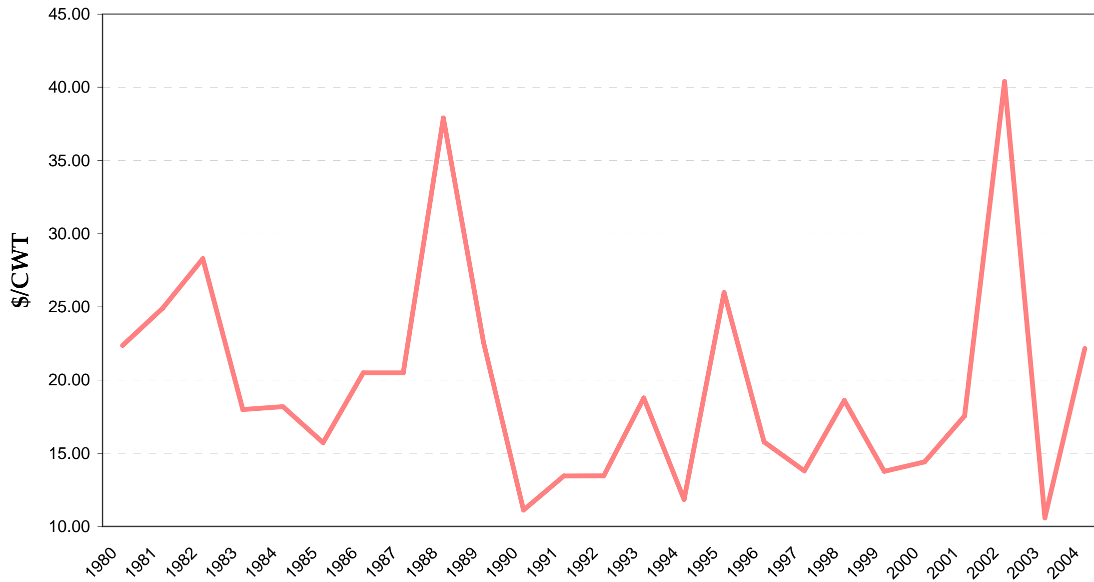


Table 7 Seasonal Price of Head Lettuce

Table 8 Average Weekly Price of Head Lettuce, 2006 season. Note: Jan through mid-April is primarily western Arizona harvest, and late April through June is primarily California harvest.

In making production decisions, growers consider not only the potential profitability of a crop but also the input costs and risks inherent in production and marketing of that crop. The variable costs of production for head lettuce and other vegetables are very high compared to field crops. A farmer who has the necessary networks in place and decides to incur the high production costs associated with head lettuce production, also is taking the risk of volatile, unpredictable market conditions. If the market price for head lettuce is low when the crop is harvested, the grower must choose between accepting those prices or plowing under the crop (thus averting harvest costs) and will likely incur a large financial loss for the season on his lettuce acreage.

Seasonal Considerations in Structuring Forbearance Programs

The time of year when growers are asked to cease irrigation has implications for compensation payments. In some instances, growers will have already produced some crop (and earned revenues) and may have also already incurred some of the variable costs of production. To accurately account for the value of foregone crop production, the timing of forbearance must be taken into account. Tables in Appendix Four provide a monthly accounting of the variable costs of production for major crops in Yuma and La Paz Counties.

Using these tables, forbearance 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 Yuma County cotton producer would not yet have incurred variable costs associated with cotton production, and thus the baseline calculation of NROVC for upland cotton would apply. If, however, irrigators are asked to cease irrigating late in the growing season (i.e. after July 30), they will have already incurred almost 57% of their variable costs without having produced a marketable crop, so approximately $677 arguably could be added on to minimum compensation per acre, substantially increasing the cost of the forbearance arrangement. (See tables in Appendix Four).

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 in alfalfa are affected by the time of year a grower is asked to cease irrigating his crop based on variable costs already incurred, and also based on alfalfa already harvested.

The production of other field crops, however, is seasonal. Growers 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.

The time of year when a forbearance option is exercised has significant consequences for the on-farm net returns foregone and forbearance program costs. NROVC for head lettuce production, for example,

are very high relative to field crops. If forbearance programs interrupt the production of lettuce (or other high value specialty crops), payments to growers would necessarily be substantially higher to account for the foregone profit of lettuce production.

The most cost effective scenario for irrigation forbearance on cropland planted in a field crop/vegetable annual crop mix is to request participating growers to forbear irrigation in the late spring and summer (forbearing production of field crops), and then provide water for production of vegetables in the winter or spring. These seasonal arrangements reduce the foregone net returns in crop production, but may also require water storage arrangements to match timing of irrigation cessation with seasonal need for additional water by municipalities or fish and wildlife programs. If, however, climate and water supply prediction tools can be used to anticipate the timing and magnitude of need for additional water in upcoming months or years, then forbearance options can be exercised for field crops and the conserved water could be banked by the lessee for use later in the year. This strategy rests on two assumptions: (1) the capacity to predict water supply shortfalls in December-February is accurate enough to inform negotiations over the structure and pricing of forbearance agreements that might be exercised the following summer (a short term, one-time option contract) and/or prediction capacity is accurate enough to inform longer term option contracts intended to assure supply reliability for 20-50 years (long term contract); (2) adequate storage capacity is available at reasonable cost to carry the unused irrigation water into future seasons and years for use by those contracting for forbearance.

Further On-Farm Financial 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 irrigation forbearance on federal price support payments. In particular, the value of foregone crop production could change if counter-cyclical payments (tied to the market price of cotton), and direct payments become affected by temporary irrigation forbearance. According to County Executive Director of the Yuma and La Paz Counties Arizona Farm Services Agency, these decoupled federal payments currently would not be affected by a farmer's decision to temporarily cease irrigation (Reinerston, 2006). The farmer would, however, still be responsible for managing noxious weeds on the fallowed lands.

Another consideration is crop insurance. Farmers can purchase yield-based insurance, known as Actual Production History, which insures producers against yield losses due to natural causes such as drought, flooding, hail, wind, frost, insects, and disease (USDA 2005). An individual farmer selects the percent of average yield to be insured (50-75%) as well as the percent of predicted price to be insured (55-100%). They can also purchase revenue-based insurance, called Crop Revenue Coverage, which provides revenue protection based on price and yield expectations. Farmers who purchase crop insurance also receive a premium "subsidy payment" (USDA, 2006; Babcock and Hart, 2005). According to University of Arizona Extension Economist Russell Tronstad, farmers who cease irrigating their cropland are not entitled to crop insurance on the acres involved in forbearance for that year (Tronstad, May 1, 2006). The foregone

insurance subsidy payment, as well as potential crop insurance payments, cannot readily be factored into NROVC calculations as they do not vary predictably with crop yield. While they could influence a farmer's decision to participate in a forbearance program, many Arizona growers do not purchase crop insurance because almost all crop production is irrigated, so the yield risk is lower than for dryland farming operations (Tronstad, May11, 2006).

A final important consideration is the role of fixed costs of production. Growers may negotiate to include some fixed costs of production in payments received to refrain from irrigating. A rationale for including some fixed costs is to maintain the economic vitality of the overall farm operation, which cannot survive indefinitely if only variable costs of production are covered.

This research examines average crop production conditions for Yuma and La Paz Counties in the University of Arizona Crop Budget framework. Many factors that influence the cost of production as well as yields and gross returns vary widely within a county. For instance, crop yields differ somewhat across soil types in Yuma and La Paz counties. Also, the type of irrigation system a farmer uses and management time and skill 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, the residual valuation method is 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. However, many of these prices fluctuate over time and the NROVC results presented in this report should be treated as *estimates* generalized to the county level. NROVC is a straightforward calculation and, following the basic procedures applied here, can readily be modified and updated to fit the specific production and market conditions faced by a particular group of growers.

CONCLUSIONS

The vast majority of consumptive water use in the Lower Colorado River Basin occurs in irrigated agriculture. When drought conditions threaten to impose high costs in other sectors, voluntary irrigation forbearance can be a means to mitigate regional drought impacts. Irrigators and irrigation districts have access to some of the most senior water in the Lower Basin, while municipalities and other CAP users in Arizona are far more susceptible to dry-year shortfalls.

Voluntary dry-year water leases are particularly conducive to minimizing drought-induced water supply variability. This research highlights promising mechanisms to enhance dry-year supply reliability and reduce regional drought impacts 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 and urban development.

A critical component of structuring and negotiating dry-year transfers is determining the appropriate exercise payment, the compensation growers receives if the option is exercised and they cease irrigating a specific amount of cropland. This research uses the residual (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 useful as a baseline in negotiating exercise payments.

The results indicate that, based on five-year average crop yields and prices, the payment a grower would need to be offered to be just as well off as if they had irrigated is $365.03/acre (or $62.94/AF of water applied) for alfalfa in Yuma County. NROVC for wheat and cotton are both negative in Yuma, suggesting that payments to forbear irrigating these crops are likely to be of interest to growers, as a forbearance payment leaves a grower financially better off than they would have been producing the crops. In La Paz County, NROVC estimates suggest an exercise payment of at least $398.10/acre ($68.64/AF of water applied) for alfalfa, $99.53/acre ($28.44/AF of water applied) for durum wheat, and 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 $3,823.56/acre or $1,062.10/AF of water applied. However, the residual method used to calculate NROVC does not provide an accurate estimate of the on-farm value of irrigation water for high-value crops like lettuce. The costs that are not accounted for in NROVC are particularly high for these types of crops. Special management skill, complex marketing negotiations and a high acceptance of risk are necessary to be successful. Since monetary costs are not readily available for these traits, the residual method overestimates water's value (Young, 2005).

Results from the farm budget analysis highlight the importance of timing in accurately establishing a baseline for exercise payment negotiations. If growers are asked to refrain from irrigating before field crop production begins, compensating them 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 they have already incurred some variable costs of production. Foregone crop revenue is also substantially higher if forbearance programs interrupt vegetable production, so creativity and care are necessary in structuring forbearance agreements in the most cost effective way possible.

The precarious balance of water supply and demand in the Lower Colorado River Basin leaves CAP 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 provide important advantage over permanent acquisitions for all parties to the arrangement. Irrigators use their water for its customary purposes during years when the demand for temporary leases is low and can benefit financially by leasing their water in dry years. Dry-year transfers also provide cities and habitat restoration programs the flexibility to lease water only when supply augmentation is necessary. Instead of incurring the economic and political costs of purchasing permanent water rights, temporary transfers allow 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 general, temporary dry-year transfers are more expensive on a per acre-foot per year basis than the outright purchase of water rights. The higher cost must therefore be justified by a significant improvement in dry-year supply reliability, and by lower third party impacts and political opposition (as compared to permanent acquisitions). Forbearance programs must be carefully structured to maximize supply reliability benefits, to focus on fallowing lower valued crops and to accept reliable "wet water" sources and reject "paper water."

In sum, effective voluntary dry-year lease programs require careful structuring, but if well planned, can decrease the pressure for permanent water transfers out of agriculture. Typically, senior consumptive users such as irrigators and Native American tribes have the most reliable water in a region that could firm supplies for other users by temporary irrigation forbearance. While the third party impacts generated by temporary transfers are lower than with permanent purchases, local economic impacts still must be systematically addressed.

Addressing potential drought shortages is not simple or inexpensive, but pre-planning is more effective and less costly than reactive, crisis management responses to drought. Water in the West creates an "inextricable web of mutuality" between rural and urban users and at the tribal, municipal, state, and federal levels. Tackling supply reliability necessitates integrated participation and acceptance of reliability enhancement strategies from all parties involved. Despite the costs, complexities and collaborative efforts required, temporary irrigation forbearance could well spare the Lower Colorado River Basin from significant economic losses in sectors lacking reliable supplies during severe drought.

REFERENCES CITED

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

Arizona Agricultural Statistics. “2005 Arizona Agricultural Statistical Bulletin.” Sept. 2006. Phoenix, AZ.

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

Arizona Agricultural Statistics. “2002 Arizona Agricultural Statistical Bulletin.” 2003. Phoenix, AZ. http://www.nass.usda.gov/Statistics_by_State/Arizona/Publications/Annual_Statistical_Bulletin/02bul/main.htm.

Arizona Water Banking Authority. “Executive Summary.” http://www.awba.state.az.us/backgrnd/exec_sum.html.

Babcock, Bruce A. and Chad E. Hart. “Influence of the Premium Subsidy on Farmers’ Crop Insurance Coverage Decisions.” Center for Agricultural and Rural Development, Iowa State University. April 2005. http://www.card.iastate.edu/publications/DBS/PDFFiles/05wp393.pdf.

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

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

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 Reclamation. “Development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead Under Low Reservoir Conditions.” Oct. 2005. http://www.usbr.gov/lc/region/g4000/strategies/factsheet.pdf.

Bureau of Reclamation. “Bypass Flow Replacement or Recovery Methods Alternatives.” Dec. 2005. http://www.usbr.gov/lc/region/programs/bypass/alternatives.html#forbear.

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.

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.

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

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.

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.

Checchio, Elizabeth. “Water Farming: The Promise and Problems of Water Transfers in Arizona”, Department of Hydrology and Water Resources, University of Arizona. 1988.

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

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.

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

Frisvold, George. University of Arizona Agricultural and Resource Economic Professor. Email Communication. June 1, 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.

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

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

Harding, Benjamin L., Taiye B. Harding, and Elizabeth A. Payton. "Impacts of a Severe Sustained Drought on Colorado River Water Resources." *Water Resources Bulletin* (Oct. 1995): 815-824.

Howe, Charles W., Lynne Bennett, Charles M. Brendecke, J. Ernest Flack, Robert M. Hamm, Roger Mann, Lee Rozaklis, Mark Griffin Smith, and Karl Wunderlich. "Urban Water Supply Reliability: Preferences of Managers, Elected Officials and Water Users in Boulder, Colorado." Colorado Water Resources Research Institute. December, 1990. cwrri.colostate.edu/pubs/series/completionreport/complete%20CR%20158.pdf.

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. "The Economic Impact of Water Transfers on Alfalfa in the West." Proceedings, Western Alfalfa and Forage Conference, 11-13 December, 2002, Sparks, NV, UC Cooperative Extension. ucanr.org/alf_symp/2002/02-031.pdf.

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).

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.

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/.

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.

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.

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

Martin, Philip. "Impact on Farmworkers of Proposed Water Transfer from Imperial County: A Memorandom to the Latino Lagislative Caucus of the California State Senate, 2003." www.ucop.edu/cprc/farmwkr**water**transfer.pdf

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.

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 Atlas of the United States. Nationalatlas.gov. http://www-atlas.usgs.gov/natlas/Natlasstart.asp

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.

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.

Oad, R. and P. King, "Irrigation Forbearance Feasibility Study in the Middle Rio Grande Conservancy District", MBK Consulting, LLC, July 2005.

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.

Pittenger, Katie, MS thesis, **"Economic Arrangements to Improve Dry-Year Supply Reliability in the Lower Colorado River Basin"**, University of Arizona, 2006.

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

Reinerston, Jim. County Executive Director, Arizona Farm Service Agency, Yuma/La Paz County office. Telephone interview. May 1, 2005.

Saliba, B.C. and D. Bush, "Water Markets in Theory and Practice", Westview Press, 1987.

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

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.

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.

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.

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

Tronstad, Russell. University of Arizona Extension Economist. Personal interview. May 11, 2006.

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

USDA. "Crop Policies." 2005. http://www.rma.usda.gov/policies/.

USDA. "ERS County Typology Codes." 2004. http://www.ers.usda.gov/Data/TypologyCodes/.

USDA. "LDP Summary." 2006. http://www.fsa.usda.gov/FSA/webapp?area=home&subject=prsu&topic=psr

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. "Premium Subsidy Schedule." 2006. http://www2.rma.usda.gov/data/premium.html.

Water Strategist, published by Strat Econ, Claremont, California, 1994.

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

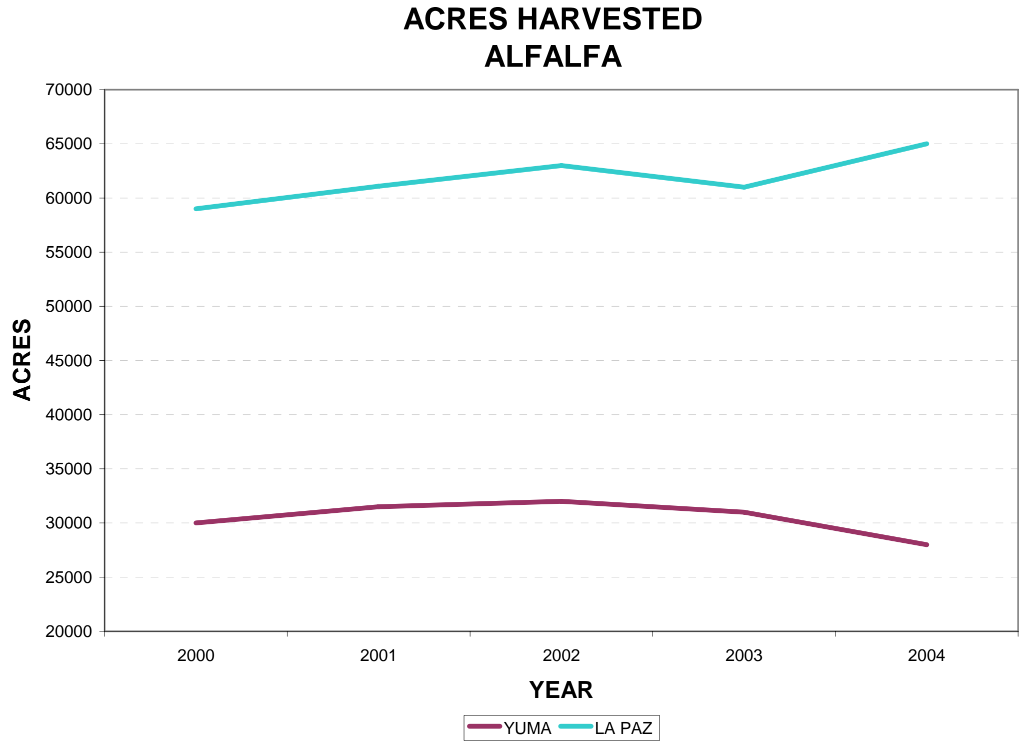
Western Regional Climate Center. "Explanation of Terms." http://www.wrcc.dri.edu/spi/explanation.html.

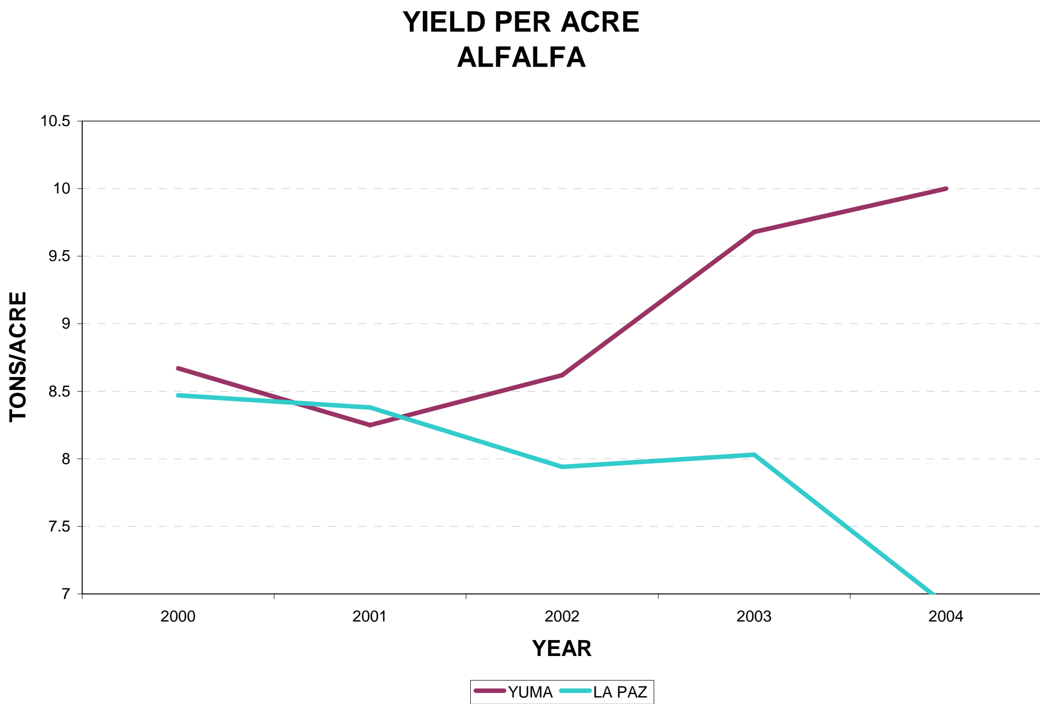
Young, Robert A. *Determining the Economic Value of Water.* Washington, D.C.: Resources for the Future, 2005.

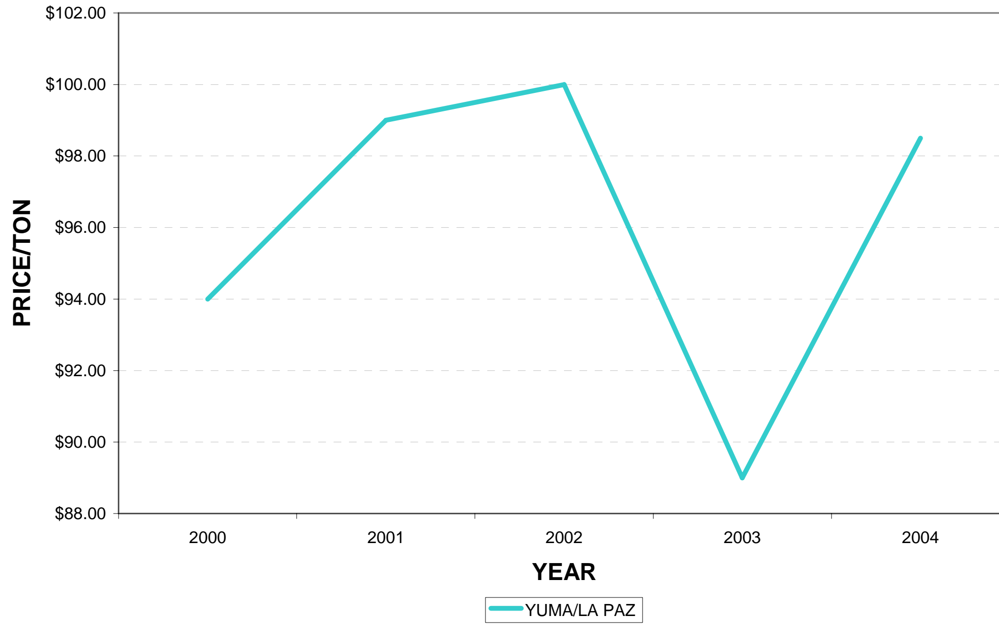
Yuma Desalting Plant/Cienega de Santa Clara Workgroup. 2005. "Balancing Water Needs on the Lower Colorado River: Recommendations of the Yuma Desalting Plant/Cienega de Santa Clara Workgroup." http://ag.arizona.edu/AZWATER/publications/YDP%20report%20042205.pdf.

APPENDIX ONE: Market Price and Yield Graphs

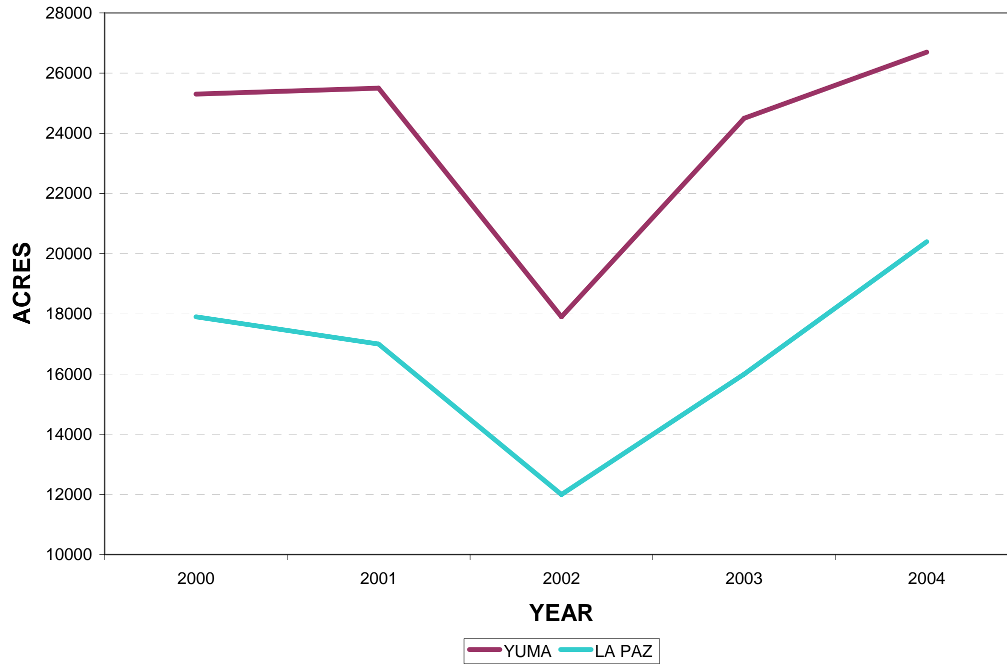
Alfalfa 5-Year Trends

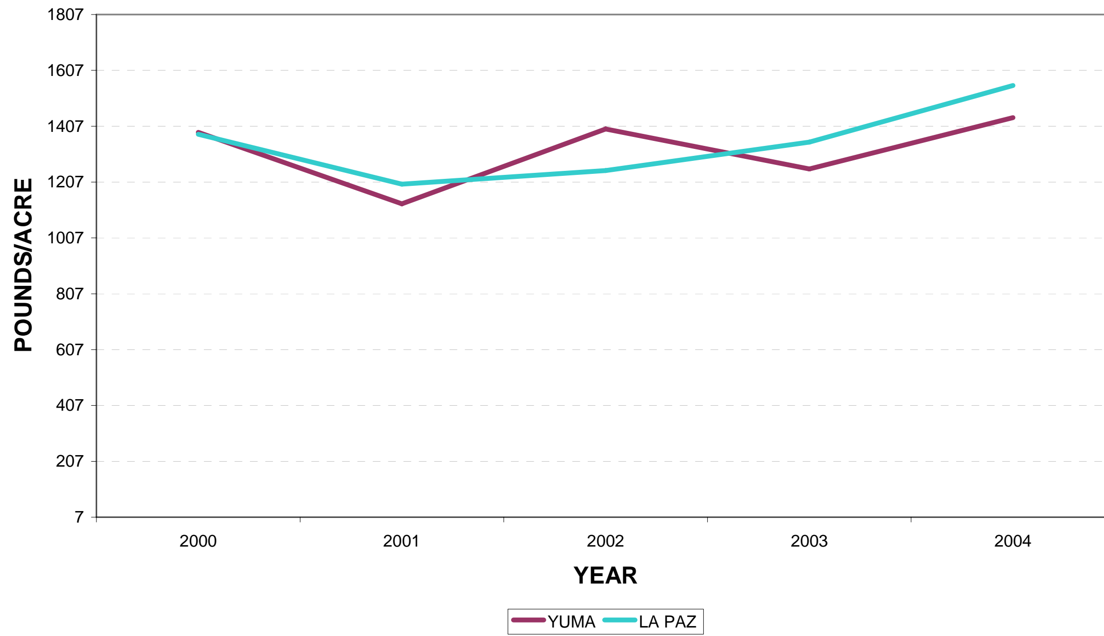


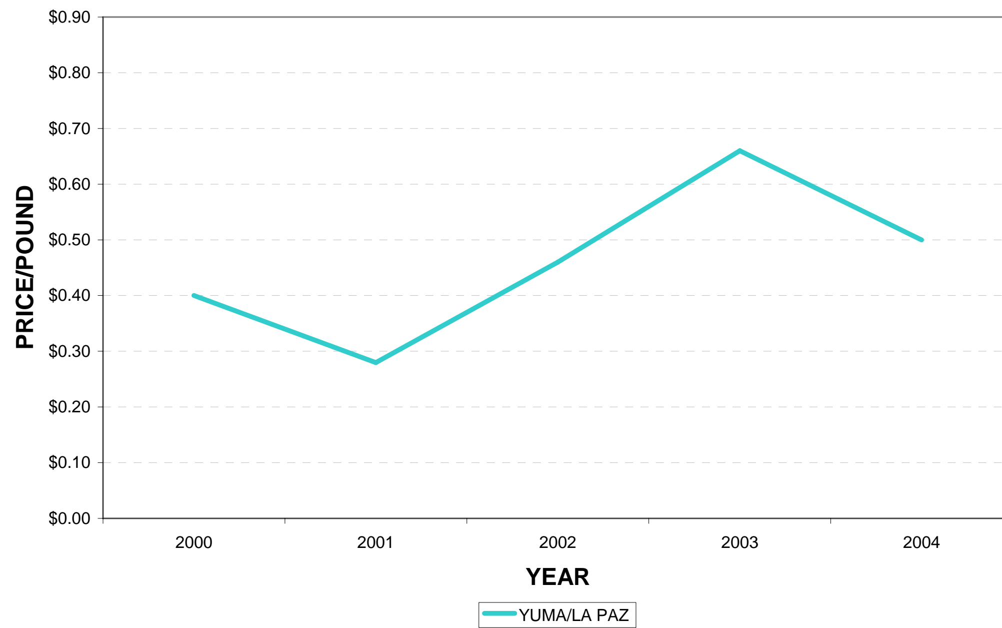




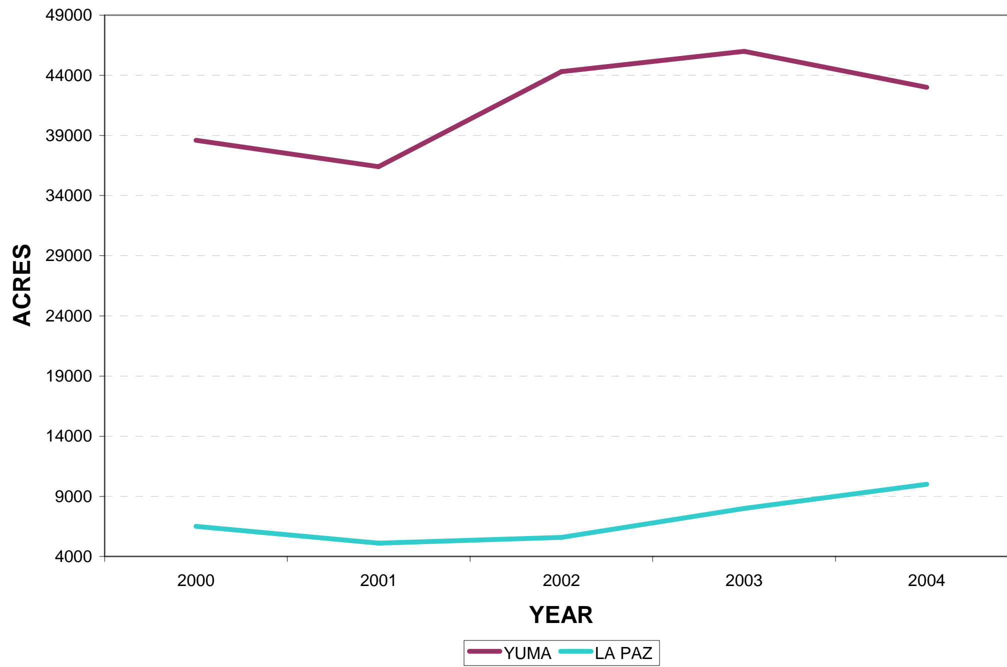
Upland Cotton 5-Year Trends

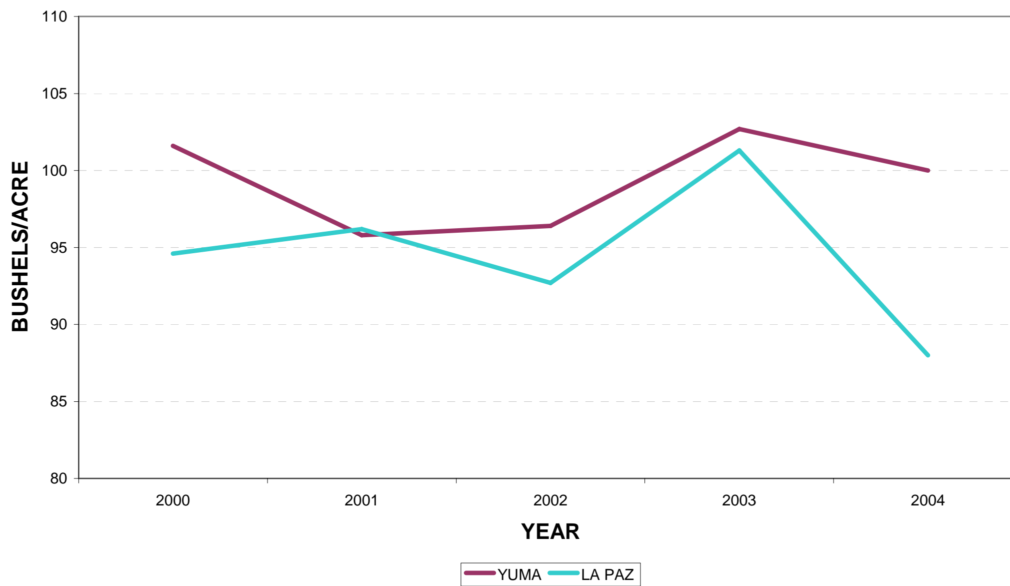


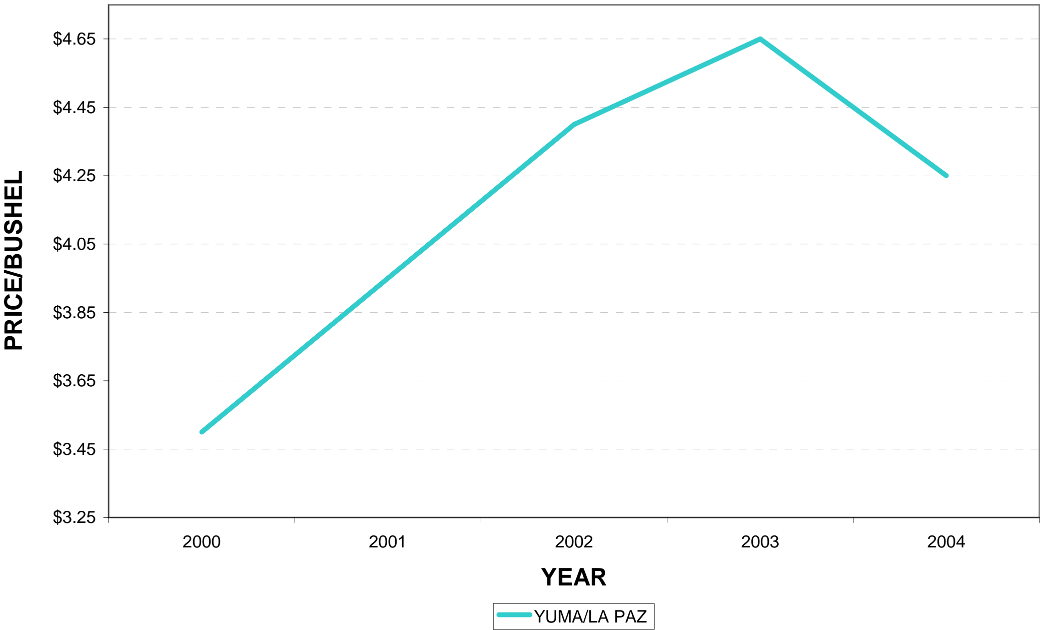




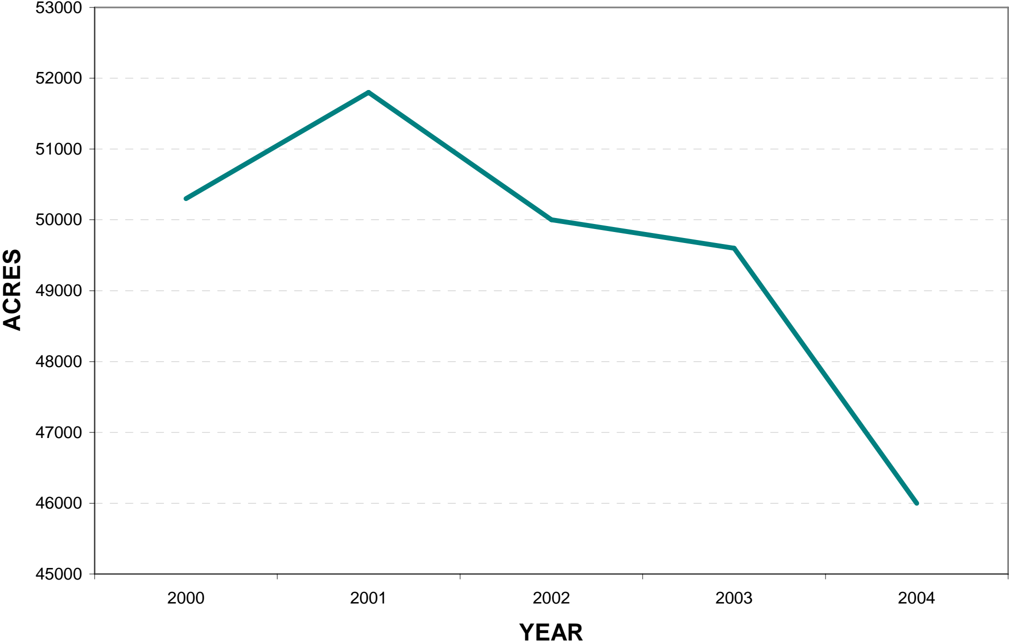
Durum Wheat 5-Year Trends

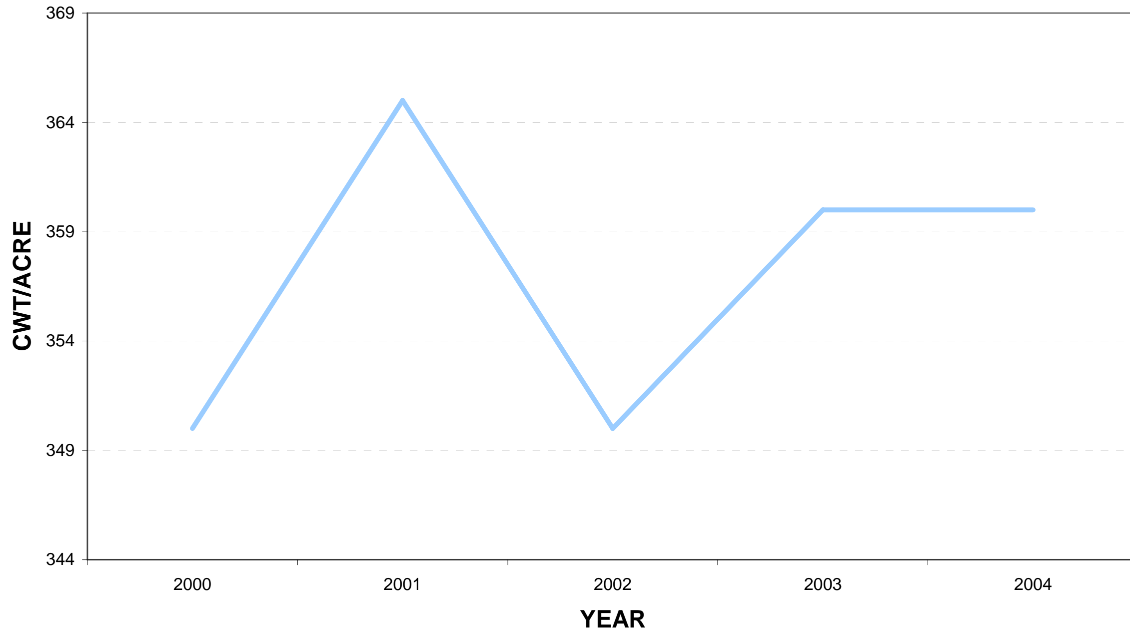

ACRES HARVESTED
DURUM WHEAT
ACRES
49000
44000
39000
34000
29000
24000
19000
14000
9000
4000
2000
2001
2002
2003
2004
YEAR
YUMA
LA PAZ

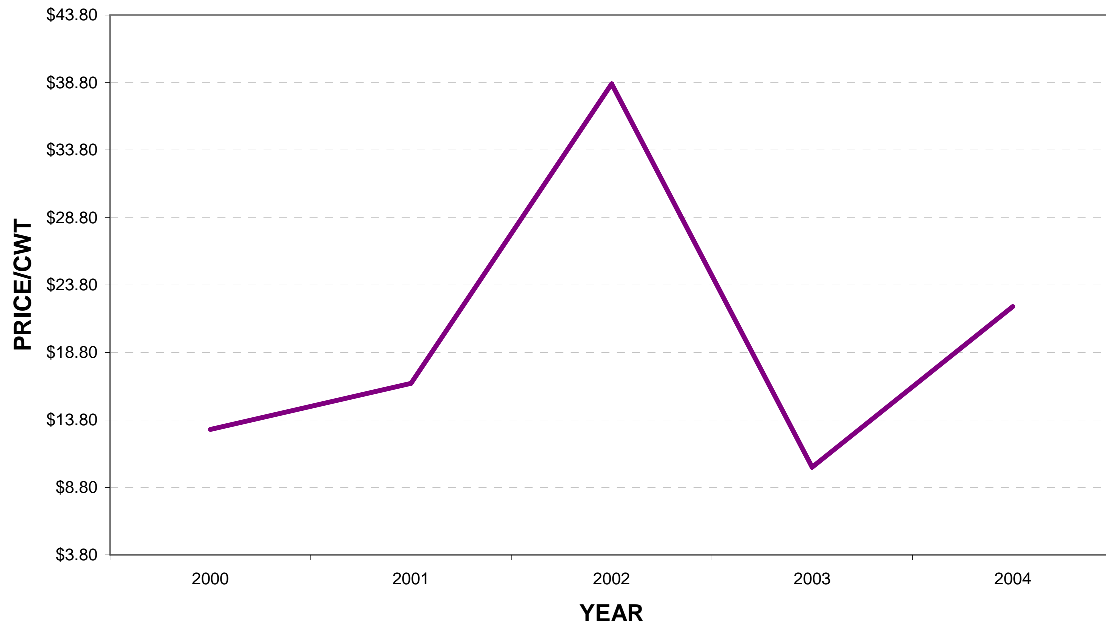

YIELD PER ACRE
DURUM WHEAT
BUSHELS/ACRE
110
105
100
95
90
85
80
2000
2001
2002
2003
2004
YEAR
YUMA
LA PAZ



Head Lettuce 5-Year Trends




YIELD PER ACRE
YUMA HEAD LETTUCE
CWT/ACRE
369
364
359
354
349
344
2000
2001
2002
2003
2004
YEAR


PRICE PER CWT
YUMA HEAD LETTUCE
PRICE/CWT
$43.80
$38.80
$33.80
$28.80
$23.80
$18.80
$13.80
$8.80
$3.80
2000
2001
2002
2003
2004
YEAR

APPENDIX TWO: Variable Costs By County and Crop

TOTAL VARIABLE COSTS PER ACRE (LESS WATER)

YUMA COUNTY	Alfalfa	Upland Cotton	Durum Wheat	Head Lettuce
<u>**Variable Costs per Acre**</u>				
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

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

APPENDIX THREE: NROVC Calculations

Yuma Alfalfa Production	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre	10	9.044	10	8.25
Price/unit	99.5	96.4	100	89.5
LDP Rate	0	0	0	0
Price Plus LDP per unit	99.5	96.4	100	89.5
Gross Revenue ($/Acre)	995	871.8416	1000	738.375
Total Variable Costs per Acre	506.81	506.81	506.81	506.81
Net Returns Over Variable Costs Per Acre	488.19	365.0316	493.19	231.565
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	84.17	62.94	85.03	39.93

Yuma Upland Cotton	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre (lint)	1438	1320.6	1438	1129
Price/unit (lint)	0.5	0.4616	0.664	0.284
Yield/acre (seed)	1.24	1.06	1.24	0.87
Price/unit (seed)	160	139.2	160	124
LDP/Marketing Gain Rate	0.149	0.143	0.076	0.28
Price Plus LDP per unit	0.649	0.6046	0.74	0.564
Gross Revenue ($/Acre)	1131.662	945.98676	1262.52	744.636
Total Variable Costs per Acre	1194.37	1194.37	1194.37	1194.37
Net Returns Over Variable Costs Per Acre	-62.708	-248.38324	68.15	-449.734
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	-14.93	-59.14	16.23	-107.08

Yuma Durum Wheat	2004	5yr Avg	High	Low
Revenue per Acre				
Yield/acre	100	99.3	102.7	95.8
Price/bushel	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

Yuma Head Lettuce	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	360	357	365	350
Price/cwt	22.2	20.16	38.7	10.3
LDP Rate	0	0	0	0
Price Plus LDP per unit	22.2	20.16	38.7	10.3
Gross Revenue ($/Acre)	7992	7197.12	14125.5	3605
Total Variable Costs per Acre	3373.56	3373.56	3373.56	3373.56
Net Returns Over Variable Costs Per Acre	4618.44	3823.56	10751.94	231.44
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	1282.90	1062.10	2986.65	64.29

LA PAZ Alfalfa Production	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	6.92	7.948	8.47	6.92
Price/unit	99.5	96.4	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	99.5	96.4	100	89.5
Gross Revenue ($/Acre)	706.54	784.1872	865	637.34
Total Variable Costs per Acre	386.09	386.09	386.09	386.09
Net Returns Over Variable Costs Per Acre	320.45	398.0972	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	55.25	68.64	82.57	43.32

LA PAZ Upland Cotton	2004	5yr Avg	High	Low
Revenues per Acre				
Yield/acre	1553	1345.8	1553	1200
Price/unit	0.444	0.45	0.664	0.284
Yield/acre (seed)	1.34	1.08	1.34	0.93
Price/unit (seed)	163	139.8	163	124
LDP Rate	0.149	0.143	0.076	0.28
Price Plus LDP per unit	0.593	0.593	0.74	0.564
Gross Revenue ($/Acre)	1139.349	949.0434	1367.64	792.12
Total Variable Costs per Acre	1060.78	1060.78	1060.78	1060.78
Net Returns Over Variable Costs Per Acre	78.569	-111.7366	306.86	-268.66
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	18.71	-26.60	73.06	-63.97

LA PAZ Durum Wheat	2004	5yr Avg	High	Low
<u>Revenues per Acre</u>				
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

2005 & 2004 Arizona Agricultural Statistics Bulletins, yield and price data.
County cottonseed yield/acre computed using actual statewide cotton lint/seed ratio 2000-2004, 2005 & 2004 Arizona Agricultural Statistics Bulletins.
USDA "LDP Summary," LDP and marketing gain rate data.
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, 2002 Census of Agriculture,* http://www.nass.usda.gov/census/census02/fris/tables/fris03_28.pdf, water application rates

APPENDIX FOUR: SEASONAL OPERATIONS AND CUMULATIVE COSTS

County: Yuma
Crop: Hay 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: 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:	Yuma					
Crop:	Upland Cotton					
Tot. Variable Cost:	$1,194.36					

Month	Operations	Class	Cost	Running Total ($)	% of Total Variable Cost	Running Total (%)
Dec	Rip	Lnd Prep	10.10	10.10	0.85	0.85
Dec	Disk	Lnd Prep	12.48	22.58	1.04	1.89
Jan	Laser Level	Lnd Prep	52.46	75.04	4.39	6.28
Jan	Roll Beds	Growing	2.38	77.42	0.20	6.48
Jan	List	Lnd Prep	6.97	84.39	0.58	7.07
Feb	Preirrigate	Growing	6.39	90.78	0.54	7.60
Mar	Mulch	Lnd Prep	5.52	96.30	0.46	8.06
Mar	Plant	Lnd 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 Insectidie/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 Insectidie/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 Hvst	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 Hvst	4.69	1126.46	0.39	94.31
Dec	Disk Residue	Lnd 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:	**La Paz**					
Crop:	**Upland Cotton**					
Tot. Variable Cost:	**$1,151.62**					
Month	**Operations**	**Class**	**Cost**	**Running Total ($)**	**% of Total Var. Cost**	**Running Total (%)**
Dec	Disk	Lnd Prep	13.03	13.03	1.13	1.13
Dec	Rip	Lnd Prep	38.84	51.87	3.37	4.50
Dec	Laser Level	Lnd 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	Lnd 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	Lnd 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 Hvst	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 Hvst	6.95	1086.53	0.60	94.35
Dec	Disk Residue	Lnd 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: **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:	**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 Inerest 6%		18.75	3423.49	0.55	100.00
	TOTAL		3423.49	3423.49	100.00	100.00