WATER FOR ECOSYSTEMS: CONTINGENT VALUATION IN COLORADO RIVER DELTA AND ANALYSIS OF WESTERN U.S.WATER MARKET ACTIVITY

By

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DEDICATION

To my family and friends

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ABSTRACT

Extensive diversions of water for agricultural, municipal, and industrial uses have left freshwater and riparian ecosystems disturbed and degraded. In order to maintain, protect, and restore these ecosystems and the benefits that they provide, several challenges must be overcome. The first is to ensure that the non-market benefits that these ecosystems provide are valued and considered in decision-making processes. The second is to physically secure water for these imperiled ecosystems. This thesis addresses both of these challenges by: 1) valuing the ecosystem service benefits of water-dependent ecosystems through a contingent valuation study in the Colorado River Delta, Mexico and 2) conducting an econometric analysis to understand water market activity in the western United States and to identify components that lead to higher levels water market activity.

CHAPTER 1. INTRODUCTION

1.1 OVERVIEW OF THE "PROBLEM"

Extensive diversions of water for agricultural, municipal, and industrial uses have left freshwater (such as lakes, wetlands, streams, springs and rivers) and riparian ecosystems disturbed and degraded. As a result of their degradation, society is faced with losing the ecosystem services and benefits that healthy ecosystems were once able to provide. Ecosystem services, as defined by the Millennium Ecosystem Assessment (MA), are "the benefits that people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005).

In order to protect, maintain, or restore water-dependent ecosystems and the benefits that they provide to society, there are several necessary actions required. The first is to ensure that the non-market benefits that these ecosystems provide are valued and considered in decision-making processes. The second necessary action is to physically secure water for these imperiled ecosystems. However, both of these objectives are not easy tasks. Determining the value of non-market goods requires careful analysis and can be time-, energy-, and resource-intensive. Securing water for the environment is difficult as well, because many river basins worldwide are already over allocated.

There are, however, promising strategies to address these issues. The Contingent Valuation Method (CVM) is a vetted technique used to value non-market goods, such as water-dependent environmental goods. A promising strategy to provide water for freshwater environmental amenities is to use markets to reallocate water from existing, low-value uses to new, high-value uses. An example of this is the transfer of a water right from an agricultural use to an environmental use. Sometimes this can involve an agreement to not divert water for crops, and therefore maintain an environmentally beneficial level of instream flow. Because using markets to reallocate freshwater is one of the most prominent strategies for acquiring water for the environment, it is important to understand the components of the water market.

This thesis addresses both aspects of this problem: 1) valuing the ecosystem service benefits of water-dependent ecosystems and 2) understanding the components of the water market. Although this thesis presents different types of economic analyses of these topics involving different locations, the overall theme is clear: valuing and securing water for freshwater and riparian ecosystems. The first aspect provides an ex-ante viewpoint. W*hy should we care about these ecosystems? What are the benefits that they provide? And how do we measure the value provided by these ecosystems?* One key framework for examining the importance of these ecosystems is derived from the ecosystem services concept. This is an important concept that links ecosystem function and processes to human welfare. While the MA publication has been fundamental in providing an easily understood definition and classification of ecosystem services, it lacks the operational capacity to quantify and value the benefits derived from ecosystems. This thesis reviews existing literature that supports an economic definition of ecosystem services and then provides a classification and valuation of select services in the Colorado River Delta. The second aspect provides an ex-post viewpoint. Given that these ecosystems and the environment, in general, are valuable to society, *how can we secure water to protect, maintain and restore these ecosystems? And what are the factors that lead to higher levels of water market activity?*

1.1.1 Case Study: Colorado River Delta

In order to address the first component of the problem, I select the Colorado River Delta (Delta) in Northwestern Mexico as the location of the study. The Delta was selected for a number of reasons. The first reason is that the Delta embodies the extreme degradation that can occur from extensive diversions of freshwater from river systems. The Delta, a once massive and vibrant delta ecosystem in northern Mexico, has been severely affected by the construction and operations of dams and diversions along the Colorado River. Prior to dams being built, the Delta covered approximately 2 million acres (800,000 hectares) and Colorado River water supported the Delta's extensive riparian, wetland, and estuarine ecosystems (Zamora-Arroyo et. al., 2005). The massive diversions of water for 3 million acres of irrigated agricultural land and for more than 30 million municipal water users in both the United States and Mexico have left very little water for the Delta and the Upper Gulf of California (Wheeler, 2007; National Geographic Society, 2010). Today, this lack of water has reduced the Delta to approximately 10% of its original size (Zamora-Arroyo et. al., 2005).

Perhaps more important than its role showing how drastically ecosystems can be affected, the Delta is the focus of this thesis because of the numerous benefits it provides. Despite the radical alterations in water availability and the resulting shrinkage, the Delta is still recognized as an immensely important ecological zone. The Delta provides habitat for over 350 species of birds, 24 protected Mexican species, several U.S. protected species, and other resident fish, marine mammals, and wildlife (Nagler et. al., 2009; Hinojosa-Huerta et. al., 2005). In addition to the habitat provided for year-round wildlife, the Delta provides a vital stopover for birds migrating on the Pacific Flyway. It is estimated that almost 200,000 shorebirds and 60,000 ducks and geese use the Delta wetlands as wintering grounds or for stopovers on migratory routes (Morrison et. al., 1992; Mellink et. al., 1997), and at least 110 species of neotropical landbirds use the Delta as a migratory stopover (Patten et. al., 2001). The wetlands (particularly the Cienega de Santa Clara) in the Delta have been recognized both nationally and internationally with its partial designation in Mexico's Biosphere Reserve of the Upper Gulf of California and Colorado River Delta in 1993 and its recognition as an important wetland by a RAMSAR decree (Zamora-Arroyo et. al., 2005; Carrillo-Guerrero, 2005).

In addition to its national and international recognition as an important area for biodiversity and bird species, the Delta provides key cultural resources for local communities. Indigenous communities such as the Kwapa (also known as the Cucapá tribe in Mexico and the Cocopah tribe in the United States) rely on the Colorado River and the Delta to keep their indigenous culture alive (Colorado River Delta Legacy Program, 2009). Furthermore, the Colorado River, Hardy River (a tributary of the Colorado River in Mexico), and wetlands of the Colorado River Delta provide a place for local communities and tourists, alike, to participate in recreational activities. Many Mexican and American families spend holidays and other vacations enjoying the nature opportunities that the Delta provides.

The third and final reason why the Delta was chosen for this study is the remarkable resilience that the Delta has demonstrated over the years. Unfortunately, the water that currently sustains the Delta arrives there inadvertently and with no assurances regarding volume, timing, and water quality. The Delta is sustained by agricultural runoff, inadvertent releases from upstream reservoirs, and the very infrequent flood control releases (Wheeler et. al., 2007). However, during those rare wet years where water has reached the Delta, portions of the Delta's ecosystems have been revived. The Delta's ecosystems (riparian, wetland, and estuarine) can and would be restored if water were to be allocated to them. Therefore, it becomes obvious that this area is an excellent candidate to participate in a water market geared at securing water for the environment. Not only is it an excellent candidate because of its resilience when water is provided, but there is also a sense of urgency to protect this unique ecosystem. The unreliability of flows to the Delta is expected to worsen due to projected increases in demand from municipal uses and the hydrological effects of climate change. All of these factors further imperil the survival of the Delta. Without assured water flows, the ecosystems of the Delta are at risk of disappearing. Water markets can be the mechanism that secures water and gives hope back to the Delta.

1.1.2 Value of Water for the Environment

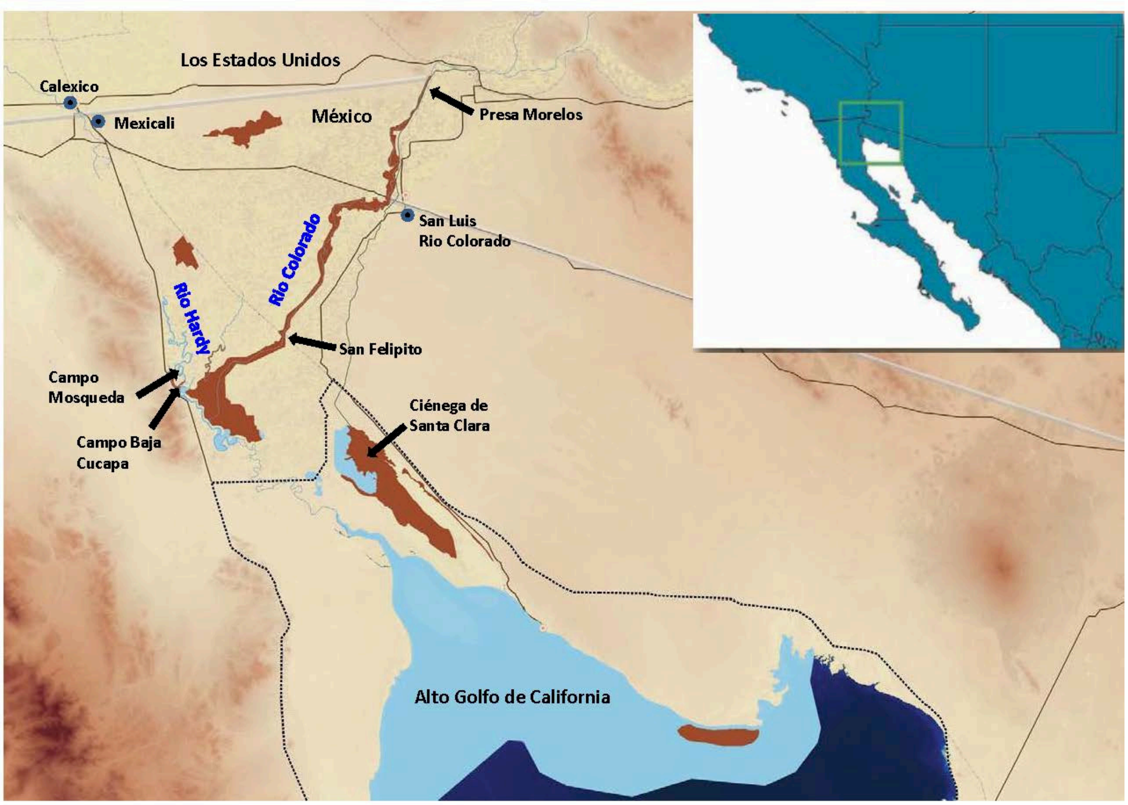
In order to contribute further to the discussion of water management in the Colorado River, one of the objectives of this thesis is to understand the economic value of water for recreation in the Delta as well as the value that visitors place on water for a healthy ecosystem. By demonstrating that the protection of the Delta's ecosystems has tangible benefits for the community and that the community values healthy ecosystems, this study can support decision-making when determining the appropriate allocation of scarce Colorado River resources. This portion of the thesis is the first in a series of studies being conducted by the Sonoran Institute, an environmental non-profit organization based in Tucson, Arizona. The projects, as a whole, seek to understand the value of water for recreational activities in the Colorado River Delta. Whereas another project focuses solely on the value of water for hunters in the Delta, this study focuses on the value of water to support a healthy Delta for all types of visitors. While the value of water for agricultural, industrial, and municipal uses can be determined by the market price of water and the link that water has to market outputs (crops, energy generation, etc.), the value of water for non-extractive uses is much more difficult to determine. Non-extractive uses, such as water for recreation and preservation of riparian and aquatic ecosystems, have significant economic importance. However, because there is an absence of market transactions, the value of water for these uses must be determined outside of the traditional market valuation.

The method employed in this study is the widely-accepted contingent valuation method (CVM). The CVM is one type of non-market valuation that economists commonly use to assess the value of natural resources that are not captured by traditional markets. It allows for the inclusion of several different aspects of natural resource value. The first is the value that an individual receives from non-consumptive direct use of the resource. Recreation is an example of this type of value. The individual is using the natural resource by being present in the recreational area, but is enjoying the area in a non-consumptive manner. Recreation, however, is not always a non-consumptive use of the resource. Hunting and fishing, for example, is a direct and consumptive use of the resource. A second category of value is non-use value. Non-use value is based on several motivations: existence value, bequest value, and option value. Existence value is the value that an individual places on the maintenance and protection of the resource. In this case, even though the individual doesn't use the resource, it has value solely because of its existence. Bequest value is the value that an individual places on an environmental resource for the preservation of the resource for future generations. Again the individual may not currently use the resource, but places value on it because they'd like future generations to have the opportunity to enjoy it as well. Finally, option value also derives its value from the preservation of the resource for future use. Even though there may be a low likelihood that an individual will use the resource, they place value on preserving the resource because then they have the option of using the resource in the future.

The value of water for non-extractive recreational uses, and the value of water for the environment, is often not considered when making water management decisions. Nevertheless, difficult decisions will need to be made regarding the allocation of scarce Colorado River water resources, and it is imperative that the economic value of recreation and preservation of the Colorado River Delta is included in these decisions.

One purpose of this thesis is to quantify the value of recreation and environmental flows in the Colorado River Delta, and to better inform water management decisions in the Colorado River Basin. For this reason, I conduct a contingent valuation study in five different recreation sites within the Colorado River Delta. The sites where the surveys were conducted are: Campo Mosqueda, Campo Baja Cucapah, Morelos Dam, San Felipito, and the Cienega de Santa Clara (see map below, survey locations are marked by arrows).

FIGURE 1. MAP OF SURVEY SITES IN THE COLORADO RIVER DELTA



Source: Sonoran Institute Map (2012)

1.1.3 Western United States Water Markets

Due to extensive over-allocation of water rights and water shortage conditions in the western United States, water markets have been increasingly used as a means to secure water for a number of different uses. The growth of water markets suggest that these are proving to be an effective tool to reallocate water based on changing demands. In order to understand how these water markets work, it is important to understand the history of water in the West and the components that facilitate these types of transfers.

Water in the West is governed by the prior appropriation doctrine. This is a doctrine based upon the "first in time, first in right" principle. Essentially, the first claimant to water has priority as long as the water is being put toward "beneficial use". In times of scarcity, a junior water right holder's diversion may be curtailed in favor of ensuring water for the senior water right holder. Thus, through the prior appropriation water right structure, an essential component to the development of a market is established: the private property right of water use (Payne and Root, 2011). In the western United States, agriculture is the primary senior water right holder.

The second component necessary for water market development is transferability (Payne and Root, 2011). In general, though to varying degrees, western states allow water to be transferred from one place of use to another, or from one use to another. In most states, water right holders can transfer their water right or a portion of their water right through a sale, lease, or trade. However, most states require that the water transfer be approved by the State Engineer and meet and abide by the state's laws regarding diversion location, beneficial use and non-injury to third-parties.

1.1.4 Water for the Environment

Historical demands and uses of water have been primarily for economic production-meaning that large amounts of water were diverted out of rivers to mines, farms, industries, and cities. There was even a notion that any undiverted water was seen as being wasteful (Scarborough, 2010). For this reason, many states did not recognize keeping water in the river for environmental and recreational uses as a beneficial use of water. As a result, water transfers for environmental purposes were not feasible until these uses were legally recognized as a beneficial use. The gradual expansion of water laws across the West to include water for the environment as a beneficial use has created the opportunity for market-based transfers to secure flows for environmental and recreational purposes (Scarborogh, 2010).

In 2012, most western states permit the trading of water rights for instream uses and/or environmental purposes. However, the degree to which there are restrictions on transactions to acquire water for environmental purposes remains varied across the states. Some states have policies very supportive of instream flows and others are very restrictive. In Washington, instream flows for "fish and wildlife maintenance and enhancement, protection of game and birds, recreation, scenic, and all other uses compatible with the enjoyment of the public waters of the state" are considered as a beneficial use (Scarborough, 2010). Wyoming, by contrast, limits instream flow rights to establish or maintain fisheries.

Understanding the factors that influence periods and locations with higher water market activity may provide insight to the strategies that should be employed to secure water for the environment. As such, the second objective of this thesis is to promote understanding of water markets and their activity. Using water transfer data from numerous western states (Arizona, California, Colorado, Idaho, New Mexico, Nevada, Oregon, and Washington) for the years 1987 to 2010, I develop several econometric models to analyze water market activity. I define market activity in three different ways: the number of transactions per year, the total volume of water transferred per year, and the total dollar value of all water transferred in one year.

1.2 Summary of Findings

The results of the CVM study (reported in full in Chapter 4) suggest that recreational visitors to the Delta are willing-to-pay in order to guarantee adequate amounts of water to support and maintain a healthy Delta ecosystem, with just under 60% willing-to-pay the amount proposed to them. Visitors to Campo Baja Cucapah and Campo Mosqueda, along the Hardy River, have a median WTP of $168 pesos ($13 USD) per car per entry. Visitors to Morelos Dam, San Felipito, and the Cienega de Santa Clara, on the other hand, have a median WTP of $97 pesos ($7 USD) per car per entry. Aggregate WTP values could be estimated if annual visitor numbers to these recreation sites were known. At the time of this study, this data was unavailable.

The results of the water market activity analysis emphasize that the factors influencing levels of water market activity vary depending on the definition of market activity. It also demonstrates that a state's level of activity varies upon the definition of market activity, with Colorado being the most active state when the number of transactions defines activity, and California being the most active when volume and total dollar value defines activity. A consistent result in the lease market is that as farm net income increases, the market activity (as defined by the total volume of water and the total dollar value expended) decreases. Intuition supports this result as we expect that farmers would be less interested in leasing water when they are experiencing high net cash income. In combination with the result that an increase in the price per acre feet of water increases the market activity, this suggests that the water market is a supply-dominated market.

Finally, the results suggest that water for the environment has secured a significant position within the lease market in terms of the number of transactions. However, if the goal is to increase the volume of water for ecosystems, special attention should be paid to the agricultural sector. Environmental organizations seeking to secure water for ecosystems could target farmers and use innovative short-term leases to ensure that farmers are compensated and larger volumes of water could be transferred to environmental purposes at the times of year when water is the most needed for environmental flows.

CHAPTER 2: LITERATURE REVIEW

Literature reviewed for this research is separated into four major sections. The first section takes a deeper look into what ecosystem services are and the important considerations that should be taken when defining, quantifying and valuing ecosystem services. The second section provides a review of the Contingent Valuation Methodology: its origins, leading research, and uses to determine the non-market value of water dependent ecosystems. The third section sheds some light on the history of the Colorado River and Delta, the ecosystems present in the Delta, and the ecosystem service benefits provided by the Delta. Finally, the fourth section provides the most recent water market literature, with special emphasis on water that has been transferred for environmental purposes.

2.1 ECOSYSTEM SERVICES: DEFINITIONS, DEBATES AND IMPORTANT CONSIDERATIONS

The idea of ecosystem services is not a new concept. Throughout history, humans have acknowledged that their well-being is related to functioning ecosystems around them. In fact, the concept of ecosystem services has been around since the time of Plato. He and other philosophers were concerned about "the environment's capacity to provide sufficient resources for a growing population" (Brauman, et. al., 2007:69). The concerns were that a degraded ecosystem would no longer be able to provide the services needed to continue on with normal life. It has only been within the last decade, however, that a framework has been developed to characterize, define and explain the dynamic interaction between ecosystem services and humans.

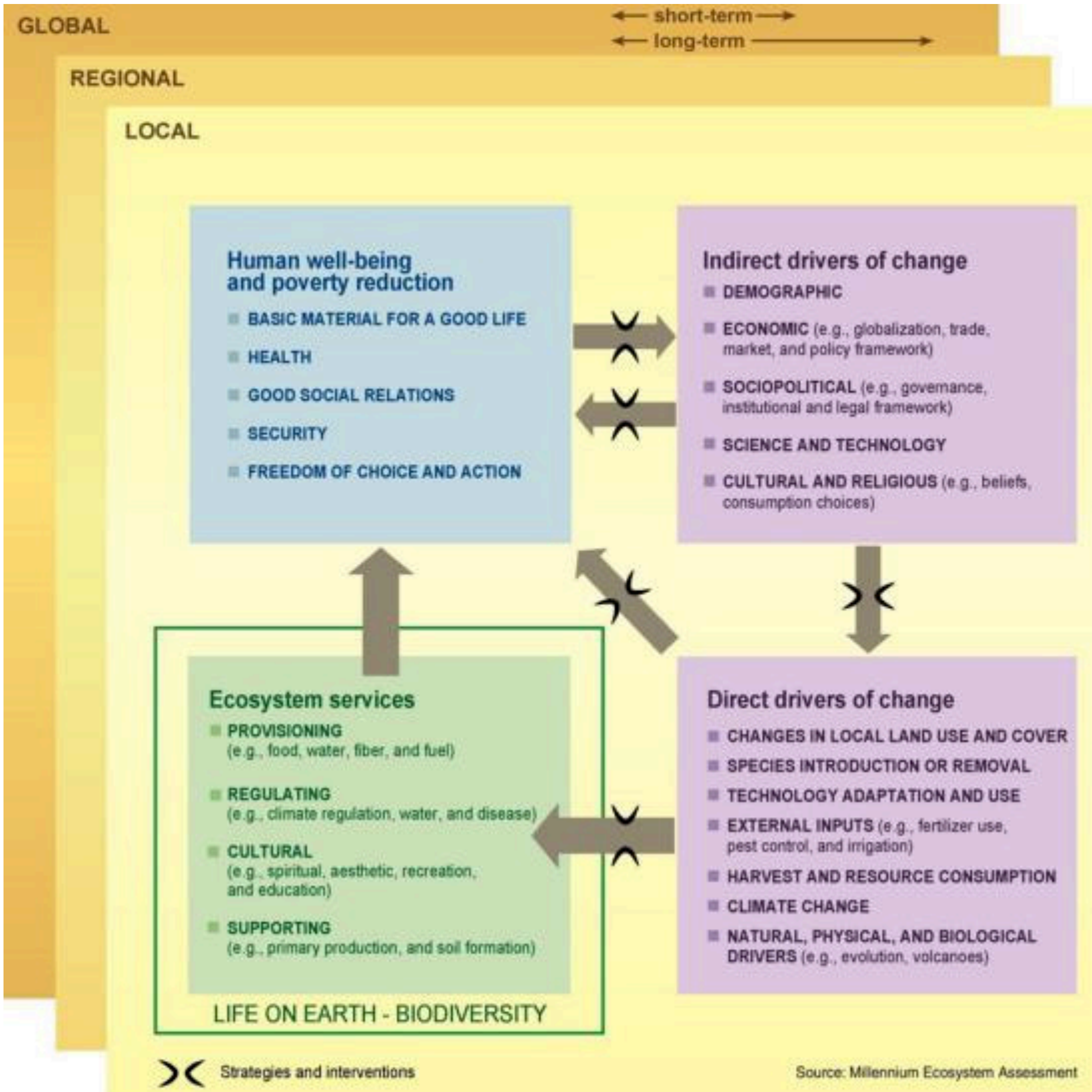
2.1.1 SETTING THE STAGE: THE MILLENNIUM ECOSYSTEM ASSESSMENT

The Millennium Ecosystem Assessment (2005), the most well-known and prominent conceptual framework, defines ecosystem services as “the benefits people obtain from ecosystems” (26). This paramount study, conducted by more than 1,360 experts worldwide, examined the conditions of the world’s ecosystems and the services they provide, as well as highlighted the complex interactions between humans and ecosystems. The study’s findings suggest that although human actions have effectively captured ecosystem services that have resulted in significant gains to human well-being, these actions have also resulted in the degradation of other essential ecosystem services (Millennium Ecosystem Assessment, 2005). A key example that demonstrates the tradeoffs that exist between multiple ecosystem services is the damming of rivers. Although societies have “reaped substantial economic rewards from these modifications to rivers- from the generation of hydroelectric power to the expansion of irrigated agriculture” to storage of water supplies for municipal use, “serious losses have mounted on the ecological side of the ledger” (Postel and Richter, 2003: 2). Rivers, in their natural state, provide other ecosystem services such as “purifying water, moderating floods and droughts, and maintaining habitat for fisheries, birds, and wildlife” (Postel and Richter, 2003: 2). It is the loss of these other ecosystem services that pose concern for current and future generations.

The MA describes ecosystem services as belonging to four different components. They define ecosystem services as provisioning, regulating, supporting, or cultural services. Provisioning services, according to the MA (2005), are “the products people obtain from ecosystems, such as food, fuel, fiber, freshwater, and genetic resources” (29). Essentially, provisioning services are the tangible products that ecosystems produce. Regulating services are the benefits that humans receive from ecosystem processes, such as climate, flood and disease regulation. Cultural services are the “nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (29). Finally, supporting services are those processes that are essential for the production of all other services. Examples of supporting services are nutrient cycling, soil formation and production of oxygen (MA, 2005).

The Millennium Assessment's conceptual framework hinges on the complex interactions between humans and ecosystems. Its focus is centered on human well-being but also describes how humans directly and indirectly drive changes in ecosystems and how, in turn, those changes in ecosystems affect the services provided, and the resulting changes in well-being. Figure 2 below, depicts the Millennium Ecosystem Assessment's conceptual framework. One key contribution of the conceptual framework is its promotion of understanding the factors that cause changes in ecosystems and service provision. As shown in the figure below, there can be indirect and direct drivers of change. By understanding where pressures on ecosystems originate, it is possible to adopt different, more sustainable management strategies.

FIGURE 2. MILLENNIUM ECOSYSTEM ASSESSMENT CONCEPTUAL FRAMEWORK



Source: Millennium Ecosystem Assessment (2005)

2.1.2 Evolution to Operational Definition of Ecosystem Services

While the MA is considered groundbreaking due to its originality and the sheer size of the study, many researchers argue that the MA provides *only* a conceptual framework; it lacks the capability to be used in an operational setting and to direct public policy. It does not provide a framework that facilitates the quantification and valuation of ecosystem services.

Why do we care about quantification and valuation of Ecosystem Services?

There has been enormous interest in quantifying and valuing the benefits that humans derive from well-functioning ecosystems. The idea is that if the benefits of healthy functioning ecosystems can be quantified, there will be arguments for protection of these ecosystems.

From a public policy perspective, quantification and valuation of ecosystem services has become an imperative component in developing environmental policy. Boyd and Scarlett (2011) outline four main drivers for heightened interested in ecosystem service research. The first driver is the potential reductions in costs associated with losses of ecosystem services. For example, restoration or maintenance of healthy ecosystems may reduce the costs from natural disasters such as flooding and hurricanes. Secondly, there are possibilities to use ecosystem services as an alternative, and potentially more cost-effective way to comply with regulations. The example given in Boyd and Scarlett's article takes place in Oregon's Tualatin Basin. Here, water managers paid farmers to plant trees along streams in order to reduce the water temperature, therefore meeting the requirements by law. The other option for reducing the water temperature would have been to build refrigeration systems to cool the water. In this case, water managers capitalized on the available ecosystem services and saved approximately $54 million in the process (2). In addition to the cost savings in regulatory compliance, there is also the possibility of reducing costs for basic community services. For example, Seattle invested in natural landscapes as opposed to using traditional engineering solutions to reduce stormwater runoff. By taking the natural ecosystem route, the cost was reduced by about 25 percent (2). Finally, there is interest in ecosystem service research because it potentially leads to "new revenue streams for landowners and land managers to support conservation, open space protection, and sustainable practices" (1). Once the benefits of healthy ecosystems can be quantified and valued, there are arguments that the public will come to pay for these services and those payments will be used to ensure the continuing provision of service by protecting, maintaining or restoring the ecosystem that provides it.

It is also important to consider how the quantity of ecosystem services are linked to human well-being and vice versa. Considerations should include how human activity affects service production and how ecosystem size and health relates to service production and provision. Land management can be effectively directed by understanding how much area and ecological integrity must be preserved to sustain a particular level of ecosystem services. Another important consideration to be made is whether the ecosystem service can be replaced by a technology substitute, and whether that substitute is effective. Brauman et. al. (2007) warn that "although some ecosystem services are partially or wholly replaceable through technology or substitution, technologies may have lower resilience, cost-effectiveness, suitability, and life span than the ecosystem services they replace" (81).

Boyd (2011) takes the argument for quantification and valuation of ecosystem services and investment in healthy ecosystems even further. Boyd argues that there should be more investment in the science and economics of ecosystem service research to better understand the option value of ecological protection. At the current state, there exists huge uncertainties of the social costs that could result from environmental degradation and the relative irreversibility of ecological losses. Therefore the option value of ecological protection, he argues, is simply the information gained through the passage of time. If policy-makers are able to incorporate the option value of protected ecosystems into decision-making, they are essentially buying themselves more time to make well-informed decisions. This is extremely important when considering that some environmental degradation could be irreversible. Boyd argues that policies must be designed to “hedge against the ecological and economic risks associated with systems likely to be altered and disturbed by climate change” (34). Ecological hedging strategies, as proposed by Boyd, involve maintaining existing refuges, investing in restoration and management of natural ecosystems and their services, and diversifying society’s “ecological portfolio”. This ecological portfolio is the geographically diverse mix of natural resources and systems. And the diversification of this portfolio functions as a hedge against the loss of ecosystem goods, and processes and functions.

To summarize, the concept of ecosystem services can be a very powerful tool used to direct policy. It is useful in its application to current environmental problems, but it can also be used to develop management strategies to protect against future ecosystem service loss. The key to its power, however, is locked in its application to real-world environmental problems and how the welfare of humans is affected by the health of ecosystems. For this purpose, it is imperative that one move beyond the MA’s definition and classification of ecosystem services toward a more operational definition. Proponents argue that a consistent, economic definition of ecosystem services is necessary in order to legitimize the concept of ecosystem services and in order to be effective as a decision support system for policy-making.

2.1.3 Economic Ecosystem Services Concept

As stated previously, the primary problem with the MA definition of ecosystem services is that it is not conducive for quantifying or valuing ecosystem services. Since quantifying and valuing the benefits humans receive from ecosystems is of paramount importance to directing public policy, economists are pushing for a more operational definition. As Boyd and Banzhaf (2006) argue, "the term 'ecosystem services' is too ad hoc to be of practical use in welfare accounting" and that a clear, consistent definition of ecosystem services is needed in order to value the services from an economic perspective (Abstract). Brauman, et. al. (2007), Tallis and Polasky (2009), Boyd and Banzhaf (2005, 2006), Boyd (2007) and Fisher et. al. (2008, 2011) all argue that the MA framework should be modified or re-defined transition to a more operational framework.

Brauman, et. al. (2007) actually follow the MA framework, but attempt to make the framework "practical, straightforward, transparent, and credible enough to be used by decision makers" (70) by taking some of the issues of classification of ecosystem services into account. One issue is that every "service" is inherently and inextricably interlinked. This is evident in the fact that supporting services are directly linked to providing every other service. So the classification and categorization of ecosystem services is somewhat arbitrary. In addition to being inextricably linked to each other, ecosystem services are also often at odds with each other. As alluded to previously, many tradeoffs exist between the services and products; the production of a certain service may come at the expense of another service. Again, the example that is relevant to this research is water that is used for provisioning services (drinking water for urban areas and irrigation for agriculture) at the expense of there being no water to support freshwater ecosystems. For hydrologic services, the tradeoffs can be even more complicated as the attributes of the freshwater (the quantity, quality, location and timing of flow) can support different services. For example, different cultural-recreational activities require different levels of flows. Whereas white-water rafters would be interested in large flows of water, recreational fishers would not be in favor of the same volume of water.

2.1.4 Valuation: Spatial Considerations

One important component of the valuation of ecosystem services is the spatial extent of the services and other relevant spatial information. According to Tallis and Polasky (2009), spatial information is incredibly important in determining the value of ecosystem services. They state that the "value of ecosystem services is determined both by the location of ecological processes that create the provision of services (supply) and the location of people who derive benefits from the services (demand)" (273). They further argue that even though all ecosystem services are biophysical processes, not all biophysical processes are ecosystem services. The distinction between these two terms is whether a human is benefiting from the services or not. In order to translate biophysical processes to ecosystem services, spatial information must be considered such as "the location, type, and intensity of use of each service" (271). Looking at this in the light of economics, it can be thought of as the "supply" side of the ecosystem service provision equation. This in itself can tell a lot about where the ecosystem services are, but in order to place value on the ES one must also know the demand side of the equation. The demand side of the equation is the people who use and benefit from the ecosystem services, also called the beneficiaries. It is important to know the location of the beneficiaries because their value of the service will often depend on the distance from the ecosystem producing the service.

Mazzotta et. al. (2001) adds to the argument for research in ecosystem services, specifically for consideration of spatial information. This article argues that analysis of ecosystem service benefits can direct public policy by ranking restoration projects based upon their ecological and economic values. By using a GIS framework and conducting ecosystem service research, a practical, cost-effective method for prioritizing projects can be developed therefore putting federal monies to the most efficient use.

Boyd (2008) sums up the general rules relating spatial information to valuation by stating that:

- "The scarcer an ecological feature, the greater its value.
- The scarcer the substitutes for an ecological feature, the greater its value.
- The more abundant the complements to an ecological feature, the greater its value.
- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic valued protected or enhanced by the feature, the greater its value" (15).

2.1.5 Valuation: Defining Ecosystem Services

One of the main issues with the existing definition of ecosystem services is that it allows for "double-counting". In welfare accounting, the MA definition allows for the value of a supporting service to be added to the value of the service directly affecting human welfare because the service being used by humans is predicated on the services supporting it. Boyd and Banzhaf (2006), however, argue that this form of logic will double count the value of ecosystem service. They argue that "if intermediate and final goods are not distinguished, the value of intermediate goods is double-counted because the value of intermediate goods in embodied in the value of the final goods" (8). To make this clearer, they give an example of a conventional market good: a car. When determining the value of the car, one would only count the total value of the car; they wouldn't add the value of the steel needed to make the car. Ecosystem services work in the same way. Although an ecosystem service that is directly consumed by humans is dependent on a range of ecological goods or functions to produce the final good, the intermediate goods should not be counted in the welfare account (Boyd and Banzhaf, 2006). The authors, however, are quick to note that this does not mean that the intermediate goods have no value. It just means that their value is already captured and incorporated in the value of the final service.

There are two leading schools of thought with regard to an economic definition of ecosystem services. The first definition of ecosystem services is led by work conducted by Boyd and Banzhaf (2005, 2006). Boyd and Banzhaf take a somewhat staunch stance on how ecosystem services should be defined. Their goal is to develop a definition of ecosystem services that is operational in both ecological and economic terms, and to create an accounting framework to measure nature's total value. Fisher, et. al. (2008 and 2011) draw from Boyd and Banzhaf, but modify it slightly to widen the definition of ecosystem services. Both, however, agree that developing an economic definition is essential to derive meaningful estimates of the value of ecosystem services. The distinctions between these two definitions are described below.

Boyd and Banzhaf began developing an economic definition of ecosystem services in their 2005 Resource for the Future publication, *The Architecture and Measurement of an Ecosystem Services Index.* The aim was to develop an accounting strategy used to measure the quantity of ecosystem services or to create an Ecosystem Services Indicator (ESI). Using ecological and economic theory, they developed an "ecological production function" where service flows are consumed directly by humans and the production of those service flows are dependent on ecological assets as inputs to the production function. However, determining the quantity of ecosystem services is very difficult. As they state, "because ecosystem services do not emerge from factories and are not sold in markets, defining and measuring their 'unit of account' requires innovation on the part of both economists and ecologists" (14).

Therefore, they suggest a guiding principle to identify and then determine the unit appropriate for measuring the ecosystem service. The guiding principle to follow is: "that the last link in the chain of ecosystem and ecosystem service production that still involved ecological factors be identified as the ecosystem service" (17). It is here that they develop a distinction between terminologies that are often used interchangeably. Boyd and Banzhaf create the distinction between ecosystem services, ecosystem benefits, ecosystem functions, and ecosystem assets.

Ecosystem services- this definition is derived from the guiding principle. An ecosystem service must be a final market good consumed by humans, but it also must include ecological factors, and it must be the last link of the production of the service.

Ecosystem benefits- according to Boyd and Banzhaf, recreation is an ecosystem benefit, not a service. This is due to the fact that a recreation experience is typically comprised of more than just the contribution of the ecosystem. They argue that while recreation benefits received by the individual are the result of services that an ecosystem provides, they are not an ecosystem service itself. In an example of recreational fishing, the bass population, not the number of fish caught, is the ecosystem service. The ecosystem service measure could not be the number of fish caught because "it includes more than the contribution of the ecosystem; it includes the skill of the angler, the quality of his equipment, and the time he invests" (17).

Ecosystem functions- these are the complex interactions that exist in the scientific realm (biological, chemical, and physical), but are not services because they are not used in an end-goal by humans.

Ecosystem assets- these are the intermediary components of ecosystem services. They are needed to generate ecosystem services, but are not services themselves. Essentially, these are the inputs of the ecological production function.

Fisher, et. al. (2008) draw from Boyd and Banzhaf's definition of ecosystem services, but broaden the definition slightly. They propose that "ecosystem services are the aspects of ecosystems utilized (actively or passively) to produce human well-being" (2051). They remain consistent with Boyd and Banzhaf requiring that an ecosystem service be an ecological phenomenon, but they broaden the definition by allowing the services to be directly or indirectly used by society. This definition allows processes to be considered ecosystem services as long as they produce benefits for humans.

Fisher, Bateman, and Turner (2011) recognize that the distinctions between the numerous terminologies and concepts that exist in the ecosystem service literature are critical when attempting to quantify and determine the value of ecosystem services. Similar to Boyd and Banzhaf (2005, 2006) they define ecosystem services as having three components: intermediate services, final services, and benefits. They argue that this delineation is the most useful for valuation of ecosystem services. Whereas intermediate service and final services are ecological phenomena, the benefits are the end-products or end-uses that are providing utility to humans. Similar to the MA's supporting service definition, intermediate services are those services that interact in complex ways to provide final services that have direct impacts on human welfare. The differences between final services and benefits are that a final service must still be an ecological phenomenon and that a benefit usually requires other forms of capital to affect human welfare. Therefore, following this definition, cultural aspects and recreation are considered benefits. They are quick to note that this delineation addresses the issues of double-counting and facilitates valuation exercises. This thesis follows the delineation as set forth by Fisher et. al. and considers the recreational opportunities in the Delta as ecosystem service benefits.

2.1.6 Valuation: Obstacles and Solutions

One of the biggest obstacles in valuing ecosystem services is that a majority of them are not bought and sold in markets. These ecosystem services, in fact, cannot be sold in a market because they lack certain characteristics: they are not rival, nor excludable. A good that is rival can be "used up", meaning that when one person uses the good, there is less of the good for other people to use. A good that is excludable is a good in which one user can prevent another person from using the good. These two characteristics produce goods that are private, marketable goods.

While most ecosystem services are non-rival and non-excludable, this does not mean that such ecosystem services cannot be valued in a conventional market. In fact, as Fisher, et. al. (2009) states, "there is a spectrum from rival to non-rival and from excludable to non-excludable" (647). On the far end of the spectrum, private goods are rival and excludable. Many of the MA's provisioning services are private goods and have well-defined market values. Examples of these goods include timber and fish. Other ecosystem services are non-rival and excludable, meaning the use of the good doesn't preclude your use, but one user can exclude the other person from accessing it. These goods are often called toll or club goods. An example, as given by Fisher (2009), would be information from nature. The use of information does not result in less information that can be used by another person, but one user can prevent another user from accessing the information by creating a patent or some other legal barring. Other ecosystem services are considered open access resources, where they are rival but non-excludable. The most common example for this type of good is ocean fisheries. While one person's fishing decreases the stock of fish for the other fishermen (rival), they can't possible exclude all of the other fishermen. Finally, many ecosystem services are pure public goods, meaning that they are non-rival and non-excludable.

For those benefits that are public goods and are not sold in markets, the value must be determined outside traditional markets. As mentioned previously, one of the most common ways to value non-market goods and services is through stated preference methods such as the Contingent Valuation Method (CVM). This method essentially asks "individuals to state their willingness-to-pay for some change in the provision of an environmental good" (Fisher et. al., 2011: 7). The next section of the literature review will elaborate on the CVM.

2.2 Contingent Valuation Method (CVM): Theory and Practice

The contingent valuation method (CVM) is one of two major types of methods to determine the value of goods that are not sold in a market. The first type of method is an indirect approach that infers the value of a good based upon observations of consumers' actual behavior. This family of methods is called the revealed preference method because it is based on the observed consumers' preferences. The second type of method is a more direct approach in which consumers are given a constructed hypothetical situation via interviews or surveys in which they must choose the scenario that they prefer (Carson, 2011). This is called the contingent valuation method because the values reported by the respondents are contingent upon the constructed situation (or simulated market) that has been developed in the survey. It is also commonly called the stated preference method because the respondents directly respond to survey questions regarding the value of the good.

The basic methodology of the CVM is as follows. The CVM proposes a hypothetical scenario within a survey and elicits values from respondents by directly asking either: 1) how much the respondent is willing-to-pay (WTP) to obtain a desired good or service or 2) how much the respondent is willing-to-accept (WTA) in terms of compensation to give up a good or service currently possessed (Carson, 2011). In this way, economists can elicit how much the respondents value the good or service.

CVM surveys generally have six major components. The first is an introductory section that identifies the sponsor of the project and general information regarding the project. The second section usually asks questions to determine the respondent's prior knowledge and attitudes toward the good. The third section sets up the hypothetical scenario. It includes the background information (ie; the problem), what the project is designed to accomplish, and how the project would be implemented and funded (Carson, 2011). Once the hypothetical scenario has been developed, the next section asks the respondent's WTP/WTA for the good. Following the WTP/WTA question, there are typically debriefing questions to make sure the respondent understood the scenario and that they answered honestly. Finally, the survey asks demographic questions.

2.2.1 Origins of CVM

The first proposals for using surveys as method to understand the values of public and social goods were put forth by Bowen in 1943 and Ciriacy-Wantrup in 1947. Bowen's goal was to understand the value of "beautification of the landscape" and Ciriacy-Wantrup sought to put a value on soil conservation programs. In Ciriacy-Wantrup's publication, often credited for being the first published reference to the contingent valuation method, he discusses the difficulties of measuring the benefits of soil erosion prevention and asked people directly how much they would be willing to pay for soil erosion abatement programs. He further proposed the use of the CVM in his influential book "Resource Conservation: Economics and Policies" (1952), which is often considered the first textbook in environmental and resource economics (Carson, 2011).

The first to empirically implement a CVM survey was Robert Davis in his 1963 Harvard dissertation entitled "The value of outdoor recreation: an economic study of the Maine woods". Since Davis's first implementation of a CVM study, the 1960s CVM literature grew slowly but steadily throughout the early 1970s. Influenced by Davis, other economists associated with Resources for the Future conducted CVM studies to value recreational amenities. One early CVM study related to water and recreation was conducted in 1969 by Brown and Hammack. This study sent a mail questionnaire to western hunters asking how much they would be willing to pay for continued access to waterfowl hunting, or how much they would be willing to accept to give up their right to hunt waterfowl. This was a very important study because the value determined in this survey was eventually adopted by state and federal fish and game agencies for the value of a waterfowl kill. Around the same time, there were many other influential studies including Weisbrod (1964) and Krutilla (1967). These two studies were theoretically important to the CVM because they recognized the importance of option value and existence value, respectively (Carson and Hanemann, 2005).

Around the mid-1970s there was a spike in CVM literature. This has been attributed primarily to a published CVM study in the first volume of the *Journal of Environmental Economics and Management* publication. Randall, Ives, and Eastman's (1974) study of the Four Corners area, which was heralded for its theoretical rigor, brought the CVM into the limelight. Since then the CVM literature has grown very quickly, almost at an exponential rate until the mid 1990s (Carson and Hanemann, 2005).

During this 20 year period, the CVM approach gained credibility and respect. During the 1970s the EPA created a program that was charged with researching the effectiveness, usefulness, and challenges facing the CVM approach. Then, in 1983 the EPA commissioned a state-of-the-art assessment of the CVM, with a panel of the prominent economists and psychologists including several Nobel Laureates. The results of the panel suggested that although significant challenges remained, the CVM was a promising method to understand the value of goods not sold in a market.

Throughout the late 1970s and early 1980s the CVM grew to become even more respected. In 1979, the Water Resources Council published regulations stating the CVM as one of three recommended methods for determining project benefits in water-related Federal agencies such as the U.S. Army Corps of Engineers (COE) and the Bureau of Reclamation (BOR). Finally, the landmark decision by the U.S National Oceanic and Atmospheric Administration (NOAA) in the 1992 Blue-Ribbon Panel co-chaired by two Nobel Laureates, Kenneth Arrow and Robert Solow, gave further legitimacy to the CVM. The Panel was convened in response to the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska where the goal was to determine whether the natural resource damage could be reliably measured by the CVM. The Panel concluded that "CVM studies can produce estimates reliable enough to be the starting point for a judicial or administrative determination of natural resource damages-including lost passive-use value" (Arrow, et. al., 1993: 43). As part of the panel, they produced a list of guidelines to conduct a proper CVM analysis. The blue ribbon panel guidelines are presented in section 4.2.3 of this thesis.

Nevertheless, opponents of CVM argue that the approach taken may not reflect the true WTP of the respondent. They argue that: 1) respondents do not take the hypothetical scenario seriously because no money is actually changing hands, and 2) that people act strategically and answer in a way that could be inconsistent with their true WTP for a public good. In either case, opponents are concerned that the estimates will be inflated above the true WTP. However, these issues have been addressed by Carson et. al. (1996) in his meta-analysis of CVM studies. The results of his analysis suggest that when comparing CVM estimates to estimates based on revealed-preference studies, the CVM estimates were on average slightly lower (Carson, 2011).

It is important to note, however, that the debate regarding the validity of the CVM still exists. In the most recent issue (Fall 2012) of the *Journal of Economic Perspectives*, there were three articles outlining the arguments for and against CVM analyses. Hausman (2012) argues against the use of contingent valuation citing issues with "hypothetical bias and overstatement, disagreements between willingness to pay and willingness to accept, and problems of scope or embedding" (54). He considers the CVM procedure to be "hopeless" and argues that "no number" is better than a contingent valuation estimate. Carson (2012), on the other hand, argues that "high-quality contingent valuation surveys appear to produce high-quality economic data" and that the CVM is better than the alternative (placing a zero value on the non-market goods that the public values) (39). Finally, Kling, Phaneuf, and Zhao (2012) provide a "middle-of-the-road" view on the CVM. They argue that the CVM literature has been continually maturing and that "we now have more tools with which to judge the accuracy of stated preference estimates and an emerging consensus on the criteria we should use to do so" (22).

Even though not all economists are supportive of CVM, the stamp-of-approval from some of the most prominent economists in the world and the continued research on its effectiveness and accuracy has given the CVM acceptance as a useful tool to assess the value of goods not sold in traditional markets. As such, the amount of CVM literature published has grown to be approximately 500 papers per year (Carson and Hanemann, 2005).

2.2.2 Use of CVM for Non-Market Value of Water-Dependent Ecosystems

There are numerous studies that have used the contingent valuation method to understand the economic value of water for water-dependent ecosystems, and almost all of these studies use recreation as a basis for the evaluation. This section of the literature will review five of the most relevant instream flow contingent valuation studies, including a study that was conducted in the Colorado River Delta (from which this study is based).

Daubert and Young (1981) used the CVM to value the recreational demands for maintaining instream flows on the Cache la Poudre River in northern Colorado. The major goal of this research was to understand the marginal demand functions for instream flow, and make policy recommendations for the management of the river. Daubert and Young examined three different river activities: trout fishing, white-water boating (kayaking and rafting), and streamside recreation (such as picnicking, camping, or hiking). They used color photographs of the river at eight different instream flow rates and asked, through a bidding game, how much the respondent would be willing-to-pay for the experience represented by the next highest instream flow photo. Of course, of the 134 total respondents, the “optimum” instream flow level varied based on the activity that they had come to the river for. The study established the total and marginal values for each activity along the river. In this way, the marginal value for each activity could be compared with other uses of water such as irrigation to see which offered the most benefits. The study determined the marginal value by month and determined that in May, June, and July instream flows exceed the optimum for fishing, so increased storage or irrigation would be welcomed. However, in September, the marginal value of fishing is higher than the marginal value of a crop return, so water should be reallocated. Finally, they argue that the results suggest that water managers should modify their practices and fill their reservoirs in the spring instead of the fall to increase the total social benefits.

Mathis, Yoskowitz, Montagna, and Richardson (2008) conducted a CVM study to determine the value of instream flows in the Rio Grande in Texas. Instead of this study being recreation based, it focused on the effects of lack of instream flows on the river, marshes, and estuary where the river meets the ocean. In this case, they were asking respondents how much they would be willing to donate to a fund that would protect freshwater flows to the ocean. This study employed the double-bounded dichotomous choice method, meaning that they were asked two dichotomous choice questions with the second value reflecting the answer to the first. This study determined that the mean WTP to protect instream flows in the Rio Grande was $129 dollars for a one-time donation.

Loomis (2012) contributed to the literature on instream flows by conducting a CVM study in an urban river in Fort Collins, Colorado. The goal of this study was to understand the total economic value of instream flows, and then be able to tease out the components of the total value into the recreational value and use value. This study was conducted at the request of the City Council of Fort Collins in response to a potential reservoir being built on the Poudre River. The City Council wanted to have "factual and objective comments on the EIS about the magnitude of the external environmental cost imposed upon its citizens" (8). This CVM study mailed copies of the survey to 550 Fort Collins residents, and received 332 completed surveys. The surveys asked two different WTP questions: 1) one to value the total economic value (TEV) and 2) one about WTP for recreation use. The report determined that the annual per household total economic value of maintaining the current river flow was $234. Of that value, 62% of the value (or $144) is attributed to non-use value and 38% (or $90) is attributed to recreation use value.

Interestingly, the report went even further to understand the policy implications of the potential reservoir. If the reservoir was put in place, there could be a potential reduction in flows by 50% from April to September. In order to offset that amount, 49,381 acre-feet (AF) of water would be required. By using the TEV calculated by the CVM, Loomis was able to calculate the annual TEV of water for instream flow at $172 per AF. He then made a comparison to the going-rate for water leases in the area and found that the value for instream flows exceeds the cost of obtaining water through temporary leases. He did the same for an aggregate annual TEV to determine if the value of instream flows exceeded the cost of permanently obtaining a water right. The results suggest, however, that the value is a little more than 50% of the monies that would be required to purchase the same amount of water. Therefore, it would be more economical in the short term to focus on leases. Loomis, did mention, however, that because residents of Fort Collins non-consumptively use the river water that downstream users may want to join forces with Ft. Collins to protect the instream flows.

The two most relevant publications to the Delta study site in this thesis were conducted by Ojeda, Mayer, and Solomon (2008) and Rivera and Cortés (2007). These two publications stand out in the literature because of the location of the WTP surveys: Mexico. Ojeda, Mayer, and Solomon (2008) conducted a CVM study in Mexico to understand the economic value of environmental services provided by restored instream flows in the Yaqui Delta. The issues there are analogous to those in the Colorado River Delta. The Yaqui River begins somewhere around the U.S.-Mexico border, travels through the Mexican state of Sonora, and is supposed to meet the Gulf of California. Similar to the Colorado River Delta, however, the river has not reached the Gulf in many years. This study used the CVM to survey 40 neighborhoods in the Delta's most populated city, Ciudad Obregon. The respondents were asked a WTP question regarding their willingness to purchase water for environmental flows through higher water bills. The surveys were conducted in-person and the results indicated that households would be willing-to-pay an average of $73 MXN pesos each month.

Rivera and Cortés (2007) produced the most relevant research for this study, and was used as a guide for the development of this CVM study. Rivera and Cortés of the National Institute of Ecology (Instituto Nacional de Ecología, INE) published an article with the assistance from Yamillett Carrillo-Guerrero of Pronatura Noroeste entitled "Valoración económica de la actividad recreativa en el río Colorado" in Región y Sociedad. The purpose of this study was to understand the value of informal recreation activities along the Colorado River. They called these informal recreation activities because there were no fees to enter the sites, nor were there services available. The surveys were conducted during the spring of 2005, when there was water in the Colorado River. One of the sites used in this study was the same site selected for this thesis, Vado San Felipito. They had 100 respondents, mainly from San Luis Rio Colorado, with 85 of those surveys usable in the calculation of the median WTP. The WTP question asked the respondents how much they were willing-to-pay to guarantee that the Colorado River would have water at all times. The results of this study suggest that people are willing-to-pay around $45 MXN pesos to guarantee water in the river. Because a large majority of the respondents were from San Luis Rio Colorado (95% of the respondents), this study was able to estimate the range of total annual benefits. Knowing the population of San Luis Rio Colorado (35,000 occupied houses), the average number of visits that respondents take to the river (1.86 times per year), and the median WTP (45 pesos) they calculated that the range of total annual benefits ranged from 1.9 to 6 million pesos annually.

2.3 Colorado River Basin and Delta

This section summarizes the history of the Colorado River and the Delta, the ecosystem services provided by freshwater from the Colorado River and the Delta, the effects that upstream diversions have had on this area, and the potential for restoration.

2.3.1 History and Governance of the Colorado River

The Colorado River Basin consists of seven western U.S. states and several states in northwestern Mexico. It supports the water needs of over 30 million people, and is an essential source of water for agriculture in the area (National Geographic Society, 2010). Agriculture is the dominant water-user, as it consumes approximately 78 percent of the water available from the Colorado River.

In the U.S., the river is governed by the "Law of the River". The Law of the River is a series of interstate and international agreements, federal and state laws, court decisions and contracts that govern the use and allocation of the Colorado River (National Geographic Society, 2010). A large component of the Law of the River was the Colorado River Compact established in 1922. It was at this meeting in November where delegates from each of the basin states met to determine how the river's water should be allocated. The Compact divided the river into the Upper Basin (Wyoming, Colorado, New Mexico, and Utah) and the Lower Basin (Nevada, Arizona, and California) (National Geographic Society, 2010). Under this agreement, each basin would be allocated 7.5 million-acre feet (maf) of water. Another component of the Law of the River was the 1944 Treaty that was entered between the United States and Mexico. This treaty guaranteed that the United States would deliver 1.5 maf per year to Mexico and allowed for the construction of Morelos Dam along the U.S.-Mexico border. Finally, the Upper Colorado Basin Contract of 1948 "allocates 50,00 acre-feet per year to a part of northern Arizona, and splits the remainder - approximately 7.5 maf- between Colorado (51.75%), New Mexico (11.25%), Utah (23%), and Wyoming (14%) (National Geographic Society, 2010). The Lower Basin allocations have been established through federal law and can be seen in the following figure. California has an allocated of 4.4 maf, Arizona has an allocation of 2.80 maf, and Nevada has the smallest apportionment with 0.30 maf (Lellouch, et. al., 2007: 25).

TABLE 1. COLORADO RIVER ALLOCATION

	Allocation (maf)
Upper Basin	7.50
Colorado	3.88 (51.75%)
New Mexico	0.84 (11.25%)
Utah	1.73 (23%)
Wyoming	1.05 (14%)
Arizona	0.05
Lower Basin	7.50
Arizona	2.80
Nevada	0.30
California	4.40
Mexico	1.50
Total	16.50

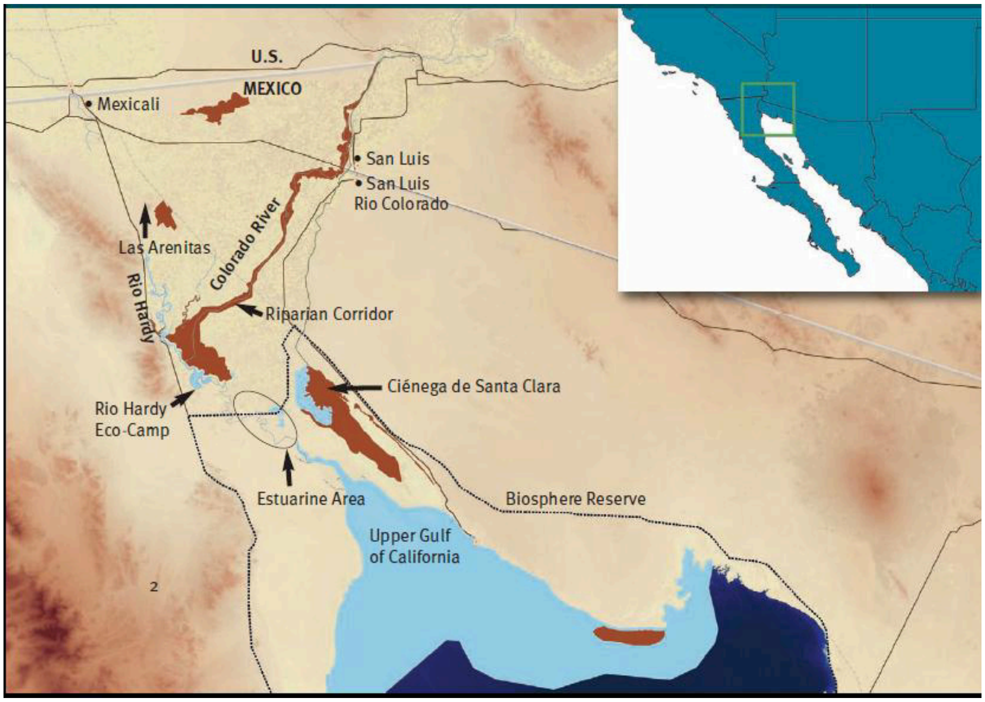
The problem with this allocation is that it was determined based upon data from a series of unusually wet years. The data at the time (early 1900s), suggested that the annual average flow was approximately 16.4 maf, but many researchers believe that the river has actually been over-allocated and the long-term annual average may be as low as 14.3 maf (Woodhouse et. al., 2006). Wheeler, et. al. (2007) emphasize the issue of allocating among the basin states due to the fact that flows can vary substantially depending on the season and the year. According to their research, historic flows of the Colorado River have been as low as 5 maf and in excess of 23 maf (Wheeler et. al., 2007).

Of course, in order to effectively allocate the Colorado River water among the basin states, there were significant developments along the river in the twentieth century. Over the years, over 110 storage and diversion dams have been built by the Bureau of Reclamation and the Army Corps of Engineers along the Colorado River. Although the dams' benefits were "flood control, to create hydroelectricity, to store agricultural and municipal water, and harness the river's widely varying flows to generate a steady water supply", these dams have caused significant ecological damage to the Delta (Wheeler et. al., 2007: 925). They have disrupted the natural flow regime of water and sediment, and with the completion of Glen Canyon Dam and the subsequent filling of Lake Powell, the Delta was deprived of flood flows for about 20 years (Wheeler et. al., 2007).

2.3.2 Ecology of the Colorado River Delta

The Colorado River Delta is located in Northern Mexico and spans across two Mexican states, Sonora and Baja California (see Figure 3). It is located in the arid Sonoran Desert and extends from the southern extent of the Colorado River (around Morelos Dam) to the Gulf of California (Wheeler et. al., 2007: 918).

FIGURE 3. MAP OF COLORADO RIVER DELTA



Source: Sonoran Institute Map (2012)

The Colorado River Delta was formed approximately 2 million years ago. Glacial periods in the Pleistocene period brought abundant floodwaters and deposited sediments as it flowed to the Gulf of California, thereby molding the Delta into its current shape (Cardoso, 2006). Today, it covers more than 7,700 kilometers and is located within the area known as the Mexicali Valley.

The Mexicali Valley is also host to a huge agricultural presence. Approximately 576,620 acres or 233,350 hectares were in production in the Mexicali Valley in 2010 (SAGARPA 2010). The agricultural industry developed in this area due to of the Colorado River's presence in the valley. The river's flows led to extremely fertile soils and the ability to irrigate crops. In fact, "more than 95% of the soil is classified agriculturally as first- or second-class" (Saille, Lopez, and Urbina, 2006) and the primary source of water for the Mexicali Valley Irrigation District is the Colorado River, with additional water being pumped from groundwater aquifers (Schuster, 2012).

The valley is also host to two growing cities: Mexicali and San Luis Rio Colorado, which also depend upon the Colorado River and groundwater aquifers for water resources. Mexicali is the bigger of the two cities with almost 1 million people residents (936,826 in the 2010 Census), and San Luis Rio Colorado lies east of Mexicali with a little over 175,000 residents (178,380 in the 2010 Census) (INEGI, 2010). Astonishingly, Mexicali has grown by over 20% within the last 10 years, resulting in significant pressures on regional water supplies. Although not located within the Mexicali Valley, Tijuana also relies on the Colorado River for its source of water.

Aside from the large agricultural presence and burgeoning municipalities, the Mexicali Valley is also host to the once expansive Colorado River Delta. There are, in general, four ecosystem types in the Delta. The first type is the riparian ecosystem. Riparian ecosystems in the southwest United States and northern Mexico are typically comprised of native cottonwood and willow trees and non-native salt cedar. The riparian corridor "extends from the U.S.-Mexico border to the intertidal portion of the river where it enters the Gulf of California" (Nagler, 2009: 1473). This ecosystem provides habitat for resident birds and an important route for migratory birds, including the endangered southwest willow flycatcher (Nagler et. al., 2009; Wheeler, et. al., 2007). The riparian corridor is supported by groundwater, agricultural return flow, and wastewater. While this ecosystem is no longer sustained by natural flows from the Colorado River, occasional floods flows are essential to maintaining the riparian habitat. Flood flows are necessary to flush salts from the soil, which allow the native trees to regenerate in salt cedar dominated areas (Nagler, et. al., 2005). Perhaps more importantly, this is one of the only areas along the entire Colorado River that still has a significant amount of native trees: the Delta's cottonwood willow habitats are four times greater in acreage than the sum of all cottonwood willow habitats found in the Lower Colorado River in the U.S (Wheeler, et. al., 2007). This has resulted in a much higher bird density and diversity in the Delta (10 times as much) than in river reaches in the U.S. (Hinojosa-Huerta, 2006).

The second type of ecosystem is open-water wetlands, such as the Cienega de Santa Clara. The Cienega is the largest marsh wetland in the Sonoran Desert and is arguably the most important wetland in the Lower Colorado River Basin. The Cienega is comprised of dense cattail, open water, and mudflats. Its importance stems from the fact that this open wetland is a critical stopover for migratory birds, is the home to the world's largest population of the endangered Yuma clapper rail, and is an important habitat for the endangered desert pupfish (Zamora-Arroyo et. al., 2005; Hinojosa-Huerta, et. al., 2001; Varela-Romero, 2002). The Cienega is supported by brackish agricultural drain water provided by the U.S.'s Welton-Mohawk Irrigation and Drainage District's MODE canal. The importance of the Cienega has been recognized with its partial inclusion in Mexico's Biosphere Reserve of the Upper Gulf of California and Colorado River Delta established in 1993 (Zamora-Arroyo et. al., 2005).

The third ecosystem present in the Delta are the numerous brackish wetlands that exist in the midsection of the Delta (areas such as El Indio Wetlands, Pangas Viejas Wetlands, Andrade Mesa Wetlands, and El Doctor Wetlands) (Zamora-Arroyo et. al., 2005). These areas are comprised almost solely of salt cedar and other salt tolerant shrubs and vegetation. Although not ideal habitat, this non-native vegetation still provides important habitat for resident and migratory birds. Agricultural drainage from the San Luis and Mexicali agricultural valleys support these wetlands and vegetation stands (Wheeler, et. al., 2007).

The final ecosystem present in the Delta is the estuarine area at the mouth of the Gulf of California. This area is comprised of the intertidal, coastal and marine zone of the Gulf of California. Tides and freshwater from the Colorado River have historically supported a very rich estuarine area, but the lack of freshwater have left the quality and extent of the estuarine environment reduced. A statement in the Conservation Priorities' document demonstrates the importance of this area by saying, "it is clear that these zones are presently functioning as breeding nursery areas for marine species, including shrimp, Gulf corvine, and the endangered totoaba-a large, high-quality endemic fish that was the basis for an early commercial fishery in the region" (Zamora-Arroyo et. al., 2005). Decreases of freshwater inputs to estuaries can cause problems with coastal sedimentation, coastal productivity, species abundance and species composition (Cintra-Buenrostro, et. al., 2012). Recent work on estuarine bivalve mollusks in the Colorado River Delta suggest that lack of freshwater from the river have led to higher salinity, therefore resulting in an decreased and unsustainable populations of *M. coloradoensis* (Cintra-Buenrostro, et. al., 2012). Although the analysis focuses only on salinity and recognizes that there other factors that could have led to the decrease in populations, they argue that there is strong circumstantial evidence suggesting that the decrease in the flow of the river has led to a decrease in the population of the mollusk. Recommendations for getting the habitat back to the pre-dam levels involve securing 150-290 cubic meters per second, equivalent to 2-4% of the river's annual discharge during June's peak flow of the river.

2.3.3 Ecosystem Services Provided by Lower Colorado River Basin and Delta

The range of ecosystems in the Delta allow for the provision of many ecosystem services. This section will summarize what the literature defines as ecosystem services in the Lower

Colorado River Basin and Delta. In all of the following cases, the literature follows the Millennium Assessment framework.

Lellouch, Hyun, and Tognetti (2007) apply the MA framework to the Delta and specifically highlight the ecosystem services provided the Lower Colorado River Basin and Delta. Below is a table outlining the ecosystem services provided. They present a somewhat comprehensive list of the services provided in the study area. An important Delta service that they mention is the supporting service of biodiversity. This could be a very effective argument for dedicating water to the Delta, as there are numerous U.S. and Mexican endangered species that use the Delta as habitat or breeding ground.

TABLE 2. CLASSIFICATION OF ECOSYSTEM SERVICES PROVIDED BY THE LOWER COLORADO RIVER BASIN AND DELTA'S RIPARIAN AREAS.

Type of Ecosystem Service	Ecosystem Service	Examples
Provisioning	Water	Drinking water for municipal uses, water for industrial applications
	Food	Agricultural products (wheat, cotton, alfalfa, etc.), aquaculture, fishing and hunting, mesquite seeds
	Fiber and fuel	willow bark
Regulating	Hydrological flows	groundwater recharge
	Pollution control	retention, recovery and removal of excess nutrients and pollutants
	Natural hazards	flood control
Cultural	Spiritual and inspirational	sacred indigenous sites
	Recreational	recreation, tourism, transportation
	Aesthetic	appreciation of natural features
	Educational	opportunities for formal and informal education and training
Supporting	Soil formation	sediments and nutrient transport
	Nutrient cycling	

	Pollination	support for pollinators
	Biodiversity	key stopover on the Pacific flyway, habitat for endangered species, breeding and nursery grounds for Gulf species (totoaba, shrimp, etc.)

Source: Lellouch, et. al. (2007).

The ecosystem service benefits analyzed in this thesis are the recreational benefits provided in the Delta. The other benefits measured are the non-use values that visitors place on a healthy Delta ecosystem.

2.3.4 Transboundary Ecosystem Services

In the book Conservation of Shared Environments, modifications were made to the MA framework to be applied to a transboundary circumstance, such as the Lower Colorado River Basin. This area provides an exemplary example of the issues that can arise with a resource that provides services for two separate nations. The idea is that ecosystem services extend beyond national borders, and more importantly, that one nation’s actions can affect the quantity and quality of services received in the other nation. Arguments are made throughout the book that “it is in the mutual interest of the United States and Mexico to conserve the ecosystems and ecosystem processes that provide their shared services” (Lopez-Hoffman, et. al., 2009: 137).

Lopez-Hoffman, Varady, and Balvanera (2009) modified the MA framework to “elucidate how drivers in one country can affect the delivery of ecosystem services and human welfare in the other country (or in both countries) and how stakeholders might collaborate across international borders to protect shared ecosystem services” (137). The authors provide several examples of shared ecosystem services, one of which involves water across the U.S.-Mexico border.

One of the more controversial shared ecosystem services between the U.S. and Mexico is the groundwater transported through the All American Canal. This canal, located in the U.S., accounts for 10 to 12 percent of the aquifer's annual recharge that provides water for irrigation and drinking water in the Mexicali Valley. The leakage from the canal also supports the Andrade Mesa wetland in Mexico. In mid-2007, the U.S. Bureau of Reclamation (BOR) began to line the All American Canal in order to prevent these unintentional releases of water to Mexico. Of course, the people and environment of Mexico who have come to rely upon these inadvertent releases, were upset and several groups sued the BOR. They claimed that the environmental impact statements completed for the lining did not consider the full range of impacts, including the impacts to wetlands in Mexico. The court declared that the "U.S. Constitution's Fifth Amendment protection against deprivation of property without due process outside U.S. territory and that disputes over international water treaties should be settled only through international diplomacy" (Lopez-Hoffman et. al., 2009: 141). Although there is bi-national committee (International Boundary and Water Commission/Comisión Internacional de Límites y Aguas) mandated to distribute surface water between the two countries, they have no control over groundwater issues and could not intervene because the canal lies solely in the U.S. As demonstrated by this example, even though the ecosystem service is shared by both nations, this does not necessarily mean that it provides mutual benefits. Groundwater is a situation in which one nation will benefit from the service, and the other will not.

In another chapter of the book, Calderon-Aguilera and Flessa, outline the ecosystem services generated in the Upper Gulf of California. The authors state that lack of river water reaching the estuary and fishing practices in Mexico have reduced populations of shellfish, degraded the nursery grounds for shrimp and finfish, and put endangered species further at risk.

For example, prior to dam construction the population density of shellfish ranged from 25-50 specimens per square meter. Today, population densities range from 2-17 specimens per square meter. Furthermore, studies have shown that increases in river flow into the estuary increase larval shrimp populations, increase shrimp catches, and benefit the populations of the Gulf corvina, a commercially sold fish (Calderon-Aguilera and Flessa, 2009).

Healthy estuaries provide numerous ecosystem services such as "habitat for the spawning, development, and subsistence of commercially important fisheries; habitat for migratory and resident birds; recreation; pollutant filtration; and shoreline protection" (155). The lack of water reaching the Colorado River estuary has resulted in a decline of the ecosystem services provided. The question in this transboundary case is, who should bear the cost of the decline in services? While the U.S. diverts 90% of water from the Colorado River, Mexico diverts the remaining 10%. The authors argue that both nations benefit from the services that the Upper Gulf of California provides, and therefore both have an incentive for ensuring that freshwater reaches the estuary.

2.4 Western Water Markets

The final section of the literature review provides reference to select literature regarding water markets in the western United States and other developed markets. While a large majority of the selected literature provides a quantitative economic analysis of water transfers (Table 3), I have also selected literature that provides a qualitative view on the structure of western U.S. water markets and outlines the impediments that exist that prevent the water market from growing (Table 4). Additionally, I have focused on literature that involves an environmental component within the water market analysis. A list of the selected literature (comprised of the author, date and location, and key research questions and findings) is summarized in the two tables below.

TABLE 3. ECONOMETRIC WATER MARKET LITERATURE

Authors	Dates and Location	Key Research Question and Findings
Hansen, Howitt, and Williams (2012)	1990-2008 12 Western U.S. states	Econometric analysis using a logit model to determine the structure of the water market. What are the factors that contribute to the type of transfer (sale or lease)? The value of agricultural production and the value of agricultural land influence whether a farmer leases or sells a water right.
Payne and Root (2011)	2002-2010 6 Western U.S. markets	Price differences across basins persist in Western water markets. Prices are highest in New Mexico, Colorado and Nevada, and lowest in Texas, all else equal. Agricultural and environmental water users pay less than urban water users.
Libecap (2010)	1987-2008 12 Western U.S. states	Agricultural-to-urban prices are significantly higher than agricultural-to-agricultural prices and prices vary drastically by state. Identifies changes needed to be made to create efficient water markets.
Jones (2008)	1987-2007 6 Western U.S. states	Compares prices for environmental transfers and non-environmental transfers. Population, income, and urban development increase sale prices, while drought conditions cause increases in lease prices.
Brewer, et. al. (2007)	1987-2005 12 Western U.S. states	Agricultural-to-urban prices are higher than agricultural-to-agricultural prices; multi-year leases and sales are becoming more prevalent while the number of short-term leases is not increasing.
Emerick (2007)	1990-2004 9 Western U.S. states	Drought leads to higher prices, but does not affect the volume of water transferred.
Brown (2006)	1990-2003 14 Western U.S. states	Higher lease prices are associated with drier climates and larger populations, and higher sale prices are associated with smaller quantities and smaller populations. Prices higher for urban transfers as opposed to environmental and agricultural.
Pittenger (2006) and	1987-2005	Lease prices are affected by drought conditions

Pullen (2006)	Western U.S.	(as measured by the Standard Precipitation Index) and sale prices are affected by demand for water and the water right characteristics, with inconclusive results on drought conditions.
Pullen and Colby (2006)	1987-2004 CBT and CAP	Determinants of price in Colorado Big Thompson and Central Arizona Project water markets. Drought leads to higher prices in both markets.
Howitt and Hanak (2005)	1985-2004 California	Analysis of environmental water transfers in California and discussion of groundwater substitution, fallowing, water banks and dry-year options. Market growth has been influenced by transfers for environmental purposes.
Howitt and Hansen (2005)	1999-2002 14 Western U.S. states	Leases dominate the market in terms of volume traded, environmental transfers have increased over time, leases will increase due to environmental and economic externalities and uncertainties about water supply.
Brookshire , et. al. (2004)	1990-2001 3 Western U.S. states	Two-stage least squares estimated to explain variations in price and estimate the demand equation. Concluded that prices were higher in New Mexico and Colorado (compared to Arizona), government buyers pay less than agricultural buyers, and prices were lower in wet periods. Demand is price elastic and quantity transferred decreases as value of agriculture rises.
Loomis, et. al. (2003)	1995-1999 11 Western U.S. states	The most common environmental use of a water transfer (sale or lease) is for instream flows. Non-market values for instream flows are similar to water lease prices.
Isé and Sunding (1998)	1990-1997 Nevada	Econometric analysis to determine the characteristics influencing whether a farmer is willing to sell his/her water right for the benefit of the wetlands in Lahontan Valley.

TABLE 4. NON-ECONOMETRIC WATER MARKET LITERATURE

Authors	Dates and Location	Key Research Question and Findings
WestWater (2012)	2002-2008 14 water rights markets within 8 Western U.S. states	Development of the Water Rights Price index (WRPIx) to track the movement of market prices. The understanding of market and price performance reduces risk and allows the private sector to become more involved in water markets.

Grafton, et. al. (2011)	5 water markets across the world, including Western U.S. markets	Developed a comprehensive and integrated framework to assess and compare water markets across countries by ranking the country's institutional foundations, economic efficiency, and environmental sustainability.
WestWater (2011)	2000-2010 Spot water market in California's Central Valley	Prices have risen (with increasing volatility) due to water shortages, persistent drought, and heightened regulatory restrictions. Origin of water affects water market value. Since 2000, environmental water users have acquired a larger cumulative volume of water on the spot market than urban or agricultural water users.
Basta and Colby (2010)	1987-2007 Western U.S.	Analysis of overall trends including total water volume traded, number of transactions, and average prices across states and regions. Findings suggest that volume traded varies among states and regions, but overall the number of transactions and prices are rising over time.
Scarborough (2010)	1987-2007 11 Western U.S. states	Identifies the underlying barriers that complicate water markets, specifically in regard to purchasing water for instream flows. Water purchases for instream flows tend to be more prevalent in states that permit and encourage private involvement, including Oregon, Washington, and Montana.
Donohew (2009)	1987-2007 12 Western U.S. states	Agricultural-to-urban trading is the most dominant form of trade in terms of number of transfers, and the rate of permanent transfers is increasing over time.
Colby (1990)	1987-1989	Identifies the attributes of instream flow that have economic value.

2.4.1 Water Markets

As shown in the extensive table above, there are numerous studies that analyze the western United States' water markets. Generally, these studies include several western states and a large majority of the studies focus on research questions relating to the prices of water transfers. Other types of analysis include the types of transfers implemented (sales or leases), the end users of the water transfer, and the overall trends of the water market.

In 2012, WestWater Research LLC (a consulting firm in the water rights industry), launched a price performance index for water rights called the Water Rights Price Index (WRPIx). The purpose of this index is to track the movement of market prices and provide investors with more information regarding the water right value performance and volatility. In this way, private investors can compare investments in water right acquisition to other types of more traditional investments. Other benefits of the index include a better understanding of the level of western water scarcity and filling in information gaps on the historic prices of water right transfers. The index helps understand the level of western scarcity because prices typically rise as shortages intensify, and vice versa. It also helps fill in information gaps by providing the water right price performance over time.

WestWater developed this composite price index using prices from 14 of the most active water rights markets in eight western U.S. states. The WRPIx is comprehensive in the fact that it "isolates the influence of time from difference in prices across states and new uses, and weight most heavily price trends in regions exhibiting high levels of trading" (WestWater, 2012: 2) and controls for the variability in prices due to the proximity to urban areas and transactions sizes. The index has performed relatively well in relation to the movement of prices from 2002 to 2010. From 2002 until 2004 the index remained relatively stable, but saw a huge increase in 2005 and 2006 that can be attributed to the expansion of land development and housing market bubble. Then, in 2007, the index fell as the national economy began to slow. WestWater notes that the recession had a strong effect on the water markets in Utah, Nevada, New Mexico, Arizona, and the Northern Colorado Water Conservancy District. Since 2007, the index has remained relatively stable. Whereas the recession decreased the water market activity and prices in several western water markets, California's prices nearly doubled in the same period which is attributed to the three-year drought that they were experiencing.

WestWater has also analyzed California's Central Valley water market in their Water Market Insider publication. The water market in the Central Valley is a "spot market" or a single-year lease market. This market is very active and important allocation tool for agricultural, urban and environmental purposes. From 2000 to 2010, the spot market lease prices rose rapidly, increasing at an average rate of approximately 6% year-over-year. This increase in price is primarily due to persistent drought conditions and stricter environmental regulatory conditions in the Sacramento-San Joaquin River Delta. The issue is that 70% of the water supply originates in Northern California whereas 80% of the water use is in Southern California. The Delta is located in Northern California and is protected by federal and state regulations aimed at protecting threatened and endangered fish species. If the water originates north of the Delta, it is 30-35% cheaper than water supplies south of the Delta. As such, the prices of water reflect the source of the water. The analysis also concluded that in addition to the drought increasing the prices; it also increased the volatility of the water prices due to the physical and regulatory constraints of water mobility. Finally, in terms of the volume of water transferred, since 2000 environmental water users in the Central Valley have "acquired a larger cumulative volume of water on the spot market than urban or agricultural water users" (WestWater, 2011: 3).

A consistent finding among several of the studies conclude that drought conditions increase the prices of water transferred (WestWater, 2011; Jones, 2008; Emerick, 2007; Brown, 2006; Pittenger, 2006; Pullen, 2006; Pullen and Colby, 2006, Brookshire et. al., 2004). This result is supported by the work of several previous University of Arizona Agricultural and

Resource Economics (AREC) students. Jones (2008) conducted an econometric analysis comparing environmental sale and lease prices versus non-environmental sale and lease prices. She found that if population, income, and urban development continue to increase, sale and lease prices for both environmental and non-environmental uses are likely to rise. Additionally, she found that drought conditions will also result in higher lease prices. Emerick (2007) also concluded that drought leads to higher prices in the water market. In his thesis, Emerick estimated water transfer characteristics using a game theory model. The conclusions of this analysis suggest that drought affects the price of water transferred (results in higher prices), but that it does not affect the volume of water transferred. Finally, Pullen (2006) and Pittenger (2006) contributed to the literature by examining the determinants of price in light of drought conditions and climate change. Pullen (2006) focused on sales and Pittenger (2006) focused on leases. In Pittenger's analysis, it was determined that in almost all models lease prices increase with drier weather and drought conditions. The result wasn't so clear cut in Pullen's analysis, as the Standard Precipitation Index (measure of drought conditions) produced mixed results on sale price. However, Pullen was able to contribute to the water rights price literature with her work with Colby in their working paper in 2006. Pullen and Colby (2006) conducted an econometric analysis of the Colorado Big Thompson (CBT) and Central Arizona Project (CAP) sale water markets. Their findings suggest that drought was associated with higher prices in both markets.

Brown (2006) also conducted an econometric analysis to determine the factors that influence price. Using sale and lease data from 1990-2003 he used ordinary least squares to determine which factors affect the prices of transfers. Using the Palmer Drought Severity Index as drought measure, he found that lease prices were linked to drier conditions. Higher lease prices were also linked to larger populations and to environmental and municipal use compared to irrigation. Sale prices, on the other hand, were not found to be linked with drought conditions. They were, however, associated with smaller quantities of water transferred and smaller populations.

In addition to analyses regarding how drought conditions affect the water market prices, there has also been research done to determine how the prices differ across states and how the price varies depending on who the water is being transferred to. Payne and Root (2011), Libecap (2010), Brewer, et. al. (2007), Donohew (2009), and Brookshire, et. al. (2004) all continue with their contribution to the literature with regard to water market prices.

Payne and Root (2011) list the four factors that influence the prices of individual water rights. These are: 1) the reliability of the water source, usually determined by the priority of the water right, 2) the proximity to the water source, 3) the volume of the water transfer, and 4) the hydrologic conditions. Obviously, the more reliable and the closer a water right is to the end user, the higher the price paid for the transfer. Volume can also affect the price of the transfer. They state that several studies have shown that large volumes tend to sell for lower per-unit prices than smaller volumes. Finally, they again mention the affect that drought conditions have on the prices. They suggest that hydrologic conditions affect single-year lease transactions significantly. Ultimately, in their analysis of transactions between 2002 and 2006 they find that prices vary greatly from state to state and that water prices are highest in New Mexico, Colorado, and Nevada and lowest in Texas. Additionally, they find that to whom the water is being transferred to also affects the price. Agricultural water users and environmental users pay significantly less than urban water users with agricultural water users paying 15-75 percent lower than urban users and environmental water users paying 35-120 percent less than urban users.

Libecap (2010) has a similar finding in his analysis of 12 Western states from 1987-2008. He concludes that agriculture-to-urban prices are significantly higher than agriculture-to-agriculture trades. He also echoes Payne and Root's conclusion that the price dispersion across the states is extreme. He provides an example to put it into perspective. He states, "prices also differ sharply by state, with averages for one-year leases ranging from $8 per acre-foot in Idaho to $87 in Arizona and averages for sales ranging from $113 per acre-foot in Idaho to $6,592 (!!!) in Colorado" (Libecap, 2010: 66).

Brewer, et. al. (2007) surveyed how Western water markets have responded to the large disparity in value between urban and agriculture uses. This study found that most water was transferred out of agriculture to urban uses and that prices for this type of transfer were higher than transfers from one agricultural user to another. In terms of the types of transactions occurring, they found that the number of sales and multi-year leases are increasing while the number of leases is not. Another significant finding when comparing among the 12 western state markets from 1985-2005, is that faster growing states are seeing more water market activity.

Donohew (2009) also found in his analysis of 12 states from 1987-2007 that the rate of sales is increasing over time whereas the rate of leases is not increasing. Additionally, like the other researchers analyzing the prices of water transfers by the end user, he finds that urban water users are paying higher prices relative to agricultural water users and that the most common type of transfer are sales from agriculture to urban uses.

Brookshire, et. al. (2004) analyzed the price and quantity of water transferred in Arizona, Colorado and New Mexico using two- stage least squares. They found that although there were differences in the water markets of each state, the common thread was that government buyers pay less for water transfers than municipal water buyers, prices were higher in drier periods and prices were higher in areas with higher income. With regard to the quantity of water transferred, they found that demand is price elastic and that the quantity of water transacted decreases as the value of agricultural production increases.

To this point, this literature review has mainly been comprised of studies that have focused on analyses regarding prices of the U.S. western water markets. In addition, I review several other studies that focus on the general trends of the water markets and the types of transfers that are occurring in these markets.

First and foremost, Basta (also a former AREC student) and Colby (2010) analyzed the water market trends of several Western states and regions. They use descriptive data to show trends across the number of transactions, the total quantity or water transferred, and the average prices. In states where the market data was not strong enough to analyze individually, the states were grouped into regions. The findings suggest that, in general, the number of transactions is increasing, average volumes tend to be decreasing, and average prices are increasing over time. The annual total volume transferred varies across states and the type of the water transfer also varies across states.

Howitt and Hansen (2005) also examine the trends of the Western water market. They note several reasons why the market has been slow to develop. The first reason is that water has a public good aspect even though it is the right to use the water itself functions as a private property right. Secondly, the fluctuations in the water supply create “thin” markets with few buyers and sellers. Finally, a third barrier to the development of markets is the high transactions costs- derived from institutional and physical constraints. The authors note that in markets where the Bureau of Reclamation is involved or there is a state water project such as Colorado Big Thompson or the Central Valley Project in California, markets have developed more. Another complication of water transfers emphasized in this research is the third-party externalities that can exist and make the sale of water prohibitively expensive. For this reason, Howitt and Hansen (2005) suggest that as water trading increases there will be more leases than sales. In fact, they found that leases are already more prevalent in 12 of the 14 states analyzed. They suggest that this is due to the fact that leases have fewer environmental and legal restrictions.

Finally, Hansen, et. al. (2012) investigated the structure of water transfers from 1990-2008: whether the transfer was a sale or lease. They used a maximum likelihood logit estimation along with regulatory, hydrological and economic variables to determine which type of transaction would be pursued. They found that high agricultural production decreases the probability of a lease, urban growth is more likely to result in a sale and higher volumes traded decrease the probability of a sale.

2.4.2 Water Markets and the Environment

Given the growing environmental market, it is becoming evident that some environmental uses of water are becoming more valuable than other off-stream uses of the water. Colby (1990) describes the attributes of instream water that produce economic value. The tangible economic benefits of keeping water instream are: water quality enhancement, recreation use, and local economic development from water-related tourism. The difficult to quantify, but very essential non-use values of instream water must also be considered when valuing water for the environment. The resource (such as a lake or river) has non-use value itself, but keeping water instream also provides important benefits and value to the surrounding ecosystem and its inhabitants. For example, instream water may have higher value when a Threatened and Endangered Species' survival depends on adequate streamflows.

Within California, the transfers for environmental purposes have led to the growth of the water market. Howitt and Hanak (2005) conducted an analysis of the California water market from 1985 to 2004 and found that the demands for environmental water, in large part, contributed to the growth of the water market in California. They note, however, that the market for environmental water rights could not have evolved without the legal reforms that began in the late 1970s and lasted until the late 1990s. These reforms not only gave the environment protection from the third-party effects of other water transfers, but it also introduced programs where the state and federal government were purchasing water for environmental protection and restoration. Between 1995 and 2001, purchases for environmental purposes were 25% of all transfers in California.

Loomis, et. al. (2003) used data from *The Water Strategist* to conduct a study of the environmental transfers in 11 Western states from the years 1995-1999. The study's purpose was to document the progress of the newly developing water market for environmental purposes. It found that approximately 88,850 acre-feet (AF) of water was sold for an average price of $609 per acre-foot over the five-year period. Annual leases produced even more astounding numbers with 1.72 million acre-feet (MAF) leased for an average price of $30 per acre-foot. They found that the most common use of both sales and leases were for instream flows, with other environmental purposes such as water for recreation and threatened and endangered species were also present. The conclusions of this study suggest that environmental uses are, in some cases, higher-valued users of water. If they were not, the voluntary transactions between farmers and the government and non-profit agencies purchasing water for the environment would not have occurred.

Isé and Sunding (1998) examined transactions in Nevada from 1990 to 1997 to determine the characteristics of sellers who would be willing to transfer their water right to the U.S. Fish and Wildlife Service to protect the Lahontan wetlands. The results of the study suggest that financial distress was the most important predictor of a sale. Other qualitative data was received from the survey, such as the feelings that the farmers felt towards the program to protect the wetlands. Some of the farmers had opposition of selling their water right because they didn't trust that the government would keep the water supporting the wetlands. These people feared that the government would end up selling the water to support development in the urban areas. Others felt that the price offered for the water was too low. The authors of this study suggest that, due to their findings that many personal reasons and beliefs affected whether a sale occurred, a water market may not always allocate water efficiently.

Lastly, Scarborough (2010) finds that states that permit private acquisitions of water rights for the environment (such as Washington, Oregon, Nevada, California, and New Mexico) have more environmental transactions than those that do not (such as Colorado, Idaho, Utah, and Wyoming).

Chapter 3. Conceptual Model

The following chapter will outline the economic theory and theoretical framework on which this thesis is based. First, I present the utility theoretic model of consumer preference that provides the framework for the Contingent Valuation Methodology study in the Delta. The CV methodology also includes statistical analyses of survey responses. The statistical model of the CVM is also briefly explained in this section. The theoretical and statistical framework for the CVM is primarily drawn from Carson and Hanemann (2005) with some reference to Loomis (2012) and Hanemann (1984). Second, I outline the framework used to elucidate the relationship between ecosystem services and water markets. This framework will use economic concepts to emphasize the importance of valuing ecosystem service benefits and the costs that may need to be incurred in order to arrive at an optimal level of ecosystem service benefit provision. This framework is drawn from Pearce (2007) and Fisher, et. al. (2008).

3.1 Consumer Preference Theory and Statistical Framework for CVM Study

The goal of a CVM study is to determine an individual's monetary value for a good or service. In the case of this thesis, I am measuring the value that visitors to the Delta place on the health of the Delta ecosystem and the resulting recreational benefits. In order to do this we must consider the individual's utility function. The utility function $U(x, q)$ is comprised of the good being valued q and x (other market commodities). Corresponding to the direct utility function, there exists an indirect utility function $V(p, q, y)$ where p are the prices of the goods, q is the good being valued and y is the person's income.

When conducting the valuation of a good, there must be a contrast between two situations. In this thesis, they have two options: 1) pay for entrance and guarantee that there is an adequate amount of water to support the Delta ecosystem or 2) do not pay for entrance and there would be no assurance of flows to support the Delta ecosystem. The interpretation within the theoretical model would be a change in q from q^0 to q^1. The person's utility therefore changes from $U^0 \equiv V(p, q^0, y)$ to $U^1 \equiv V(p, q^1, y)$. If the individual believes the change to be an improvement then $U^1 > U^0$; if the individual sees it as a change that makes them worse off then $U^1 < U^0$; and if the individual is indifferent then $U^1 = U^0$.

The change in value in monetary terms is measured by the Hicksian compensating variation C, where C measures the maximum willingness-to-pay (WTP) for the change. It is evaluated by the following equation: $V(p, q^1, y - C) = V(p, q^0, y)$. If the individual considers the change as an improvement then $C > 0$.

Essentially the WTP function is evaluated as:

$$WTP\ (q^0, q^1, p, y) = C(q^0, q^1, p, y) \qquad if\ C \geq 0$$

Now to translate the WTP function into a probability distribution for the CVM survey responses we denote the WTP cumulative distribution function (cdf) by $G_c(x)$. This cdf outlines the probability that the individual's WTP is less than x, $G_c x\ \equiv \Pr\ (C \leq x)$ where C still represents the compensating variation. In the case of a close-ended, single-bound discrete choice format, like the one used in this thesis, we use outline the probability as

$$\Pr(Response\ to\ close - ended\ question\ is\ 'Yes') = \Pr(C \geq A) \equiv 1 - G_c(A)$$

where A is the amount proposed to the respondent. In this case the respondent is asked, "Are you willing to pay \$$A$ in order to support the change from q^0 to q^1?" If the respondent answers "Yes", then his/her value of C is greater than or equal to A. Although this method does not provide the exact value of C it provides an interval on which C must lie.

Statistically, I use the logit model (with a logistic error distribution) to estimate the WTP model. The logit model specifies the probability of a "Yes" response with β values as the slope coefficients and X values as the independent variables. The logit regression was selected for this study because it is the most common method used in the literature for calculating the median WTP. The estimation of a logit model is done by maximum likelihood. The Xs are the specific characteristics of each individual observation. The general specification of the logit model is outlined below Loomis (2012).

$$L_i = \left(\frac{Pi}{1 - P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + u_i$$

Once the WTP logit equation has been estimated, the median WTP over the whole sample can be calculated by using a formula from Hanemann (1984). The equation used to calculate the WTP is:

$$WTP = ((\beta_0 + \beta_2 X_{m2} + \beta_3 X_{m3} + \cdots + \beta_n X_n)/|\beta_1|)$$

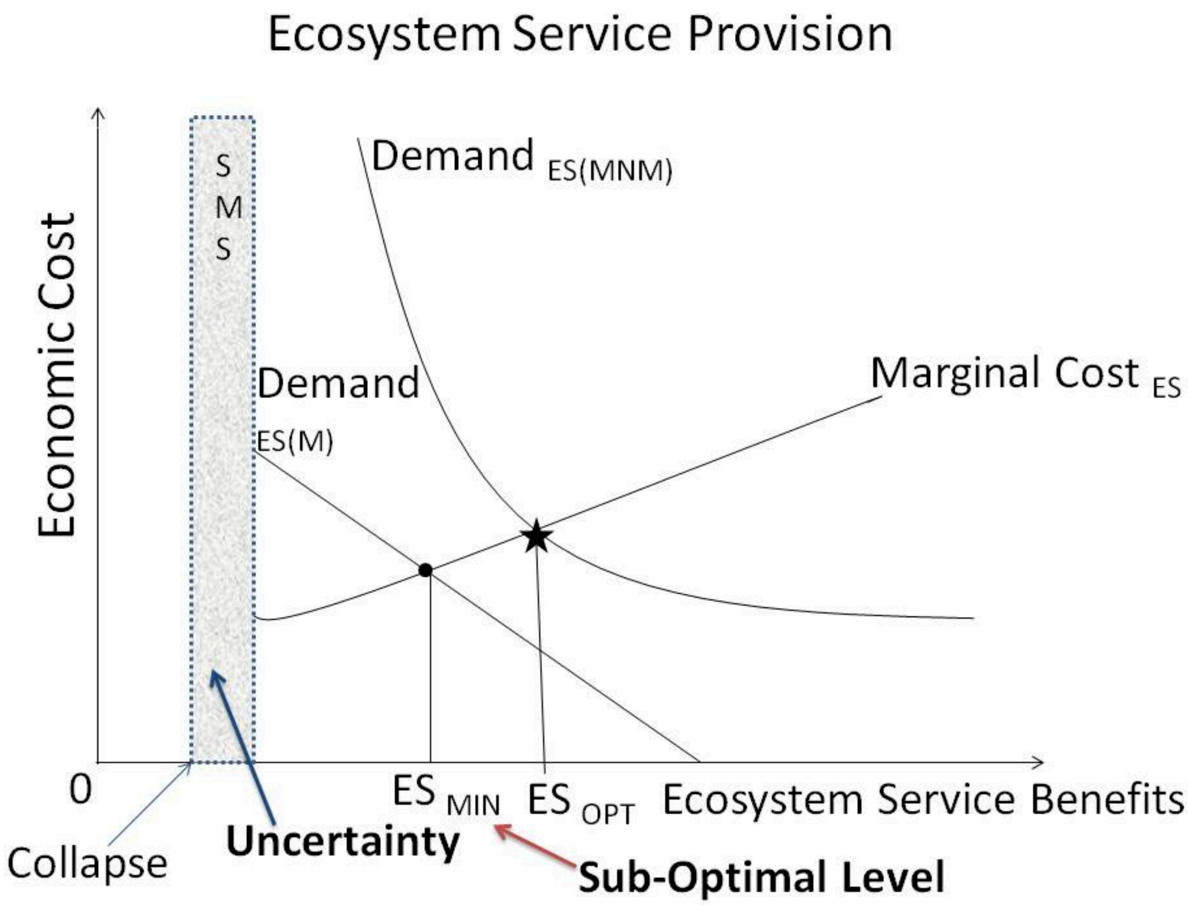
Where β_1 is the coefficient on the fee amount and $X_{m2} \ldots X_{mn}$ are the sample medians of the independent variables.

The use of the logit model and Hanemann's equation allows researchers to statistically infer the maximum WTP. This parametric approach includes linear specifications of the random utility model and constant marginal utility of income. One could also calculate the median WTP using a non-parametric approach (such as the median of the raw data), but using this method does not consider any assumptions regarding the underlying utility functions (Loomis, et. al., 1997; Hanemann, 1984). The method presented by Hanemann facilitates evaluating changes to the respondents' WTP based upon changes in the characteristics of the respondent or changes in the level of quality of the good. For example, one would be able to calculate the changes to the WTP for a good with higher income levels or level of education.

3.2 ECONOMIC ECOSYSTEM SERVICE FRAMEWORK

This section provides the conceptual economic framework that relates ecosystem service benefits to human welfare. The graph below is a simple supply-demand relationship. The x-axis represents the ecosystem service provision- or the ecosystem service benefits. The y-axis measures the economic cost of ecosystem provision. The demand curve *ES(M)* represents the ecosystem service benefits that are tangible, marketable goods. These goods have a market price and are sold in markets (e.g., timber and fish). Note that the demand curve is downward-sloping and as ecosystems are converted and supply decreases (moving left on the x-axis) the marginal value of the good increases (moving up the y-axis).

FIGURE 4. ECONOMIC DEFINITION OF ECOSYSTEM SERVICES AND OPTIMAL PROVISION



The second demand curve on the figure takes into account all of the services and benefits that an ecosystem provides, regardless of whether they are sold in markets. *ES(MNM)* are the cumulative marketed and non-marketed ecosystem services. Non-marketed service benefits include the ecosystem services that are not sold in a market such as aesthetic enjoyment, recreation, biodiversity, etc. Due to the fact that many of the ecosystem services are public goods and not sold in markets, it is assumed that *ES(MNM)* is significantly higher than *ES(M)*.

The supply curve is represented by the marginal cost curve *ES*. This curve captures the marginal costs of acquiring and maintaining one more unit of ecosystem service benefits. The positive slope shows that as each additional unit of ecosystem service benefit, the cost to secure that benefit is also increasing. The example of a potential cost in this thesis is the purchase of water for the environment.

Another important component of the graph is the SMS section to the left of the graph. This area represents the safe minimum standard (SMS) or the "minimum quantity of ecosystem structure and process (including diversity, populations, interactions, etc,) that is required to maintain a well-functioning ecosystem capable of supplying services" (Fisher, 2008: 2053). As can be imagined, there are enormous amounts of uncertainty about where this level lies. If ecosystems are converted to the point where they are no longer able to provide ecosystem service benefits, they could reach the point of collapse. Uncertainty regarding the SMS threshold therefore provides incentives for following the precautionary principle and encourages investment in ecosystem service research and restoration of ecosystems. As Boyd (2011) argued, not only is it is better to invest in healthy ecosystems in order to maintain the provision of current ecosystem service benefits, but it's also important to hedge against the potential irreversible ecological losses from ecosystem collapse.

This issue of irreversibility and uncertainty is extremely relevant in the Colorado River Delta as some experts concluded that the Delta's ecosystems had already reached the point of collapse when they had not received water for decades. When 90% of the Delta's riparian, freshwater, and wetland ecosystems had disappeared it seemed like the Delta's ecosystems had reached the point of collapse. But the floods in the 1980s, due to the El Nino weather patterns, suggested that the ecosystems were more resilient than had been expected. The degradation in the Delta appeared near the safe minimum standard threshold, but it is not possible to know how close the ecosystem was to irrecoverable.

Continuing with the graph, the two points highlighted in the figure show the points were the marginal cost equals the marginal benefit- following the equimarginal principle. ES_{min} marks the point where only marketed services are considered. When considering only the benefits provided from the marketed goods *ES(M)* the equimarginal principle would lead to the ES_{min} point because at any point to the right of ES_{min} the cost would outweigh the benefit. However, when one includes the non-market ecosystem service benefits the equimarginal principle leads to the optimal level ES_{opt}. This demonstration shows that if non-marketed ecosystem benefits are not included there will be a serious under provision of ecosystem services ($ES_{min} < ES_{opt}$) and increasing probability of reaching the SMS threshold.

The major points of this diagram show that:

- Uncertainty regarding the SMS threshold warrants precaution and creates incentives to invest in restoration to prevent ecosystem collapse and the resulting loss of ecosystem service benefits.
- Ecosystem service benefits are undervalued and underprovided when the value of non-marketed ecosystem service benefits are not considered.

This conceptual framework very clearly links the two components of this thesis. The first objective of the thesis is to understand the value of the non-marketed ecosystem service benefits provided in the Delta using the contingent valuation method. The second objective of understanding the water market is necessitated by the uncertainty and investment costs needed to secure continued provision of ecosystem service benefits. In the case of the Delta and other similar degraded freshwater ecosystems, the purchase of water for the environment using water markets are the types of costs demonstrated in the marginal cost curve that need to be incurred to sustain ecosystem service benefit provision and prevent further degradation that could go beyond the SMS threshold.

Chapter 4. CVM Study Methodology, Data, Econometric Model and Results

4.1 Survey Sites

The five areas selected for contacting visitors and eliciting values for recreation and environmental flows were scattered throughout the Delta. Two locations were on the Colorado River itself: a site at Presa Morelos (Morelos Dam) and a place called Vado San Felipito. Two locations were on the Hardy River, a tributary of the Colorado River: Campo Mosqueda and Campo Baja Cucapah, and the final site was at the Cienega de Santa Clara (see Table 5).

The Morelos Dam site is located near Morelos Dam, the diversion dam that provides water to the agricultural Mexicali Valley. The dam is located 1.1 miles (2 km) from the U.S.-Mexico border, where the California and Baja California land boundary intersects the river (IBWC, 2012) and within the state of Sonora and Arizona. At the dam, almost all of the Colorado River water is diverted into the Canal Reforma and taken to the agricultural Mexicali Valley. Visitors to Morelos Dam typically go to an open area near the dam to spend time with family, have picnics, and take part in community activities. For example, during Holy Week (the time of surveying), there is a small carnival that operates at the site. There are no services offered at this location.

Vado San Felipito is a bridge that crosses the Colorado River along the Sonora-Baja California railway and Carretera Luis B Sanchez el Faro highway. It is located approximately 6 km east of Guadalupe Victoria (GEER Association, 2012) and quite close to Kilometer 57 (Zamora personal communication, 2012). At this location, the Colorado River usually has water in the river, but there are some instances where the water is very shallow. There are no services or facilities at this location. People congregate at San Felipito primarily just to spend time with friends and family and have picnics, to race motorcycles or ATVs, or to swim. The name literally means "Little San Felipe" and is derived from the fact that visitors to this site see it as an alternative to traveling to the coastal city San Felipe.

Campo Mosqueda and Campo Baja Cucapah are privately owned "resorts". Campo Mosqueda is owned by the Mosqueda family, originally established in 1959 by Jesus and Romelia Mosqueda. It is located at Km. 53 ½ on the highway to San Felipe, approximately 45 minutes from Mexicali. This site offers a restaurant, a conference room, river front palapas (shade umbrellas) with barbeque grills, a sand volleyball court, campsites with restrooms and showers, and rental pedal boats and kayaks (Campo Mosqueda, 2011). Visitors who come to Campo Mosqeuda can participate in water activities such as fishing, swimming, boating, water or jet skiing, kayaking or riding on pedal boats. Visitors can also ride motorcycles and ATVs on the nearby dunes. Others just enjoy picnics or day-trips to the river or camp overnight. The cost to enter Campo Mosqueda is around $20 USD for a day trip.

Campo Baja Cucapah is owned by Omar Escodero (Zamora personal communication, 2012). It is located at Km. 48 ½ on the highway to San Felipe, near Colonia Terrenos Indios. Campo Baja Cucapah offers cabanas (cabins for overnight stays) that are complete with a kitchen, living room, and sleeping accommodations for five people. For day trips, the site offers the rental of palapas, or shade umbrellas, as well as the use of picnic tables and small pedal-boats. Additionally, the site offers a "Canopy Tour" which is a zip lining and suspension bridge activity. The cost to enter Campo Baja Cucapah is $250 MXN pesos per vehicle, which includes the rental of a palapa for day use. Visitors staying overnight in the cabins are expected to pay $1100-$1300 pesos per day (Campo Baja Cucapah, 2012).

The Cienega de Santa Clara, as previously mentioned, is a very large open-water wetland. A portion of it is protected by the Upper Gulf of California and Colorado River Delta Biosphere Reserve managed by the Comisión Nacional de Areas Naturales Protegidas (CONANP). It is also recognized as an internationally important wetland by the RAMSAR decree (Carrillo-Guerrero, 2005). Interestingly, in all federally protected areas in Mexico except the Cienega, visitors are required to pay an entrance fee to the site. Experts suggest that installation of fee booths has not been pursued because there are too many entrance points to the Cienega. So although the visitors to the Cienega are still required to pay the entrance fee, it is not enforced. Visitors to this area come for a variety of reasons including sport fishing, hunting, and bird watching. The Cienega attracts a significant amount of visitors from the United States due to the sport fishing activities (specifically bass fishing) offered at the site. The site also provides a few cabins and restroom facilities. The facilities, however, are not well taken-care-of.

TABLE 5. SURVEY LOCATION SITES

Site Name	**Location**	**Ownership**	**Services**
Morelos Dam	Colorado River	Public	None
San Felipito	Colorado River	Public	None
Campo Mosqueda	Hardy River	Private	Many
Campo Baja Cucapah	Hardy River	Private	Many
Cienega de Santa Clara	Open Wetland	Public	Few

4.2 Methodology

The overarching goal of this contingent valuation study is to determine visitors' willingness-to-pay for a guaranteed source of water needed to sustain the Colorado River Delta's ecosystem. The WTP was estimated from the responses of surveys conducted during Holy Week at five different recreation locations in the Colorado River Delta. The survey included questions concerning their expenditures, activities, reasons for choosing that particular site, visitation patterns, knowledge and importance of conservation in the area, and demographic information. The key component of the survey, however, was the willingness-to-pay section. The respondents' WTP was elicited through a hypothetical scenario in which the respondent was asked if they were willing-to-pay a specific amount to enter the site knowing that the site would be guaranteed to have an adequate amount of water to support the Delta ecosystem. The analysis of this data was conducted in SAS, a statistical programming software, using the logit regression (the standard regression for this type of CVM study). The analysis will result in a median WTP over the whole sample and the determination of which factors/variables influence the respondents' WTP for the good. If there were estimates of visitor numbers to these sites in the Delta, an aggregate WTP would also be calculated.

The methodology presented here is in chronological order starting with a detailed account of the considerations made in the design of the survey, the steps taken to prepare for implementation of the survey, and the actual implementation of the surveys. I then present the blue ribbon panel guidelines and how the study compares to the standard criteria.

4.2.1 Survey Design

Mitchell and Carson's (1989) book, *Using Surveys to Value Public Goods: the Contingent Valuation Method*, emphasized the importance of survey design and highlighted the types of biases and misspecifications that can occur if the survey is not carefully designed (Carson and Hanemann, 2005). Careful consideration must be taken when designing the survey. Specifically, care needs to be taken when developing the WTP scenario, choosing the payment vehicle, and the payment elicitation method. This section outlines the considerations that need to be made when developing the willingness-to-pay section of the CVM survey.

As stated previously, the design of this survey is based upon a survey developed and conducted by Rivera and Cortés (2007) of the Instituto Nacional de Ecologia (INE) with assistance from Yamilett Carrillo-Guerrero of Pronatura. The article was published in Spanish in *Region and Society* in 2007. Major modifications were made to this survey to broaden the scope of the project to the Delta and to focus specifically on the WTP for a guaranteed source of water to support the health of the Delta ecosystem.

4.2.1A Components of Survey

When designing the survey it is important to think about the factors that contribute to whether a respondent would be willing-to-pay for an entrance fee in order to guarantee adequate amounts of water to support the health of the Delta's ecosystems. Factors affecting the likelihood of a respondent being willing-to-pay for entrance to the recreation site are a function of the frequency that they use the site, the activity that they participate in, their beliefs about the importance of Colorado River Delta and conservation in general, and general demographic information such as age, education, and income. To cover these topics, the survey comprised four distinct sections:

1. Visitation information
2. Use and conservation of the ecosystem
3. Preferences about the Colorado River Delta, and
4. Demographic information.

The first section of the survey has two separate components of visitation information. The section began with questions regarding the respondent's visit on that particular day. The respondents were asked how many people were in their party, their expenditures, the length of time they were planning to stay, and the activities that they came to partake in. The subsequent section refers to any past visits they had taken to the site. If the survey date was their first trip to the site, the respondent could skip to the next set of questions. Otherwise, the respondent was asked the average amount of time they stayed in the recreation site, whether they had seen the recreational site dry, the activities that they normally come to partake in, and the season that they prefer to visit the site.

I develop the second section to help understand the respondents' awareness of the Delta ecosystem and the importance that they place on conservation of the environment. The respondents were asked if they have heard or read about the Delta's significance to the region in the last few years. These questions were specifically designed to elicit an honest response from the respondents. The original question asked if they were aware that a protected area, the Upper Gulf of California and Colorado River Delta Biosphere Reserve, existed. Upon further review, however, we decided to re-word the question to ask if they had *heard* or *read* about the Biosphere Reserve to address any false positives, or people saying that they were aware of the Reserve to appear knowledgeable or prevent embarrassment. They were also asked a couple questions regarding the level of importance that they place on conservation practices. On a 5-

point Likert scale, the respondent was asked to indicate the importance of designating a secure supply of water for the environment, such that the water level is adequate to maintain the health of the ecosystem. Similarly, they were asked to indicate the importance of taking part in conservation efforts to maintain habitat for native species.

The third section is the heart of the CVM study as it is the portion of the survey that elicits the respondents' WTP. It constructs the hypothetical market by giving some background information, the proposed changes, the WTP questions, and a follow-up question for a select group of respondents. The details of this section are elaborated upon in the next two segments of this paper.

The final section of the survey asks general demographic information such as the respondent's age, gender, marital status, occupation, education and income. At the end of the survey the respondent was also given the opportunity to make any comments or suggestions about the survey or the situation in general.

4.2.1B SCENARIO

The development of the scenario is one of the most important sections of the CVM study. This is where the constructed market is developed and the data for the estimation of the value of the good is elicited. This section should be as clear, concise, and neutral as possible. The respondent should be given enough information to make an informed decision, but the amount and content of the information should not overwhelm or bias the respondent. It should be carefully designed to avoid any confusion or misunderstanding between the interviewer and the respondent. Furthermore, it is imperative that the constructed market is meaningful, realistic, and plausible. If the respondent does not believe that this market is feasible or realistic, their true value may not be captured.

The scenario should include a baseline of the current situation and must "convey the change in the good to be valued, how that change would come about, how it would be paid for, and the larger context that is relevant for considering the change" (Carson and Hanemann, 2005: 897). Again, this should be as clear and concise as possible in order to avoid misunderstandings between the respondent and the enumerator.

The scenario, or hypothetical market, for this study was developed so that the respondent could place value on securing adequate amounts of water to sustain the Delta's ecosystem. The market was constructed by: 1) giving background information regarding the status of the Delta ecosystem today (the baseline/problem), 2) the proposal to address this problem, 3) how the project would be implemented and paid for, and 4) a value elicitation question to elicit the respondents' WTP.

The scenario presented to the respondents stated:

> "In recent decades, portions of the Delta's rivers and wetlands have dried due to lack of water flows. Conservation groups and visitors are concerned that inadequate flows are harming the flora and fauna of the region. Without adequate flows, the health of this ecosystem is threatened and local communities are faced with declining recreational benefits.
>
> Conservation groups and people who value this ecosystem and the benefits it provides to local people want to ensure that there are adequate amounts of water to sustain a healthy and vibrant Delta ecosystem. Funds for securing adequate water could be generated through various sources: one of these sources could be entrance fee collection booths at the main entrances of recreation sites such as this.
>
> Now, we ask you a series of questions regarding a possible entrance fee. In answering, please assume that the fees will be collected and managed by a non-profit trust responsible for securing water to sustain a healthy ecosystem. Please think carefully

about your response and keep in mind that you would need to reduce expenditures on other items in order to contribute."

4.2.1c Payment Vehicle

Another important decision to be made when designing a CVM study is to choose the payment vehicle, or the mechanism in which the respondent would hypothetically pay for the good. Once the hypothetical market has been established to value the good, there must be a mechanism through which the respondent would pay the amount specified in the valuation process. Typical payment vehicles include higher taxes, higher product prices or total bills, entrance fees, or payments to a designated fund. This CVM study used an entrance fee as the payment vehicle.

4.2.1d Payment Elicitation Method

The final important decision to be made is to choose the payment elicitation method, or the way in which the respondent is asked for their WTP. Two commonly used elicitation methods are open-ended and closed-ended questions. Open-ended questions, not as commonly used in today's CVM studies, ask the respondent's WTP and let them answer freely. An open-ended question would ask : "What is the maximum amount of money you would be willing to pay for…?". In this case, the respondent can answer with ANY value. This type is seen as more difficult for respondents to answer, especially if the respondent is unfamiliar with valuing a natural resource.

The second method is through a closed-ended question. Closed-ended questions can take many forms including the use of a dichotomous choice question, or the use of payment cards or a bidding game. The dichotomous choice question, also known as the take-it-or-leave-it question or referendum question, presents a randomly assigned amount and asks the respondent for a simple “yes” or “no” of willingness to pay that specific amount. The amount varies by respondents and can therefore trace out a demand curve over the entire sample. The benefits of using this form is that it doesn’t require much effort on the part of the respondent and it is familiar to respondents because the decisions to “buy” is similar to ordinary market decisions that a person has to deal with everyday. A bidding game starts originally as a dichotomous choice question: an amount is proposed to the respondent and they choose whether they are willing-to-pay that amount or not. If the respondent states that they are willing-to-pay the proposed amount, the amount is then raised and the respondent is asked if they are willing-to-pay again. This process is continued until a “no” WTP is reached. The highest “yes” amount is recorded as the respondent’s maximum WTP. The advantage of this type of elicitation method is that it allows the surveyor to hone in on a more accurate WTP value. Finally, there is the payment card method in which the respondent chooses the maximum they would be willing-to-pay from a range of values. This has the advantage in that it is doesn’t require much effort from the respondent, but also must be designed carefully so as not to produce starting point bias.

This CVM study asks two similar WTP questions with two different payment elicitation methods. The WTP question of the utmost interest followed the dichotomous choice method and the second question followed the payment card format. The value elicitation questions directly followed the scenario. The first question followed the dichotomous choice payment elicitation method and asked:

“Which of the following options would you prefer? (choose one)

a) Pay [X] pesos per car per entry to this site and the site would be guaranteed to have adequate amounts of water to sustain a healthy and vibrant ecosystem.

b) Do not pay for entry to the site, and have no assurance of water to help sustain the ecosystem. (sometimes there could be more water, sometimes less, as they release water from the United States)."

The fee amount in pesos per car varied across each survey and also varied depending on the location where the survey was conducted. If the survey was conducted along the Rio Hardy, at either Campo Mosqueda or Campo Baja Cucapah, the values inputted for [X] were 20, 50, 100, 175, 275, or 400 Mexican pesos. The survey values were stratified so that the first survey began with the value of 20, the second 50, and so on so that each value would be represented in the sample approximately the same number of times. The same methodology for inputting the values was used for the three other sites, but their fee amounts were significantly less. For surveys conducted at the Cienega de Santa Clara, Presa Morelos, and Vado San Felipito the values inputted for [X] were 10, 20, 35, 50, 70, or 100 Mexican pesos.

The range of values differs between the locations based on information received from a previous study conducted by the Sonoran Institute. During Holy Week of 2011, they conducted a similar survey where they determined the maximum amount a respondent would be willing-to-pay based upon an open-ended question. The results of the 2011 survey showed that the locations along the Rio Hardy, Campo Mosqueda and Campo Baja Cucapah, had a significantly higher median WTP as opposed to the other sites. The median WTP for these two sites was 100 Mexican pesos, whereas the median WTP for the other sites was only 35 Mexican pesos. This study followed the advice of Alberini (1995) and Kanninen (1993, 1995) and chose 5 to 8 values that were clustered around the median WTP as the range of values to be used as the values for the dichotomous choice question (Boyle, 2003).

A second WTP question was asked as a follow-up question to the first. This question followed the payment card elicitation format and asked:

> "If you had to pay, what is the **maximum** you would pay for entry (per entry/car) to the site in order to ensure that it has an adequate supply of water to sustain a healthy and vibrant ecosystem?"
> ______ $/car (per visit)

When the enumerator asked this question, they would then hand a separate sheet of paper with a list of values where the respondent could circle the maximum that they would be willing-to-pay. Again, the range of values differed depending on the survey location. Those respondents at Campo Mosqueda or Campo Baja Cucapah could choose from the following:

0	10	15	20	25	30	35
40	45	50	60	70	80	90
100	125	150	175	200	250	275
300	325	350	375	400	450	500

The respondents who were surveyed at the Cienega de Santa Clara, Presa Morelos or Vado San Felipito could choose from the following range of values:

0	5	10	15	20	25	30

35	40	45	50	60	70	80
90	100	110	120	130	140	150

Every respondent also had the option of providing a value that was not provided in the table.

Finally, if the respondent answered the last question with a maximum of $0 WTP, they were asked a follow-up question to determine whether it was a valid WTP bid of zero pesos ($0) or whether it was a protest bid. The difference between these two types of bids is that the respondent with a true zero peso bid believes and accepts the constructed market, but is not willing-to-pay for the natural good or service. A protest response, on the other hand, is when a respondent objects to the hypothetical scenario altogether. Slightly more detail will be given when the removal of ineligible surveys is discussed in subsequent chapters.

4.2.2 Enumerator Training

Prior to the survey implementation, a training session was offered for the enumerators in the last week of March 2012. The session was conducted via a teleconference with myself and Joe Marlow, land economist for the Sonoran Institute, in Tucson, AZ and the enumerators in Mexicali, MX. Francisco Zamora, Director of the Colorado River Delta Legacy Program at the Sonoran Institute, translated all communication. A copy of the training agenda is provided in the Appendix. Several topics were covered in the training session, one of which suggested that enumerators wear neutral clothing and avoid wearing shirts with logos or slogans to reduce the risk of biasing the respondents.

In addition to the training, each enumerator was given a checklist to help remind them of important tasks and to help facilitate the interaction with visitors/respondents. The enumerators were also given a tally sheet to track the number of visitors approached, the number of respondents who completed the survey, and the reasoning, if given, for non-participation. Both of these documents can be found in the Appendix.

4.2.3 Survey Implementation

The survey can be administered to respondents in a number of ways. Common methods include using US postage mail, telephone, or in-person interviews. Mail surveys have the advantage that they are the least expensive and can be void of any bias an interviewer may produce, but they also typically have lower response rates and may not be able to effectively communicate complex scenarios. Telephone surveys are also generally cheaper than in-person interviews, but can be seen as impersonal and may not be relevant for the target population. Finally, an enumerator can administer the survey in-person. This can be done one of two ways: the respondent can read and respond to the survey him/herself or the enumerator can read the survey to the respondent.

The survey methodology chosen in this study was the in-person interviews with the enumerators reading the surveys to the respondents. This method was chosen for several reasons. First and foremost, this study is following the NOAA panel recommendations by using in-person interviews as opposed to telephone or mail surveys (Mitchell and Carson, 1989). Secondly, this study had considerable assistance from Sonoran Institute staff in the Mexicali office. There were almost a dozen individuals that were able to help in the administering of surveys at the five different locations. Finally, we chose to have the enumerators read to the respondents due to potential literacy problems[1].

The surveys were conducted during the weekend of Holy Week (Semana Santa) in 2012. Surveys were conducted on Friday, April 6th through Sunday April 8th. Over this timeframe, 674 surveys were completed with 584[2] of them usable in the econometric analysis. The enumerators contacted all persons above the age of 18 to participate in the survey.

TABLE 6. SUMMARY OF VISITOR CONTACTS

Location	People Contacted	People Declined	Completed Surveys
Campo Baja Cucapah	150	7	143
Campo Mosqueda	209	24	185
Cienega de Santa Clara	102	9	93
Presa Morelos	176	26	150
San Felipito	121	18	103
Total	758	84	674

As much as possible, this study followed the blue ribbon panel guidelines to conducting a valid and proper CVM study. The following list of guidelines provides a standard for whether a CVM analysis could be included in judicial proceedings or in public decision-making (Arrow et. al., 1993). The guidelines and how this thesis measures up in presented in the following table.

TABLE 7. NOAA CONTINGENT VALUATION BLUE RIBBON PANEL GUIDELINES

Guidline	Consistency
1. For a dichotomous choice question, total sample size of at least 1000 is required.	N
2. Tests for interviewer and wording biases are needed.	Y
3. High non-response rates render the survey unreliable.	Y
4. Face-to-face interviewing yields the most reliable results.	Y
5. Full reporting of data and questionnaires is required.	Y
6. Pilot surveying and pretesting are essential elements in any CVM	Y

[1] In one location, there were several respondents that requested to review the survey themselves. The enumerators agreed, and flagged those surveys that were not read to the respondent.

[2] Deletions from the original number of surveys completed is explained on page 34-35. Represents 87% of total sample.

study.	
7. A conservative design, more likely to underestimate WTP, is preferred to one likely to overestimate.	Y
8. A willingness-to-pay format is preferred over willingness-to-accept and other alternatives.	Y
9. Valuation question should be posed as a vote on a referendum, ie; dichotomous choice question.	Y
10. Accurate information on the valuation situation must be presented to respondents.	Y
11. Respondents must be reminded of the status of any undamaged substitute commodities.	Y
12. Time-dependent influences of WTP should be considered by averaging across WTP results collected at different points in time.	N/A
13. A "no-answer" option should be explicitly allowed, in addition to the "yes" and "no" vote options.	N
14. Yes and no responses should be followed up by an open-ended question: "Why did you vote yes or no?"	N
15. Survey should include questions that help to interpret the responses to the valuation question, ie; income, distance to the sire, prior knowledge of the site, etc.	Y
16. Respondents must be reminded of alternative expenditure possibilities, especially when "warm glow" effects are likely to be present (purchase of moral satisfaction through the act of charitable giving).	Y
17. Time value of money- account for varying years and change purchasing power (CPI) over time.	N/A

Source: Colby (2012). AREC 575 class notes, adapted from Knowler and Lovett (1996).

Of the seventeen guidelines, this study was able to address twelve and two were not applicable to this study. The first guideline that this study was not able to meet was the requirement to have at least 1,000 respondents. Due to the short timeframe for survey implementation (over the Holy Week weekend), this study was only able to complete 584 usable respondent surveys. The survey also did not provide a "no-answer" option for the WTP question. Due to the short time-frame for sampling, we decided that the inclusion of a "no-answer" option would decrease the response rates too much. Additionally, the survey did not provide an open-ended question to the dichotomous choice question. It did, however, provide a multiple choice question for those respondents who answered "no" to identify protest responses.

4.2.4 DATA HANDLING AND REMOVAL OF INELIGIBLE SURVEYS

When conducting surveys, there are often cases in which some questions are not answered or not recorded. This can pose problems when the data analysis and econometric modeling is done. To combat this issue, there are two major avenues: 1) delete the entire record of observation, or 2) use statistical data from the remaining sample to fill in values for the missing information. Both methods were employed in this project.

In total there were 90 records deleted from the sample. As can be seen in the Table 8, this brought our usable sample to 584. The records that were deleted either had missing information on their income, age or gender or they were deleted because they had a protest zero response.

TABLE 8. REMOVAL OF INELIGIBLE SURVEYS

Total Surveys Collected			674
	Deletions		
	Protest Response	45	
	Missing Income	42	
	Missing Age	1	
	Missing Gender	2	
	Total Deletions	90	
Useable Surveys			584

All respondents who stated that they had a maximum WTP of $0 Mexican pesos were asked a follow-up question to determine *why* they were not willing to pay the entrance fee to contribute to the fund to acquire water. Responses that demonstrated that the respondent disagreed with the hypothetical scenario or the constructed market were considered protest bids. All zero bids were categorized as either a valid zero bid (in which the answer of $0 MXN was considered to be a genuine and true value) or a protest bid (in which the respondent disagreed with the scenario, felt that it was implausible, or disagreed with the means of collecting money). The table below shows the list of potential responses to a $0 bid as well as the number of responses that were considered valid and protest bids. Overall, 45 of the $0 bids were flagged as protest bids and deleted. The remaining 42 $0 bids were kept within the sample.

TABLE 9. IDENTIFYING PROTEST RESPONSES

	Valid Response	**Protest Bid**
Reason that best explains the zero bid	**No. of Bids**	**No. of Bids**
Our party cannot afford to pay the entrance fee	30	
Any amount I pay would be too small to make an impact.		5
I do not think the deterioration to the Delta's health is urgent.	4	
I can go to other locations to enjoy nature.	8	
Water for the Colorado Delta should be acquired at no cost to me.		12
Local people will be unfairly burdened by paying for entrance.		2
I do not trust that the money would be handled correctly.		11
I need more information/time to answer this question.		3
Other reasons:		
Portions of the fees already charged should go to this fund.		12
Total Zero WTP Bids	**42**	**45**

Another legitimate way to handle missing information is to fill the variables missing with relevant values based on statistical measures. For example, in this sample, there were two respondents who did not specify their level of education, one who did not answer their maximum WTP, and 5 who did not indicate the number of visits they make to the area. In order to fill these with appropriate values, we determined the median level of education, maximum WTP, and number of visits based on the respondents' income level. For example, the median education for a respondent with an income level of less than $40,000 MXN/year was secondary school. The education information was then inferred based on their income level. This methodology is consistent with the literature.

For other missing variables that do not necessarily relate to the respondents' income, the median over the whole sample was used. An example of this type of variable is *water_value*. The first variable related to a question in which the respondent answered the level of importance via a 5-point Likert scale for maintaining a water level high enough to support a healthy ecosystem. Two respondents did not respond to this question and were therefore given the median value of the whole sample, which was "1" (or very important). In the final analysis this variable needed to be re-coded to make more intuitive sense. Therefore, for the analysis "1" symbolized that the respondent considered it the least important and "5" was the most important.

Knowledge of the area and the area's prominence were two other variables that had several missing responses. These variables asked whether the respondent was aware that the Delta was part of a protected area called the Upper Gulf of California and Colorado River Delta Biosphere Reserve and whether they were aware that the Delta is known worldwide for its flora and fauna. It was assumed that if the question was not answered, the respondent was not aware of these things.

Other issues with missing information were handled in logical, systematic way. There were six respondents that did not answer the WTP dichotomous choice question. If we had not asked a follow-up WTP question of, "What is the maximum you would be willing to contribute?" and given payment card values, we would have had to delete these six observations. However, because we had the maximum WTP question, we were able to infer whether or not they would have answered "Yes" or "No" to the dichotomous choice question. If the maximum WTP was higher than the amount given in the dichotomous choice, we assumed that they would have said "Yes". If the maximum WTP was lower, we assumed that they would have said "No".

One of the biggest issues with the survey data dealt with the problem of “yea-sayers”. In this analysis, a yea-sayer is a respondent who answers the dichotomous choice question positively for a certain amount, but then answers the follow-up question for their maximum WTP by specifying a maximum WTP that is ***less than*** the amount in the dichotomous choice question.

Yea-saying, as defined by the psychological and sociological literature, is “the tendency to agree with questions regardless of content” (Blamey, et. al., 1999:126). Specific to economic CVM literature, yea-saying is defined as “the tendency to subordinate outcome-based or ‘true’ economic preferences in favor of expressive motivations when responding to CVM questions” (Blamey, et. al., 1999:126). The motivations behind the tendency could be either socially motivated or internally motivated. For example, a respondent may answer the dichotomous choice question positively due to societal pressure or to please the enumerator. The respondent could also answer positively to express their beliefs, even though they may not be truly willing to pay the fee amount proposed to them (Blamey, et. al., 1999).

There were several steps taken in the design phase of the survey that supported reduction of yea-saying. First and foremost, instead of presenting the dichotomous choice options in terms of a “yes/no” answer, the survey asked the dichotomous WTP question in a “either/or” format. It also included the follow-up question regarding the maximum that they would be willing to pay. This follow-up question allowed for the identification of yea-sayers in the sample (Blamey, et. al., 1999).

As stated previously, a yea-sayer is defined in this sample as a respondent who answers positively to the amount proposed to them but then answers the follow-up question with a value less than the value proposed to them. For example, a yea-sayer is a respondent who answers “yes” to the proposed amount of 50 pesos, but then states in the following that the maximum amount that they would be willing to pay is 20 pesos.

This sample was particularly heavy with yea-sayers with 109 (or 18.6% of the sample) having this characteristic. Surprisingly, there were even six respondents who stated that they were willing to pay the dichotomous choice amount but also stated a maximum WTP of $0 MXN. All yea-sayers were flagged as such, and a variable called *TRUE_YES_WTP* was created. This variable is the dependent variable in the econometric analysis and was calculated where an observation with a positive response on the dichotomous choice question that has NOT been flagged as a yea-sayer is denoted as a true positive response (y=1). On the other hand, the dependent variable is equal to zero (y=0) when the respondent did not answer positively to the dichotomous choice question *or* when they answered positively, but were flagged as a yea-sayer, therefore denoting that the answer to the dichotomous choice question was NOT their true WTP. This adjustment accounting for yea-sayers produces a more conservative estimate, therefore meeting the conservative bias guideline described by the NOAA blue ribbon panel.

Due to the complexities of first-hand data collection there were several other issues to be addressed. For example, one question asks the number of hours the respondent stays at the recreational site. Most respondents answered in the approved format, but several answered “1 day”. In this case, 1 day was assumed to be a working day, or 8 hours. Another problem in the data entry was a misunderstanding by the enumerator. Question #6 asked the respondent to rank the top two activities that they came to partake in on that particular trip. They were only supposed to mark two selections, and rank the two in order of preference. There were 108 surveys in which all-possible activities were marked with a “1” or a “2”. These surveys were flagged, and any activities with a value of “1” were considered to be the main activity. A dummy variable was then created across all of the surveys where *d_water_recreation*=1 whenever an aquatic activity, swimming, or fishing were either ranked #1 or #2.

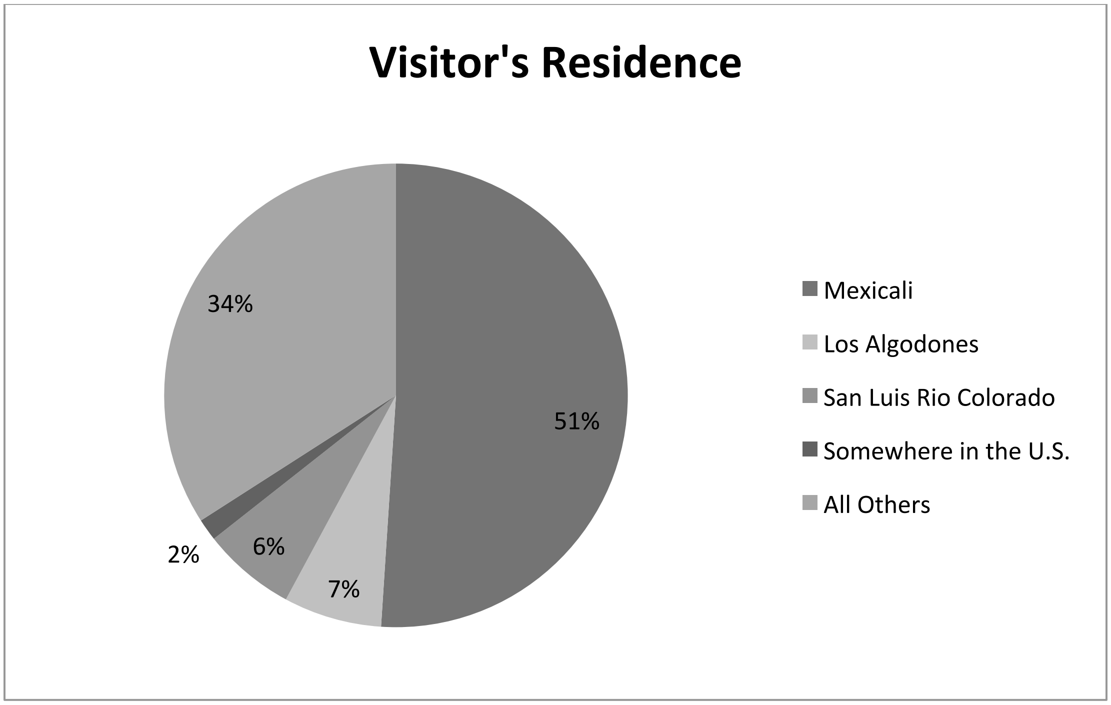
4.3 Initial Analysis

4.3.1 Visitor Profiles

The visitor profiles and travel pattern preferences of the 584 eligible respondents are presented in this section. Components covered in the visitor profile include the visitor's residence and the distributions of age, gender, level of education, and income. Travel pattern preferences includes whether the main reason for the trip is for a water-related activity and the frequency of their visitation to the site. This section also presents the percentages of "yes" and "no" answers based upon the proposed fee amount at the sites along the Hardy River and the sites along the Colorado River and at the Cienega.

As shown in Figure 5 below, a large majority of visitors to the Delta's recreational areas during Holy Week are what we consider local visitors, or visitors who traveled less than 100 kilometers to arrive at the site. The figure shows the primary residence of visitors to all five Delta recreation sites. Over fifty percent of the visitors surveyed are from Mexicali, seven percent are from Algodones (located within the Mexicali Valley), and six percent were from San Luis Rio Colorado. While thirty-four percent of the visitors are from other locations, a large majority of these visitors are from the ejidos located in the Mexicali Valley.

FIGURE 5. VISITOR'S RESIDENCE



The visitors surveyed in the Colorado River Delta ranged in age from 15 to 78 years old (Table 10). The mean age of the visitors was 33, and 53% of the sample was male. Approximately 79% of the sample had an education level equal to or lower than high school attainment (Table 11), and the majority of the people sampled were in the $41,000- $80,000 Mexican peso annual income bracket.

TABLE 10. DISTRIBUTION OF RESPONDENTS' AGE

Age (in years)	Frequency	%
15-19	42	7%
20-29	202	35%
30-39	186	32%
40-49	100	17%
50-59	40	7%
60-69	9	2%
70+	5	1%

TABLE 11. EDUCATIONAL ATTAINMENT OF RESPONDENTS

Eduation Level	Frequency	Percent	Cumulative Percent
None	3	1%	1%
Elementary School	59	10%	11%
Junior High School	204	35%	46%
High School	195	33%	79%
University	114	20%	98%
Masters	9	2%	100%

As suspected, income levels differed depending on the location visited. Those respondents who visited locations along the Rio Hardy had a median annual income of $81,000-$125,000, whereas the median of those respondents at the other three sites were in the lower annual income bracket of $41,000- $80,000 Mexican pesos.

Only 9% of the sample stated that they came to the recreation site to join in some sort of water recreation (aquatic activity, swimming, or fishing). Somewhat surprisingly, almost half of the sample responded that the survey date was their first trip to the recreation site. The next most prevalent response was that the respondents come on average one time per year, with approximately 23% answering in this way (Table 12).

TABLE 12. RESPONDENTS' AVERAGE NUMBER OF VISITS

Average Number of Visits	Frequency	Percentage
It's my first visit.	264	45%
Less than once a year.	53	9%
One time per year.	136	23%
2-5 times per year.	62	11%
6-10 times per year.	21	4%
More than 10 times per year.	48	8%

The figures below show the distribution of the proposed fee amounts at the different locations and the percentages of responses to the proposed fee amounts. Figure 6 shows that along the Hardy River (at Campo Mosqueda and Campo Baja Cucapah) 87% of the respondents who were proposed a fee amount of 20 pesos were willing to pay that amount for entrance to the site. At the far right, one can see that only 10% of those respondents who were proposed a fee of 400 pesos were willing to pay that amount.

FIGURE 6. HARDY RIVER FEE AND "YES" RESPONSE DISTRIBUTION

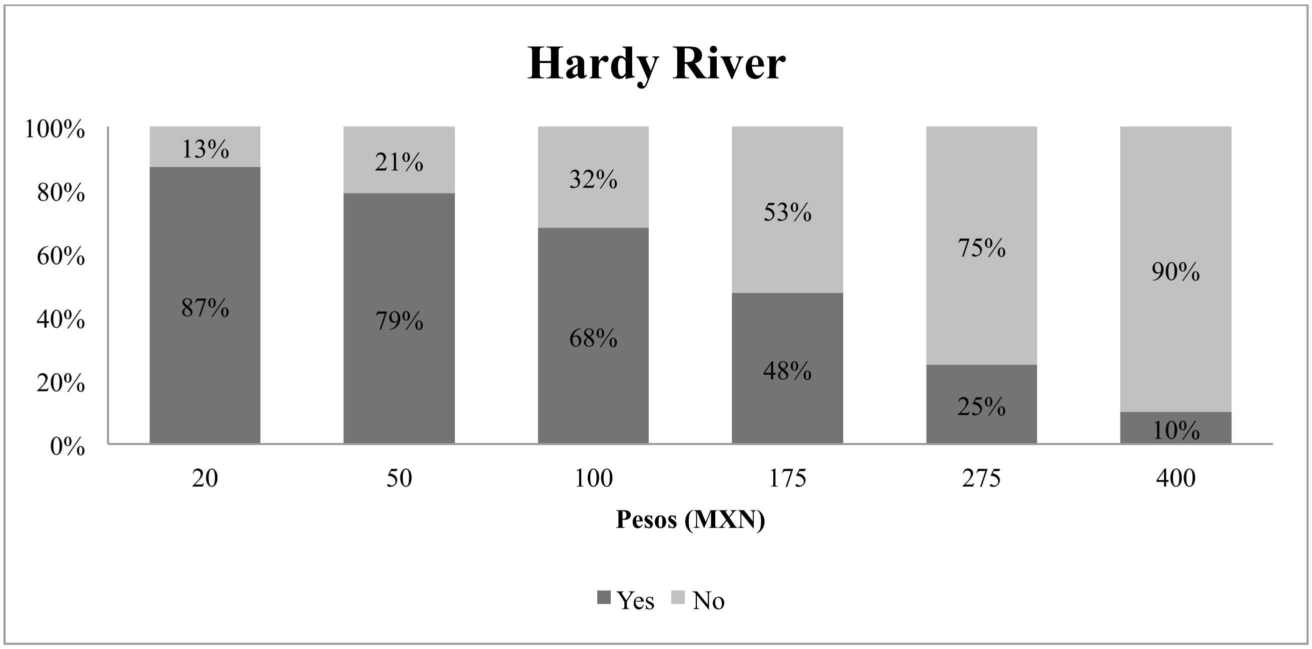
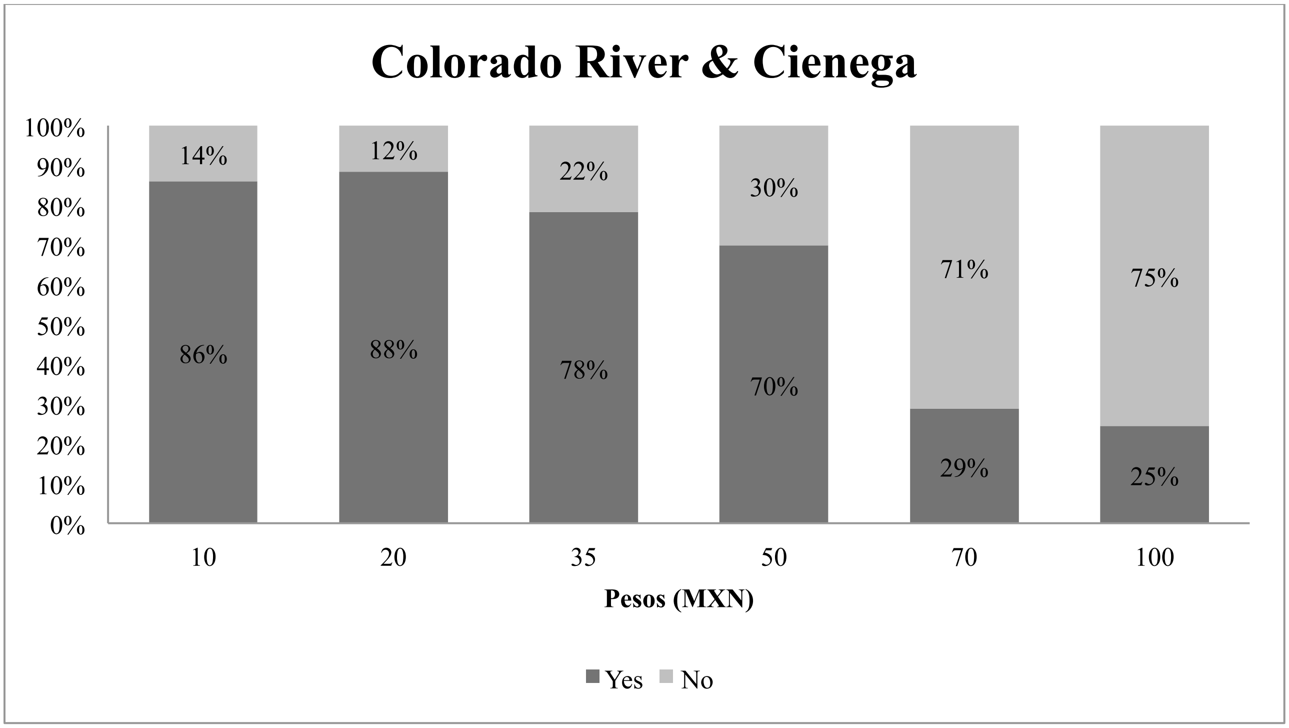


Figure 7 are the results from the other three locations- the sites along the Colorado River (Morelos Dam and San Felipito) and the Cienega de Santa Clara. Of all the respondents who were proposed the 10-peso fee amount, 86% of them were willing to pay that amount. Of the respondents who were proposed the 100-peso fee amount, only 25% of them were willing to pay that amount. Note that both of these figures exhibit the traditional downward-sloping demand.

FIGURE 7. COLORADO RIVER AND CIENEGA FEE AND "YES" RESPONSE DISTRIBUTION



4.4 Econometric Model and Results

Willingness to pay for a guaranteed source of water to sustain a healthy Delta ecosystem was estimated and explained using a logit regression model using the statistical software, SAS (Version 8.3). The dependent variable was *TRUE_YES_WTP* which is a binary variable where *TRUE_YES_WTP*=1 when the respondent is willing-to-pay the fee amount proposed to them and they have ***not*** been flagged as a yea-sayer. Again, when the dependent variable equals 1 when the respondent has agreed to pay the fee amount (therefore has a true, positive WTP) and 0 when the respondent has not agreed to pay the fee amount. Of the total sample of 584 respondents, 343 visitors (59%) responded that they were truly willing-to-pay the fee amount proposed to them and 241 were not willing-to-pay. If yea-sayers had not been accounted for, there would have been an additional 109 respondents that stated that they were willing-to-pay the fee amount. This would have inflated the percentage to 77%.

The logit model specifies the probability of a "Yes" response with β values as the slope coefficients and X values as the independent variables. The logit regression was selected for this study because it is the most common method used in the literature for calculating the median WTP. The estimation of a logit model is done by maximum likelihood. The Xs are the specific characteristics of each individual observation. The general specification of the logit model is outlined below (Loomis, 2012).

$$L_i = \left(\frac{Pi}{1 - P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + u_i$$

$$WTP = ((\hat{\beta}_0 + \hat{\beta}_2 X_{m2} + \hat{\beta}_3 X_{m3} + \cdots + \hat{\beta}_n X_n)/|\hat{\beta}_1|)$$

Where $\hat{\beta}_1$ is the coefficient on the fee amount and X_{m2}…X_{mn} are the sample medians of the independent variables.

The estimation of the logit model and Hanemann's equation allows the median WTP to be estimated parametrically as opposed to non-parametrically (that is, taking the simple mathematical median). The importance of using statistical techniques to calculate the median WTP is that it allows for the inclusion of the underlying utility functions (Hanemann, 1984). Section 4.4.3 provides a comparison of the median WTP estimates based upon the parametric and non-parametric methodology.

4.4.1 Model Variables

The model variables, their description, type of variable and expected signs are listed in Table 13[3]. The expected sign denotes whether the variable is expected to have a positive or negative impact on a "yes" response to the proposed fee amount. A variable with an expected positive sign implies that this factor will increase the likelihood that a respondent will have a "yes" response. A variable with an expected negative sign implies that we think that this factor will decrease the likelihood of the respondent saying "yes" to the proposed fee amount.

The variable *No_Visits* has an ambiguous expected sign because the theory supports both signs. The frequency that a respondent visits the site could be an expression of the importance or value of the site to that person. In this case, we would expect the sign to be positive. However, for those respondents who visit the sites very frequently, they would be less likely to say "yes" to an entrance fee because they would have to pay each time they visited the site. Age and the

[3] Descriptions of the categorical variables are presented in Appendix E.

dummy variable for male are also ambiguous because theory does not suggest whether these factors will increase the likelihood of a "yes" response to the dichotomous choice question.

TABLE 13. VARIABLE DESCRIPTIONS AND EXPECTED SIGNS

Variable	Description	Expected Sign	Min	Mean	Median	Max
TRUE_YES_WTP	=1 if "Yes" on dichotomous choice and NOT a yea-sayer	Dependent Variable	0	0.59	1	1
Amount	Amount of fee proposed	-	10	100	50	400
Income (Categorical)	Annual family income	+	1	2.73	2	6
No_Visits (Categorical)	No. of visits to site	+/-	1	2.43	2	6
Water_Value	Likert scale of importance of water to support ecosystems	+	1	4.58	5	5
Age	Age of respondent	+/-	18	33.53	32	78
Education (Categorical)	Education level	+	1	3.66	4	6
D_Water_Recreation (Binary)	=1 if Activity is aquatic activity, swimming, or fishing	+	0	0.09	0	1
D_Male (Binary)	=1 if respondent is male	+/-	0	0.53	1	1
D_rio_hardy (Binary)	=1 if on Rio Hardy (CM or CBC)	+	0	0.45	0	1

4.4.2 WTP Regression Model

The variables listed in Table 13 were used in the estimation of the logit regression model. The results of the regression model are listed in the Table 14 below, with significant variables denoted by asterisks. As expected *Amount* is negative and significant; the higher the fee amount, the less likely the respondent will say "yes". *Income*, *Water_Value*, *Education*, *D_Water_Recreation*, and *D_Hardy_River* were positive as expected. *No_Visits*, *Age*, and *D_Male* also turned out to be positive.

The variables that were significant at the 1% level are *Amount, Income, Water_Value,* and *D_Hardy_River*. This makes intuitive sense because we would expect that these variables represent some of the most important factors that would influence whether a respondent would be willing-to-pay the proposed fee amount.

TABLE 14. LOGIT REGRESSION RESULTS

N = 584
Generalized R-Square = 0.2782

Likelihood Ratio ChiSq = 190.35
Pr > ChiSq = <.0001

Parameter	**Estimate**	**Pr > ChiSq**
Intercept	-2.1322***	0.0059
Amount	-0.0148***	<.0001
Income	0.2606***	0.0008
No_Visits	0.0917	0.1723
Water_Value	0.3206***	0.007
Age	0.0167*	0.0863
Education	0.0845	0.4689
D_Water_Recreation	0.5159	0.2223
D_male	0.3911**	0.0581
D_Hardy_River	1.0475***	0.0002

*** significant at 1%, ** significant at 5%, * significant at 10%

4.4.3 MEDIAN WTP

The median WTP among the sample is calculated using the formula developed by Hanemann described above. The median values for each of the independent variables are inputted in for the X values, and the parameter estimates shown above are the $\hat{\beta}$s. Using this equation, it was calculated that the median WTP per entry per car is:

- $168 pesos (approximately $13 USD)[4] at sites along the Hardy River (Campo Mosqueda and Campo Baja Cucapah)
- $97 pesos (approximately $7 USD) at Morelos Dam, San Felipito, and the Cienega de Santa Clara.

After calculating the median WTP for the sites, I use the statistical software STATA 12 to estimate the 95 percent confidence intervals based upon Krinsky and Robb's (1986) procedure. The procedure involves estimating the logit parameter estimates and variance-covariance matrix, calculating the Cholesky decomposition, estimating new parameter estimates, and repeating this procedure 5,000 times to obtain an empirical distribution of WTP. The WTP values are then sorted in ascending order and the top and bottom 2.5% of the observations are dropped to obtain the 95% confidence interval. I use the formulas and code developed by Jeanty (2007) to estimate the confidence intervals presented in Table 15.

[4] MXN peso-USD dollar conversion as of 8/5/12.

TABLE 15. MEDIAN WTP AND CONFIDENCE INTERVAL ESTIMATES

	Hardy River (Medians)	Other Sites (Medians)
Median WTP	168	97
Upper Bound	201	129
Lower Bound	138	70

Because there were two explicitly difference ranges of values used as the fee amount at the different sites, we need to make sure that this difference is accounted for. One method to account for the difference (as shown above) would be to create a dummy variable, *D_Hardy_River*. Another method would be to run two completely separate regressions. I use the Chow test to test whether the sample should be estimated in two separate models (the estimated βs differ between the two sub-samples) or whether the sample should be estimated as a whole with the dummy variable (the βs do not differ across the sample).

The Chow test analog for the logistic regression, outlined by Allison (1999) and then again by DeMaris (2004), is given below.

$$X_{df}^2 = -2\ln L_c - [-2\ln L_1 + (-2\ln L_2)]$$

Where $\ln L_c$= the fitted log-likelihood of the combined model, $\ln L_1$ is the log-likelihood of the first group, and $\ln L_2$ is the log-likelihood of the second group. Using the above equation, it was determined that the most appropriate model is the combined (or whole) model. The difference between the βs across the two groups was not statistically different from zero, therefore only one model should be estimated for the entire sample.

Table 15, above, provides the median WTP estimates for the different sites. It is important to note that these estimates were calculated at the median values for the independent variables. As such, these values represent the median WTP for males who did not come to the site for a specific water recreation (the median for *D_male* and *D_water_recreation* were evaluated at 1 and 0, respectively). To get a better understanding of the differences that exist among respondents, I estimate the median WTP and confidence interval estimates for the other groups represented in the study. I limit the analysis to evaluating the differences due to gender and the reason for the visit (whether the respondent came to the site for a water-related activity).

The table below shows that respondents that come for a water-related activity are consistently willing-to-pay more for entrance to the site in order to guarantee an adequate amount of water to support the ecosystem than those who do not come for water-related activity. Additionally, the results suggest that men are willing-to-pay higher amounts than women, all else equal.

TABLE 16. MEDIAN WTP AND CONFIDENCE INTERVAL ESTIMATES ACROSS GROUPS

	Median WTP ($MXN)	**Upper Bound ($MXN)**	**Lower Bound ($MXN)**
Hardy River			
Male, Water Recreation	203	262	148
Male, No Water Recreation	168	201	138
Female, Water Recreation	177	236	120
Female, No Water Recreation	142	171	112
Other Sites			
Male, Water Recreation	132	197	74
Male, No Water Recreation	97	70	129
Female, Water Recreation	106	170	46
Female, No Water Recreation	71	99	45

As demonstrated by the table above, parametrically estimating the median WTP using the logit regression and Hanemann's (1984) WTP calculation allows for the calculation of the WTP based upon characteristics of the respondent. This is a significant improvement over the simple mathematical estimation (univariate) of the median WTP of the sample. If I were to calculate the simple mathematical mean and median WTP using the amounts that respondents said "yes" to, the values would be as follows:

TABLE 17. UNIVARIATE MEDIAN WTP ESTIMATES

	Median WTP	Mean WTP
Hardy River	50	98
Colorado River and Cienega	35	35

The mathematical mean and median WTP are noticeably lower than the amounts calculated parametrically. The parametric estimates provide more information and suggest a higher median WTP. Estimating the WTP at the medians, the model suggests that the median WTP of visitors to Campo Baja Cucapah and Campo Mosqeuda, along the Hardy River, is $168 pesos per car per entry. The WTP of visitors to Morelos Dam, San Felipito, and the Cienega de Santa Clara is $97 pesos per entry.

Chapter 5. Water Market Study Data, Methodology, Econometric Model and Results

5.1 Data Description

The transaction data for the analysis of the water market activity in the Western United States comes from the *Water Strategist* (formally known as the *Water Market Update*) (Stratecon, Inc). This was a monthly publication that reported water sales and leases in the Western U.S. as well as any new developments in water policies and laws. This publication ceased at the end of 2010, but was a unique and widely used source of information from the late 1980s. The data used in this analysis spans from 1987-2010.

The *Water Strategist* publication describes water transactions in narrative form. Therefore, researchers in the Agricultural and Resource Economics department under the direction of Dr. Bonnie Colby have translated the narrative information into a quantitative database. The publication reports transactions by month and year. However, the time a transaction is reported does not necessarily represent the date of the transaction occurred or when the transfer agreement was finalized. Some transaction entries may have been reported in the same month when the transaction occurred, but others could have occurred the previous month or possibly within the last year. Due to this ambiguity in the timing of reporting, I decided to conduct the market activity analysis on an annual timescale. On the spatial dimension, the publication reports the transactions by state, the same spatial dimension used in this analysis.

The amount of information provided on each transaction varies. However, the publication usually reports the price, quantity, whether the transfer was a sale or lease, and some information on the buyers and sellers. A transaction is defined as one agreement for the transfer of water from one entity to another. So, a multi-year lease (such as a 10-year lease) is recorded as one transaction and the length of the lease is noted as 10 years. Leases of more than 50 years were re-classified as sales. If more than one transaction was reported in a *Water Strategist* entry it was separated into the number of transactions recorded with as much detail as possible. When there were entries with multiple transactions where individual transaction information could not be confirmed the combined transaction was left as is.

An important consideration must be made when examining the data generating process for these transactions. The *Water Strategist* does not report all types of water transactions, it only reports those that have been reported and recorded in their database. Therefore, the transactions may not necessarily be representative of the water market as a whole. However, I assume (as Howitt and Hansen, 2005), that any selection bias is consistent across states.

Instead of analyzing individual transactions, this data was aggregated to an annual and state basis, with sales and leases in separate databases. Some states have both sales and leases occur in every year, but some states do not have any transactions in certain years. Additionally, some states have more active lease markets whereas others have more active sale markets.

Each state's annual water transfer data was matched with climate and demographic information. For consistency, these variables were also designed to be on the same spatial and temporal scale. The climate variable used in this analysis was the Standard Precipitation Index (SPI). The SPI is a drought index based solely on precipitation- and it is a transformation of the probability of precipitation over several different timescales. The SPI is a single numeric value that measures precipitation and allows for comparisons across regions with markedly different climates. The SPI compares the total precipitation for a certain timescale to the historic precipitation for the same timescale (NCDC, 2012). The timescale used in this analysis is a 12-month period. The SPI values used in this analysis are the state-wide values (which are aggregated climate division data weighted by area) (NCDC, 2012). A major concern with matching the climate data to the water transfer data was that they would not match up. Therefore, I determine where a majority of the water transfers are occurring and attempt to match the climate data based upon that. Appendix E shows the results of those efforts. Based upon the findings of that analysis, I decide to update the SPI values for Colorado, Nevada, and New Mexico. As a large majority of the transactions and volume occur in certain climate divisions in these states, I choose to use the SPI value from their climate divisions instead of the state as a whole.

Demographic information such as state personal income and population were also obtained at the annual timescale. State personal income was used as a measure for the relative economic condition of the state of the 24 year time period. The state population was also included in the analysis and acted as a variable related to demands for water across time. Finally, because a large portion of water transfers originate from agriculture, I also include a variable that captures the profitability of farming in the state: farm net cash income.

5.1.1. Data Cleaning

There were several specific circumstances in which transactions were removed from the original transaction dataset. If the price of the transfer was undisclosed or undecipherable, (the information was too ambiguous to extract price or quantity) the individual transaction was deleted. Instances where this could be the case were when a water right was sold with land or when not enough information was provided. This thesis also followed Jones (2008) by deleting transactions sold or leased for less than $5.00/acre-foot. These transactions were removed because they are unlikely to represent true market transactions as they are either transfers between family members or administratively set prices. Transactions that were donations and exchanges were also deleted due to the lack of pricing data. Additionally, due to the inherent difference between reclaimed water and surface and ground water, transactions with reclaimed water were also deleted. Finally, I deleted transactions for storage if they only included storage space and did not include the physical sale of water.

After completing the data cleaning of the individual transactions in the original database, the dataset was aggregated to the state and annual level. The variables created from the transaction database were the "market activity variables": the total number of transactions, the total volume of water transferred, and the total dollar value expended for water transfers by year and by state. The years spanned from 1987-2010 and the states included in the analysis are Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, and Washington. If there were years that did not have any transactions, the period was denoted by zeros in each of the market activity variables, therefore creating a balanced panel. In addition to aggregating the individual transactions in the preceding fashion (a sum by year and state), I also create several variables that represent the percentage of water transferred for a specific purpose. For example, I create a variable denoting the percentage of the total volume transferred for an environmental purpose as well as for a municipal purpose. Additionally, I create a variable that computes the average length of leases in the lease market and the average volume-weighted price. Finally, when aggregating, the periods where there were no transactions did not have a volume-weighted average price because there were no transactions. In order to impute missing values, I test several methods, including conducting simple regression analysis between sales and leases, between states, and a combination of the two, to try to impute the price based on the data available.

Unfortunately, prices do not follow a consistent pattern between sales and leases nor between states. Consequently, for the final analysis I imputed a simple average of the 4 most consecutive years' prices (2 years prior and 2 years after). In the lease market, 14% of the total observations had an imputed weighted average price in the lease market. The sale market had 5% of the total observations imputed.

Due to the preponderance of years with zero transactions in the sale market in the Northwestern states (Idaho, Oregon, and Washington), these three states were not included in the sales market analysis. Therefore, the sale market analysis for all models includes data on the annual market activity levels from 1987-2010 for Arizona, California, Colorado, Nevada, and New Mexico. The lease market also is a sub-sample of the original database. Again, due the preponderance of years with zero transactions in the lease market, Nevada and Arizona were not included in the lease market analysis. Additionally, to account for the slow growth of the lease market in the Northwestern states (markedly demonstrated as important players in the lease market), the timeframe of the analysis was also changed. Therefore, the lease market analysis for all models includes data on the annual market activity levels from 1989-2010 for California, Colorado, Idaho, New Mexico, Oregon, and Washington.

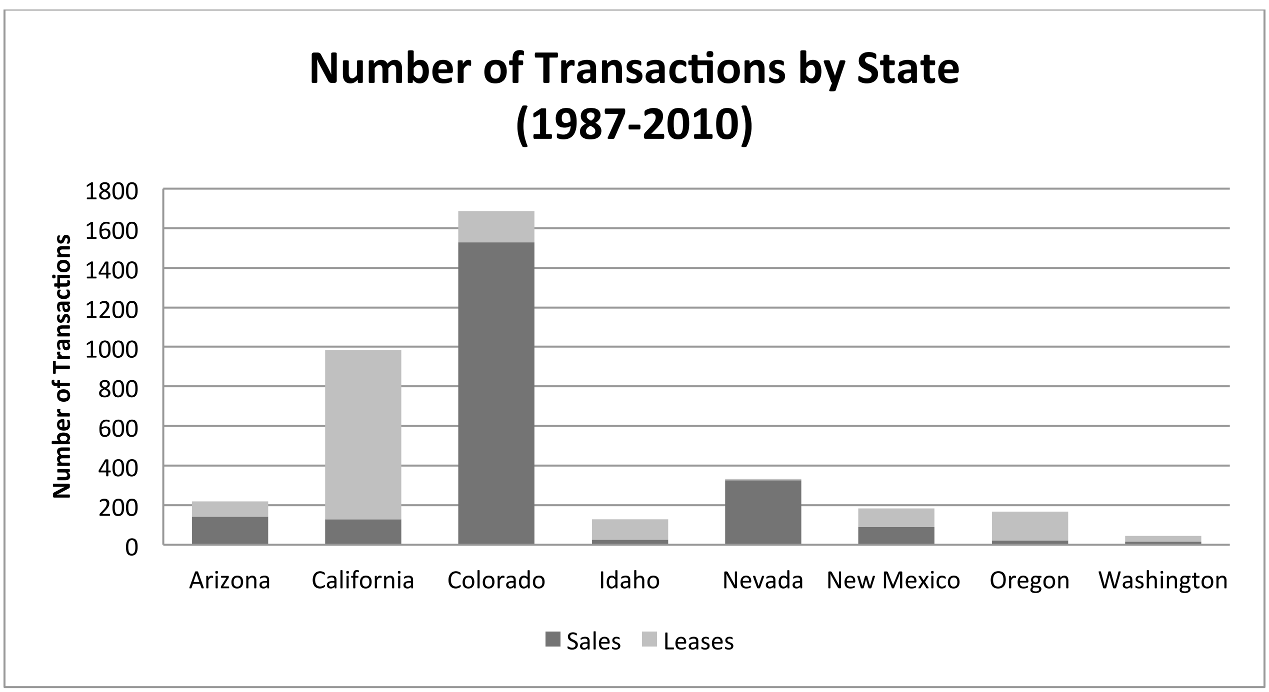
5.2 Methodology

The overarching goal of this research is to understand patterns of activity in water markets. In order to analyze fluctuating activity in water markets, I define water market activity in three different ways: 1) the number of transactions, 2) the total volume of water transacted, and 3) the total dollar value expended on water transfers. An active market could be defined as having a large number of transactions in a designated period, in this case one year. Or an active market could be defined as a market that transfers large volumes of water in a single year. Finally, an active market could be defined as the market that has a large total dollar value transacted (incorporating the volume transferred and the prices paid). As will be shown in the descriptive statistics, whether one would consider a market "active" depends greatly on the how market activity is defined. The following section will show how market activity (using the three definitions) varies across states and across time (1987-2010). It then delves a little deeper into the data to understand the interaction between periods with higher market activity and the states where that higher market activity is occurring. Finally, this section provides some insight on the trends in the water transfers by end use. All comparisons break sales and leases into separate categories as suggested by the literature.

5.2.1 Data Descriptive Statistics

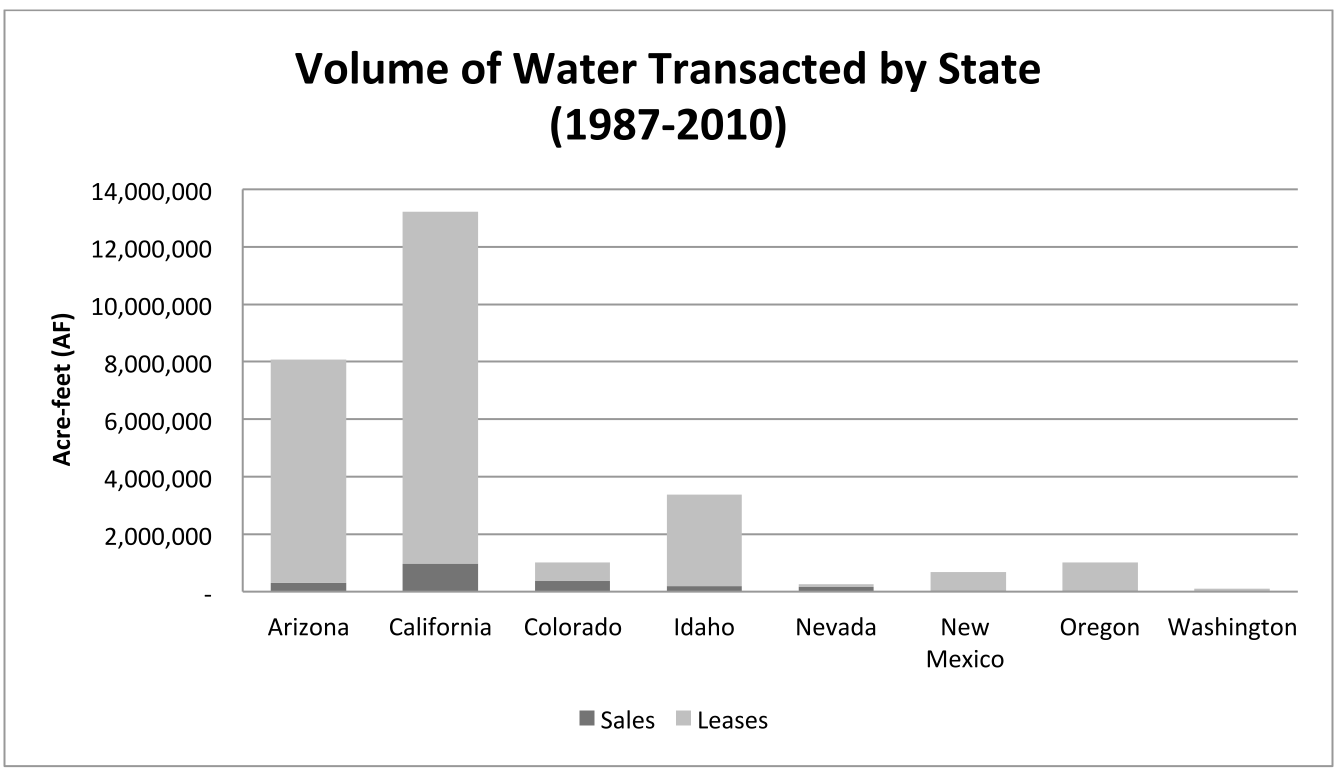
5.2.1a. Cross-Sectional Variation

FIGURE 8. TOTAL NUMBER OF TRANSACTIONS BY STATE



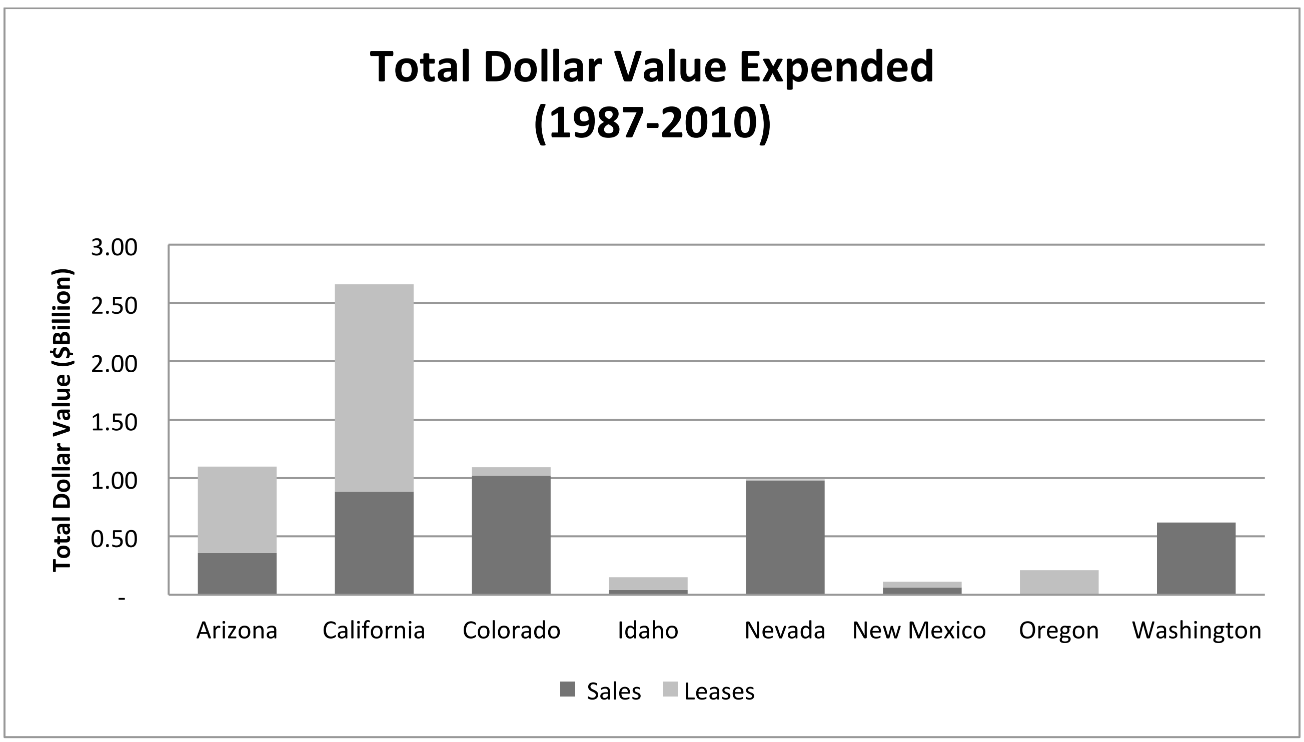
Of the eight states in this research, Colorado has the most active market in terms of the number of transactions. Colorado has over 1,500 transactions over the sample period from 1987-2010. California is the second most active market with just under 1,000 transactions. Note, however, that these two markets differ significantly due to the type of transactions that have occurred. Whereas Colorado's water market is dominated by sales, leases dominate California's water market. Sale-dominated water markets occur in Nevada, Colorado, and Arizona with sales equaling 98%, 90%, and 64%, respectively of total transactions. On the other hand, leases occur much more frequently in California, Oregon, Idaho, and Washington. California and Oregon are tied with 87% of all transactions being leases. Idaho has 82% leases followed by Washington with 65% leases. Finally, New Mexico has almost the same number of leases as sales over the sample period.

FIGURE 9. TOTAL VOLUME OF WATER TRANSACTED BY STATE



When examining the activity of the water market in terms of the volume of water transferred, California becomes the most active market in the analysis with almost 13 million-acre-feet (MAF) of water being transferred over the 24-year sample period. Note that Colorado, the most active state in terms of the number of transactions, becomes one of the least active markets when the definition is changed to the volume of water transferred. Another interesting finding is that, in general, a larger percentage of the volume of water transferred is through leases. Nevada is the only exception, with 63% of the volume of water transferred through sales. All of the other states have between 63% to 97% of the volume transferred through leases. So even in cases where there are more sales than leases, like Colorado and Arizona, there are larger volumes transferred through leases than through sales.

FIGURE 10. TOTAL DOLLAR VALUE EXPENDED BY STATE

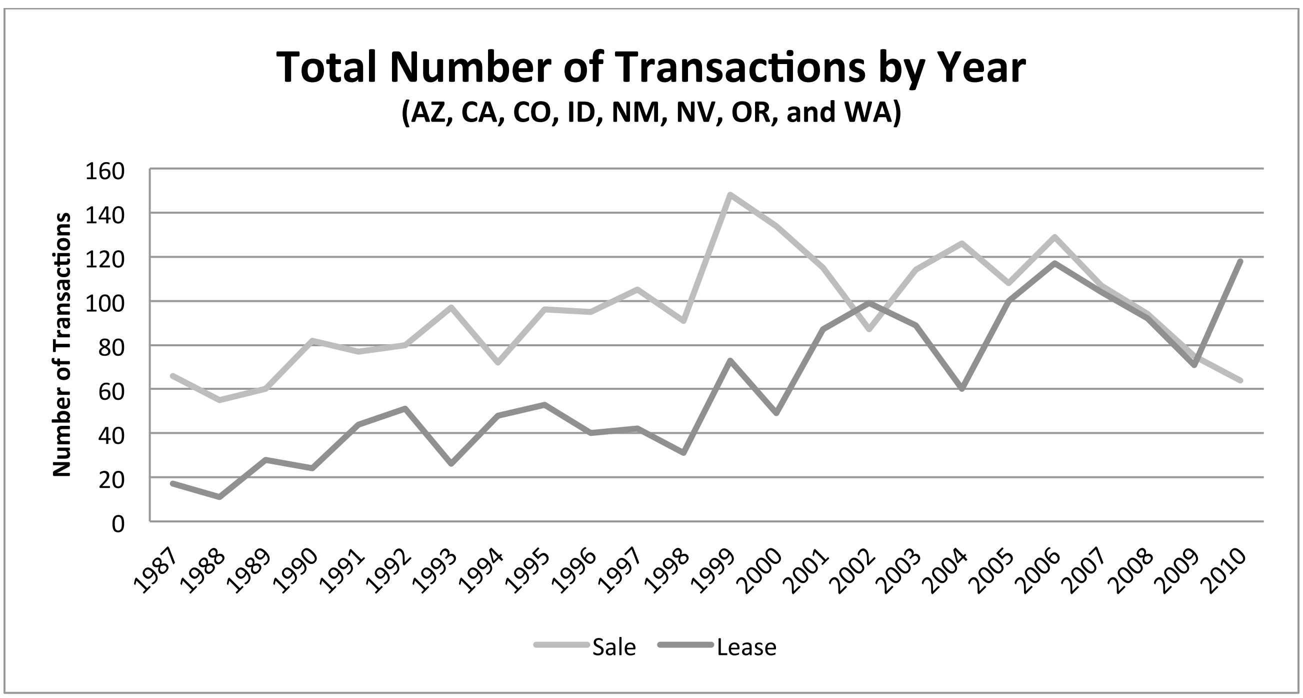


Switching the definition of an active market to the total dollar value expended, California remains the most active state, with over $2.5 billion spent for water market acquisitions from

1987-2010. Arizona is the second-most active state, followed closely by Colorado and Nevada with around $1 billion spent over the 24 year period. The breakdown between sales and leases shows that even though there may be larger volumes of water transferred through leases, the total dollar value expended for sales tends to dominate the amount of money spent on water acquisitions. This is most evident in the Colorado water market. In Colorado, where leases dominate the total volume of water transferred, sales have a larger market share in terms of the number of transactions and the total dollar value spent over the study period.

5.2.1B. TEMPORAL VARIATION

FIGURE 11. TOTAL NUMBER OF TRANSACTIONS BY YEAR

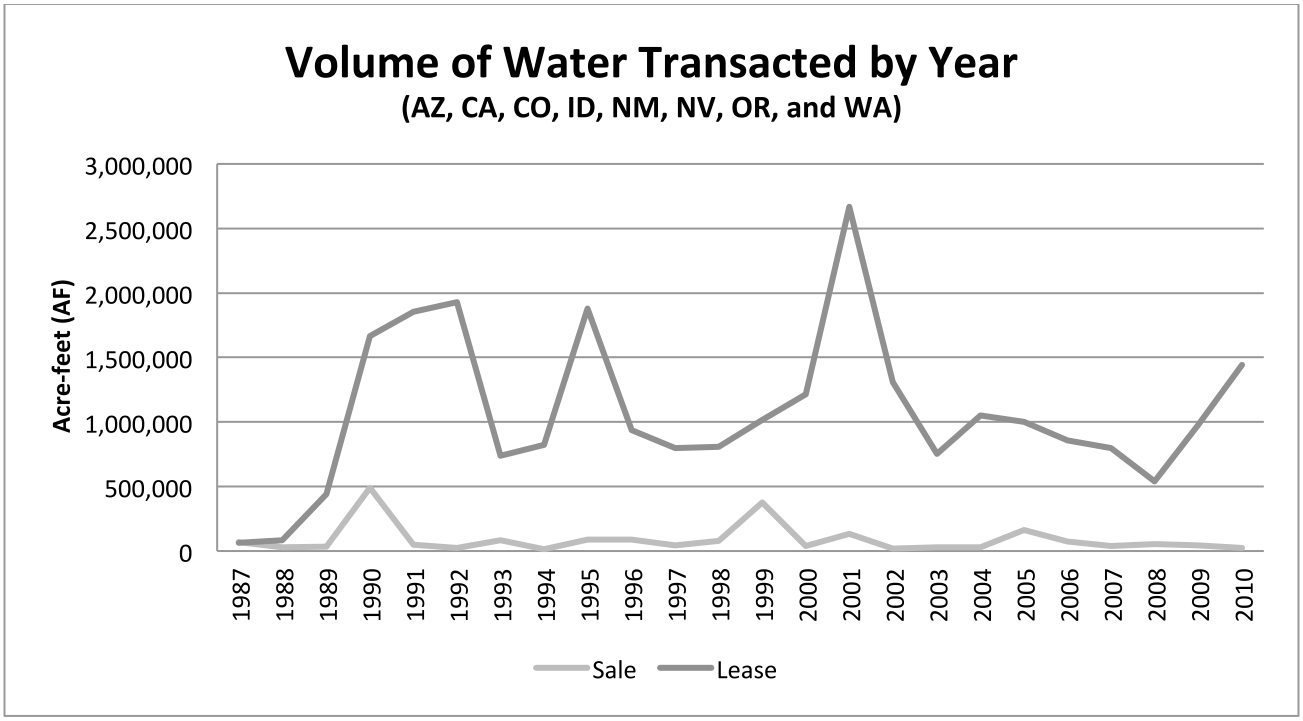


When analyzing the water markets over the 24-year period, it can be seen that the number of transactions is, generally, increasing. However, it appears that the type of transaction is beginning to change over time. Whereas sales dominated in the late 1980s, leases and sales converged in terms of the numbers of transactions per year in the early 2000s. If the 2010 trend continues, the lease market will be more active than the sale market when measuring market activity by the number of transactions in a year.

If we were to look more closely at the data by adding the cross-sectional information, we would see that the state of Colorado is a main driver in the sale market. The highest peak in the sale market that occurred in 1999 was attributed to primarily to Colorado’s 106 transactions (approximately 72% of the transactions in that year). Not surprisingly, California’s activity primarily drove the lease market activity over the 24-year period. During the peak for leases in 2010, California contributed with over 75% of the transactions. Virtually the only two years in which California did not lead the lease transaction market were in 2006 and 2007. In 2006, Oregon led the market with over 53% of the transactions (compared to California’s 21%). In 2007, Idaho just barely beat out California with 38% of the transactions occurring there as opposed to California’s 35%.

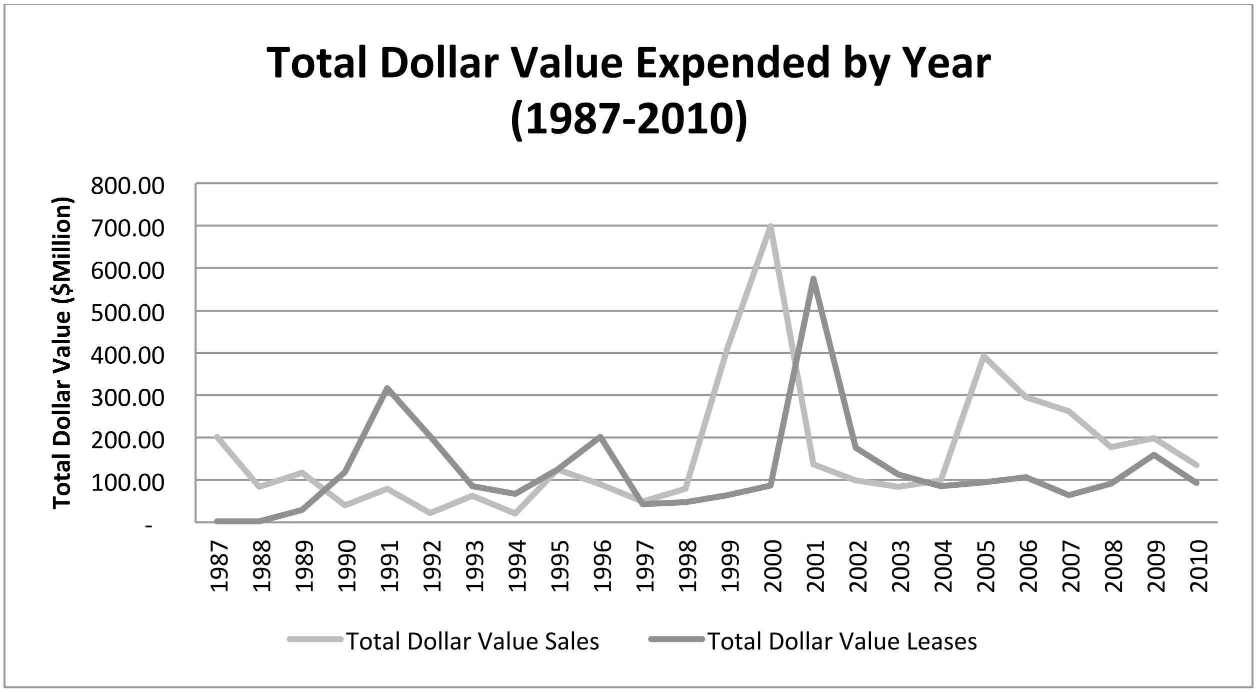
Switching to focus on the definition of market activity as the total annual volume of water transferred a year, we can see in Figure 12 that even though the sales market dominated in terms of the number of transactions in the late 1980s there was still a larger volume of water transferred through leases. This trend persists through time, with a larger volume of water consistently transferred through leases as opposed to sales.

FIGURE 12. TOTAL VOLUME OF WATER TRANSACTED BY YEAR



Whereas the highest volume of water transferred through a sale in a single year is only approximately 500,000 acre-feet (AF), the highest volume of water transferred through a lease in a single year was nearly 5 times the sale amount with just over 2.5 million-acre-feet (MAF) transferred in 2001. The lease market was also particularly active in 1992 and 1995 in terms of the volume of water transferred in a single year.

FIGURE 13. TOTAL DOLLAR VALUE OF WATER EXPENDED BY YEAR

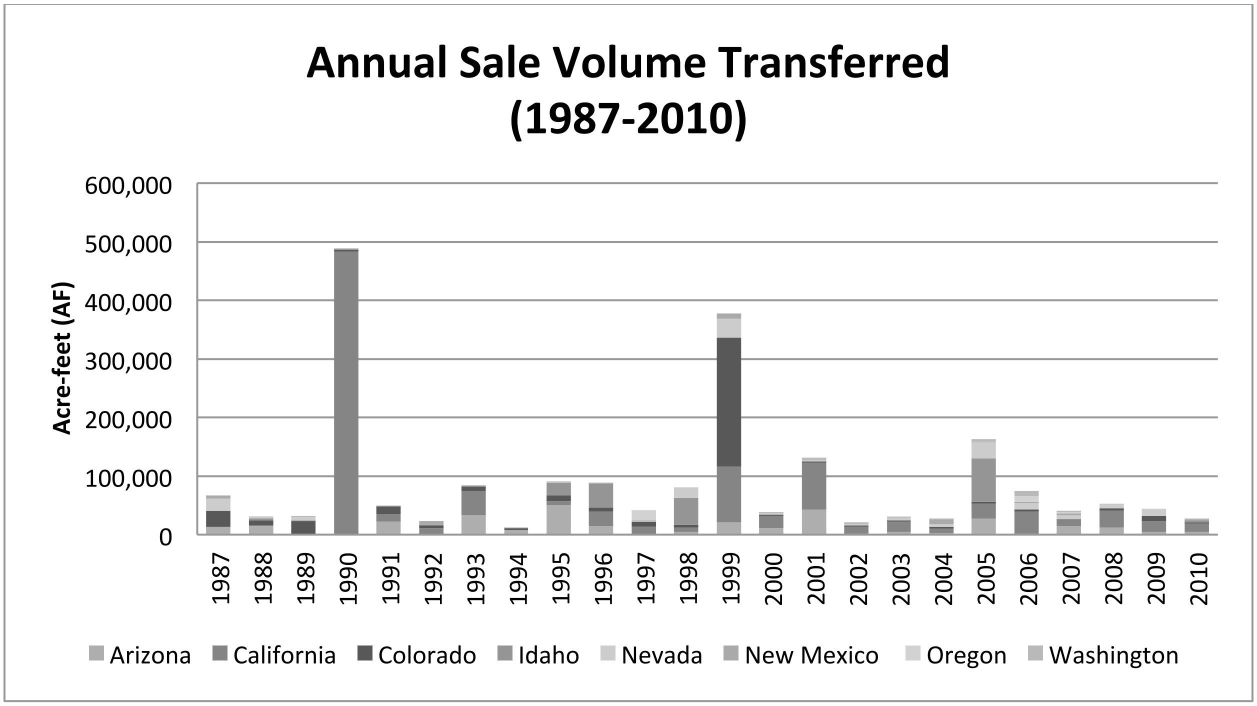


As seen in the graph above, the temporal variation in the third market activity variable, total dollar value, doesn't produce a noticeable pattern. In some years, the total dollar value spent for sales exceeds that of leases and in others the leases exceed the sales. There is no consistency across the years. However, it is interesting to note the year and the magnitude when the largest amount of money was spent for water acquisitions. The year with the highest total dollar value spent in the sale market was in 2000 when nearly $700 million was spent (in $2010 as calculated by the Consumer Price Index). In contrast, the highest total dollar value spent in the lease market was in 2001 for just over $575 million ($2010).

5.2.1C. TEMPORAL AND CROSS-SECTIONAL MARKET ACTIVITY

Examining the graph more closely by adding the cross-sectional information, we can see which states have contributed to the uptick in market activity. Examining the volume of sales first, we can see that the sale market was particularly active in 1990 and 1999.

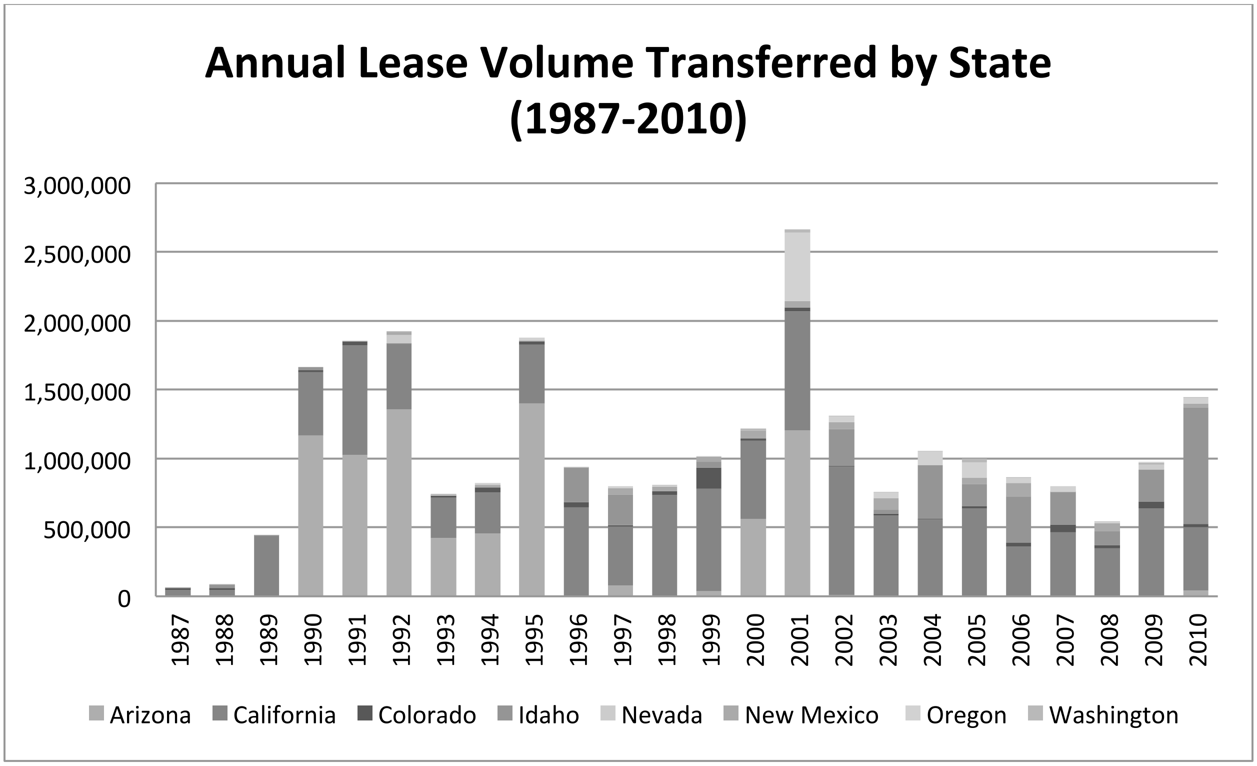
FIGURE 14. ANNUAL SALE VOLUME TRANSFERRED BY YEAR AND STATE



As shown in the Figure 14 above, the market activity in 1990 was primarily driven by the state of California. Of the 488,000 AF of water transferred in that year 99% (or 483,000 AF) was transferred in California. The large volume of water transferred in California was, in large part, due to one agreement. In 1990, when the rest of the state was suffering through the fourth year of drought, the Yuba County Water Agency (YBWA) had water to sell and agreed to transfer up to 300,000 AF of water to the California Department of Water Resources to meet State Water Project contracts (Stratecon, Inc., 1990). The uptick in the sale market in 1999 was primarily driven by Colorado, with California and Nevada contributing as well. The major transaction driving the total volume transferred up in 1999 was a transfer between The Nature Conservancy of Colorado and Rocky Mountain Bison, Inc. In this agreement, the Nature Conservancy purchased rights to 205,000 AF of water for wetland preservation, instream flows, and well augmentation (Stratecon, Inc., 1999).

Now focusing on the lease market, recall from Figure 12 that the most active year in terms of the volume transferred was in 2001. As shown in the following figure, the volume of water transferred in 2001 was primarily due to activity in Arizona, California, and Oregon. The activity in 2001 would have been similar to previous years with large volumes of water transferred if it were not for the increase in activity from Oregon. It is also interesting to note that, in terms of the volume of water transferred, California's lease market did not fully develop until 1989. Since that date, however, California has seen consistent activity in terms of the volume of water transferred. Also, whereas Arizona was a major player in the market during the early 1990s and early 2000s, there was little activity (in terms of volume) in the late 1990s and there has been virtually no large volume of water transferred in Arizona since 2001. Idaho has increasingly become more active in terms of the volume of water transferred with Idaho contributing to 58% of the volume transferred in 2010.

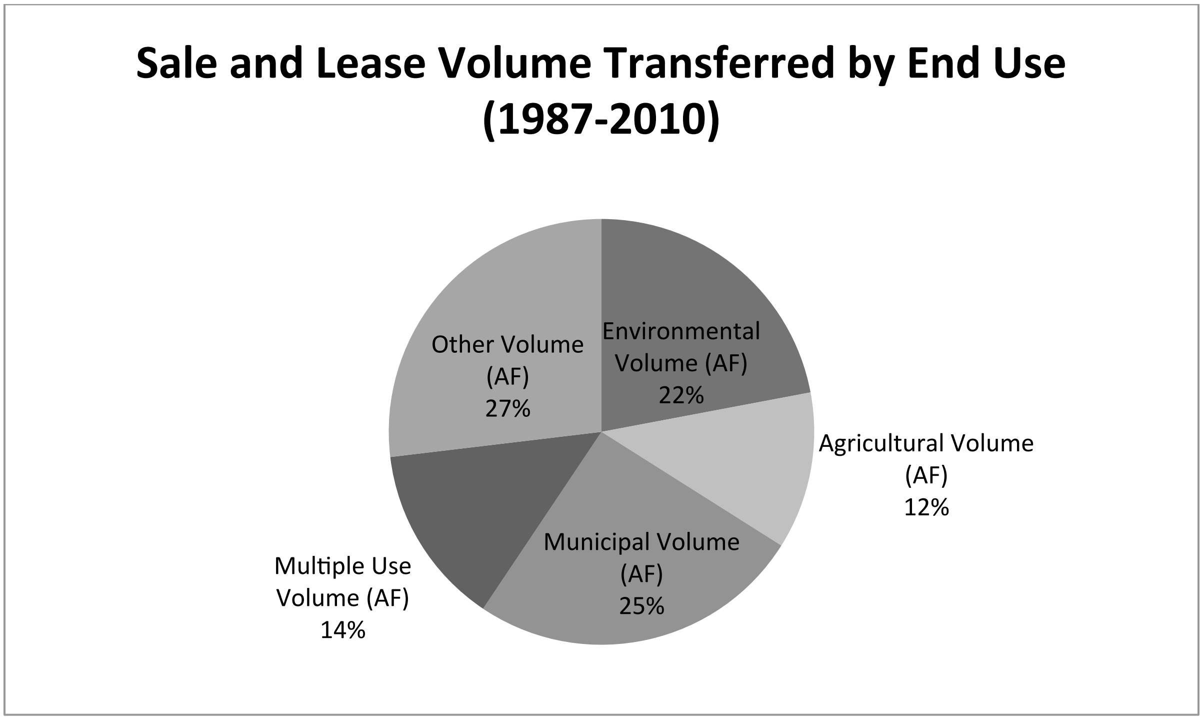
FIGURE 15. ANNUAL LEASE VOLUME TRANSFERRED BY YEAR AND STATE



5.2.1D. MARKET ACTIVITY TRENDS: ENVIRONMENTAL PURPOSES VS. NON-ENVIRONMENTAL PURPOSES

Another market activity trend of interest for this research is the volume of water transferred for environmental purposes. An environmental purpose is defined as an end use that is for general environment use (such securing water for instream flows, pulse flows, wetland protection, and other freshwater restoration activities) as well securing water for recreation. As can be seen in the next figure, the volume of water transferred solely for an environmental purpose over the 24-year period is 22% of the total water transferred. The actual volume of water transferred for an environmental purpose may actually be more than shown here due to the fact that the multiple use volume is comprised of water transferred for both environmental and non-environmental uses. Due to the reporting of these transfers, I was unable to break them down further. The category "other" is comprised of several different end uses such as water for development purposes, mining, power plant use, tribal settlements, storage, or mandatory transfers such as for threatened and endangered species or water quality improvements.

FIGURE 16. SALE AND LEASE VOLUME TRANSFERRED BY END USE



Although water transfers for environmental purposes are shown here as a major end user, this was not always the case. It wasn't until the late 1990s that the environment became a major beneficiary of water transfers, and even then the environmental market is segmented between sale and leases. As explained previously, most states did not recognize an environmental use as a "beneficial use" until the late 1980s and early 1990s.

The next two graphs show how the volume transferred for environmental uses compares with other uses from 1987 to 2010. The first figure depicts the end use of water transferred through the sales market. The year with the largest volume of water transferred for an environmental purpose was 1999, and the large volume transfer was primarily due to the transaction mentioned previously in Colorado in which the Nature Conservancy bought the water right from a private company. For comparison between the sale and lease markets it is important to note the scale in which these environmental transfers are occurring. In 24 years, there is only 1 year (1999) in which the volume sold for an environmental purpose exceeds 200,000 AF.

FIGURE 17. ANNUAL SALE VOLUME TRANSFERRED BY END USE

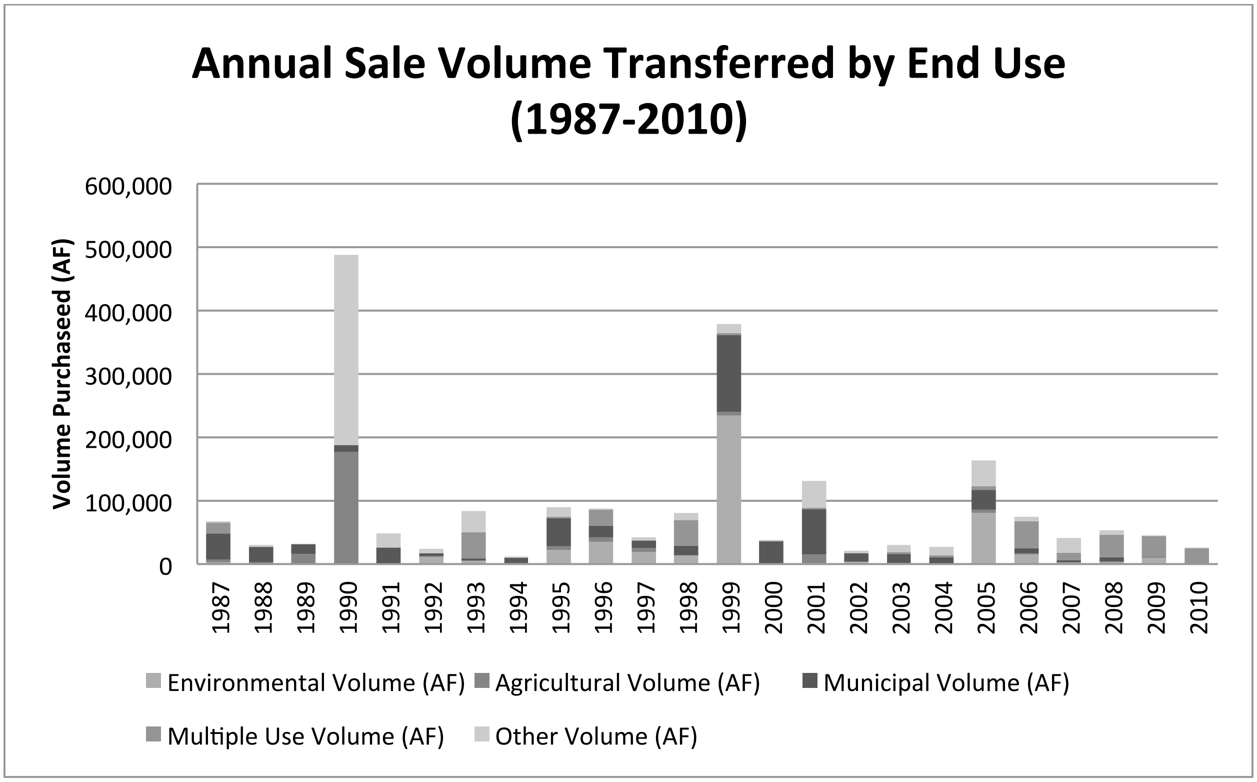
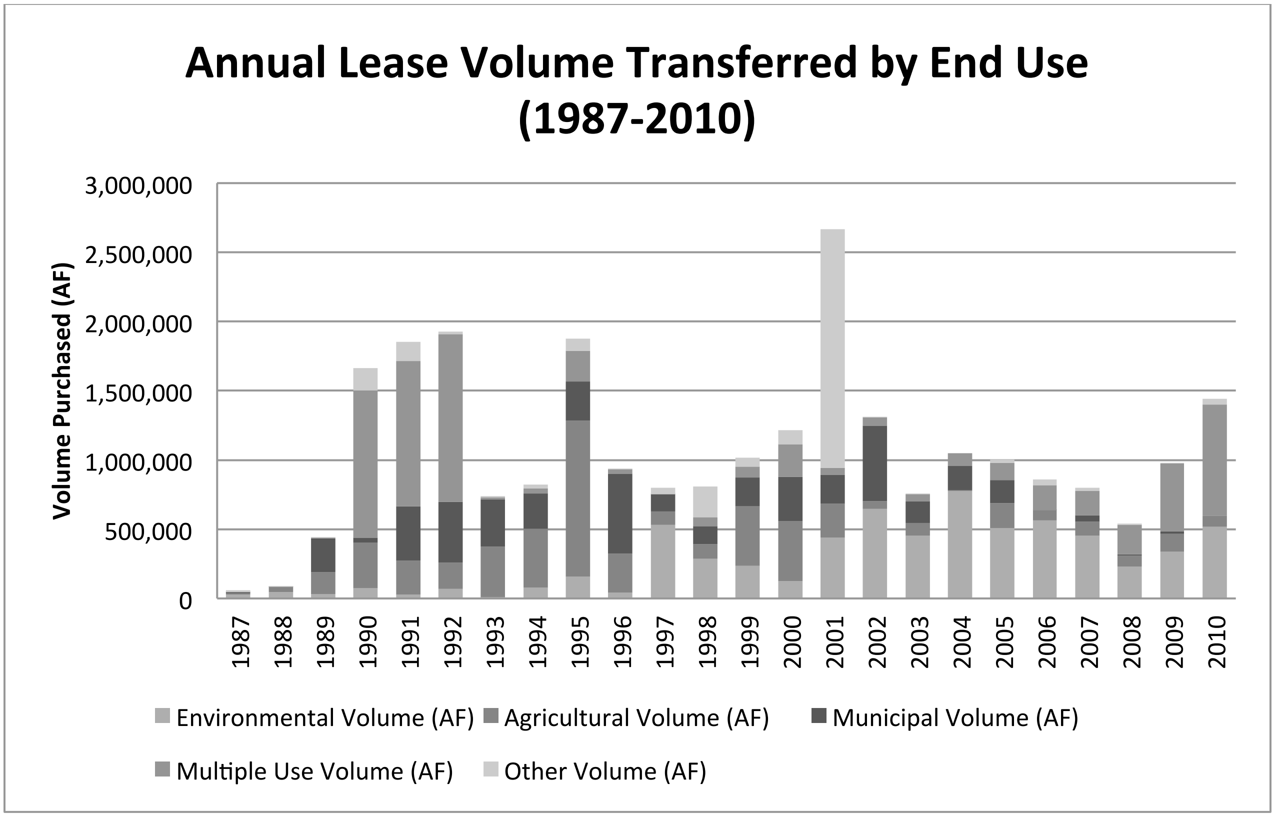


FIGURE 18. ANNUAL LEASE VOLUME TRANSFERRED BY END USE



As demonstrated in the figure above, the lease market is more conducive to environmental water transfers. Not only are there more years with a higher percentage of total volume transferred for environmental purpose, but the volumes are also significantly higher. Note that at least six years from 1997-2010 had volumes of water transferred to an environmental purpose that were near 500,000 AF or above. Again, these volumes may be slightly understated due to the fact that some environmental transfers could not be distinguished and are present in the multiple use category.

5.2.2 Econometric Model Specifications

Due to the data generating process and varying level of market activity across states, I chose to conduct analysis on an annual timescale. While some states are active enough to conduct an analysis at a shorter time-scale, to include most states in each of the lease and sale market analysis, I chose to use the annual timeframe. The nature of the data (with repeated observations over time for the same state) results in a panel dataset. Incorporating the panel nature of the data into the modeling makes the econometric models more complex, but adds the benefits of addressing bias caused by unobserved heterogeneity and allows for the examination of the dynamics of cross-sectional and temporal variation (Dougherty, 2011). All models incorporate the panel nature of the data. The models conducted in this analysis are:

1. Transaction Model- the dependent variable is the number of water transfers in a state in a year,
2. Total Volume Model- the dependent variable is the total volume of water transferred in a state in a year, and
3. Total Dollar Value Model- the dependent variable is the total dollar value expended for water transfers in a state in a year.

As stated previously, the literature suggests that the sale and lease market are markedly different from one another and should be modeled separately. This analysis follows the literature and conducts each of the models separately for the sale and lease markets. It is also important to note that the transaction models are balanced panels with every state having the same number of observations across time. If there were no transactions in a year, the dependent variable for the transaction model would be equal to zero. The total volume and total dollar value models, on the other hand, are not balanced panels. If there were no transactions during a year, the observation is not present in the dataset. The total volume and total dollar value models were not estimated as balanced panels for methodological simplicity. The preponderance of zeros across the dataset would have required more difficult estimation techniques. As such, the interpretation of the total volume and total dollar value results are conditional on a transaction occurring. The figure below provides a simple outline of the models conducted in this analysis.

TABLE 18. ECONOMETRIC MODELS

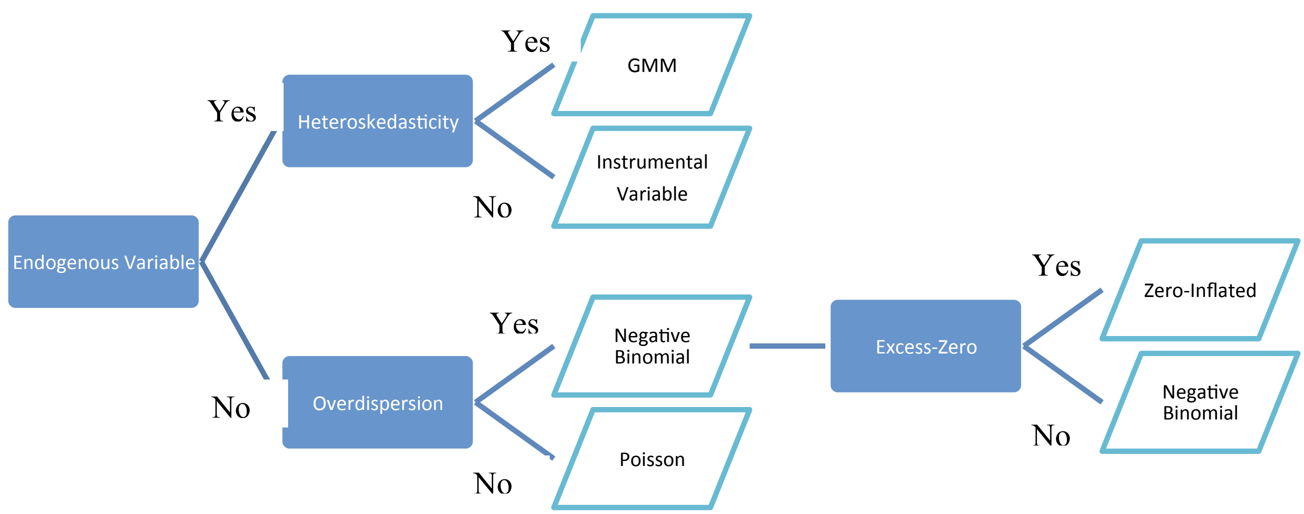
	Transaction Model		**Volume Model**		**Dollar-Value Model**	
	Sale Market	Lease Market	Sale Market	Lease Market	Sale Market	Lease Market
Dependent Variable	No. of Transactions		Volume of Water Transferred		Dollar-Value Spent	
Estimation Technique	Unconditional fixed effects negative binomial		Panel fixed effects		Panel fixed effects	

5.2.2A. TRANSACTION MODELS

The transaction models, or count models, are the first models I analyze. Count models refer to the number of times an event occurs, in this case, the number of transactions in the water market in each state by year. In the simplest econometric terms, the dependent variable is constrained to be a non-negative random variable whose conditional mean depends on some vectors of regressors (Cameron and Trivedi, 1998). There are several varieties of count models, but the standard count model upon which all other models are based is called the Poisson model. This model, however, has very strict assumptions in which most real-world data does not fit. The Poisson, a nonlinear regression model, assumes that the mean is equal to the conditional variance, or that it is equidispersed. If the conditional variance exceeds the conditional mean, the data is overdispersed and the Poisson model is not the appropriate model because it will result in incorrect standard errors and t-statistics (Cameron and Trivedi, 1998).

In order to determine the correct specification of the count model, I follow the procedure of Hidayat and Pokhrel (2010). The procedure is as follows:

FIGURE 19. COUNT MODEL SPECIFICATION PROCEDURE



Following the diagram, I first test for endogeneity using the regression procedure of the Hausman test. If there is endogeneity present in the model, the procedure requires that I check for heteroskedasticity using Pagan and Hall's test. If there is heteroskedasticity present in the model, the model should be estimated using General Method of Moments (GMM). If we can reject that there is heteroskedasticity, we can use a general instrumental variable estimation such as two-stage least squares.

If the original test for endogeneity suggests that there is not endogeneity, I move to test for overdispersion in the model. I test for over dispersion in the model using the likelihood-ratio test to determine whether to use the Poisson model or the negative binomial regression. If there is overdispersion, the negative binomial model is more appropriate than the Poisson. Finally, if there is overdispersion there is one final test to arrive at the correct specification. The Vuong test is used to determine if the data necessitates a zero-inflated negative binomial regression or a standard negative binomial regression model.

I begin by testing for endogeneity in the model. Endogeneity occurs when there is an independent regressor that is correlated with an unobserved regressor or correlated with the error. In this model, I suppose that there are two variables endogenous in the model. I assume that weighted average price and the percent of transactions for environmental purposes are endogenous. I use the regression procedure of the Hausman test to test for endogeneity (Wooldridge, 2002; Hilbe, 2007). This procedure involves running an initial regression using ordinary least squares. In this regression the suspected endogenous variable (weighted average price and percent count environmental) is regressed on the proposed instruments and the residuals are saved. The second stage of the procedure calls for the estimation of the structural model, in this case the count model (as estimated by the negative binomial model). The market activity level (number of transactions) is regressed on the suspected endogenous variable, the exogenous variables, and the residuals. A significant parameter estimate on the predicted residuals suggests that the errors from the endogenous variable are related to the errors in the market activity equation, therefore suggesting that the variable is endogenous. I run two separate Hausman tests to test for endogeneity in the weighted average price and percent count environmental variables, respectively. For both tests, I follow the literature when choosing the instruments for the first-stage regression (Jones, 2008; Emerick, 2007; Brown, 2006; Pittenger, 2006; Pullen, 2006; Pullen and Colby, 2006). For lease markets, the literature suggests that drought conditions and larger populations contribute to higher lease prices. For this reason, I chose instruments reflecting the drought conditions and the state population. For sale markets, as the literature suggests, I use population, income, and drought conditions as instruments. In both the sale and lease markets, the parameter estimates are not significant, suggesting that endogeneity is not a problem for the weighted lease price variable (see Appendix G). When testing for endogeneity for the percent count environmental variable, the Hausman regression test suggests that the variable is not endogenous in the lease market, but is endogenous in the sale market (see Appendix G). To maintain consistency among the model specification, the endogeneity of the percent count environmental was not accounted for. The endogeneity present in the sale market is an area for future research.

Following the diagram, I move to test for overdispersion (essentially testing between the Poisson regression model and the negative binomial regression model). In order to check for overdispersion in the sale and lease transaction models, I utilize several different methods. First and foremost, I make a simple comparison between the sample mean and variance. If the variance is significantly larger than the mean, this suggests that the data is overdispersed (STATA FAQ, 2012). In the table below, it is evident that both the lease and sale markets exhibit overdispersion.

TABLE 19. SUMMARY OF MEAN AND VARIANCE OF TRANSACTION MODELS

	Mean	Variance	Sample Size
Lease	10.32	265.75	132
Sale	18.47	639.11	120

The second method I employ to test for over-dispersion is the likelihood ratio test in the negative binomial regression model. The Poisson is a special case of the negative binomial in which the dispersion parameter (α) equals zero. I estimate the negative binomial regression using STATA 12 and test for over-dispersion using the likelihood ratio test. The null hypothesis for this test is H0: α=0 and the alternative is α>0. If α is significantly different from zero, I can conclude that the model is overdispersed and the Poisson is not the correct specification (STATA FAQ, 2012). Table 20 shows that both the lease and sale market data are overdispersed, and that a negative binomial model should be used.

TABLE 20. LIKELIHOOD-RATIO TEST OF ALPHA=0

	Chi2(1)	Prob>Chi2
Lease	365.32	0.000
Sale	189.25	0.000

It is clear that the Poisson is not the correct specification for the data, but there is another test that must be conducted to determine which type of negative binomial model should be used. Even though I trimmed the data to not include states with a majority of zeros, it is still necessary to test whether the data necessitates a zero-inflated negative binomial model. A zero-inflated negative binomial regression accounts for the possibility that a "certain zero" is present in the dataset. A certain zero occurs when some other outside factors are preventing the event from occurring. The zero-inflated negative binomial model estimates two separate models and then combines them. It estimates a logit model to predict the certain zero scenario and then estimates the negative binomial model, and finally combines them. To test for zero-inflation I use STATA 12 to run a zero-inflated negative binomial regression and test using the Vuong command. The Vuong test compares the zero-inflated negative binomial regression to the standard negative binomial regression. If the z-value is significant, the test suggests that the zero-inflated model is more appropriate than the standard negative binomial model (STATA Annotated Output: ZINBR, 2012). In both the lease market and sale market, the test is not significant at the 5% level suggesting that the zero-inflated model is not a better fit than the standard regression model.

TABLE 21. VUONG TEST FOR ZERO-INFLATION

	Z-score	Prob>Z
Lease	-0.12	0.548
Sale	0.87	0.191

Based upon the model specification tests above, I choose to model the count data using the negative binomial regression. However, in order to account for the panel nature of the data, I must make additional considerations. The advantage of incorporating the panel nature of the data into the analysis is that it helps to control the heterogeneity that exists in the data and any correlation across time by including the individual-specific effects (Cameron and Trivedi, 1998).

First and foremost, I must determine whether to use the fixed-effects or random-effects model. The fixed-effects model is "an appropriate specification if we are focusing on a specific set of N firms" and our inferences are restricted to these specific firms (Baltagi, 2001: 12). Essentially, as Greene (2002) states, if we are primarily concerned with explanation (and not prediction), we can use the fixed-effects model. Because my data is a selection of Western U.S. states and I am primarily concerned with explaining the market activity in these states, I choose to use the fixed effects model. I do not employ a Hausman test to the count model to test for fixed effects versus random effects because the theory and objective of this analysis warrants a fixed effects model.

Cameron and Trivedi (1998) discuss the different approaches that can be used to estimate the fixed effects model. The negative binomial fixed effects regression model was first proposed by Hausman, Hall, and Griliches (HHG) (1984). In this specification y_{it} has a mean of $\alpha_{it}\lambda_{it}$ and variance $\left(\frac{\alpha_i\lambda_{it}}{\Phi_i}\right) * (1 + \frac{\alpha_i}{\Phi_i})$ where $\lambda_{it} = \exp(x'_{it}\beta)$, the parameter $\alpha_i$is the individual-specific fixed effect, and Φ_i is the overdispersion parameter (Cameron and Trivedi, 1998). The model proposed by HHG calculates the conditional negative binomial model for panel data. However, recent literature by Allison and Waterman (2002) and Guimarães (2008) suggest that the model proposed by HHG is not a "true" fixed effects model. Allison and Waterman (2002) conclude that the HHG model "allows for individual-specific variation in the dispersion parameter rather than in the conditional mean" (Allison, 2012). The problem that results is that one can obtain estimates for time-invariant variables (which is normally impossible in other conditional likelihood methods). Guimarães (2008) reached a similar conclusion stating that "the conditional maximum likelihood estimator of the negative binomial with fixed effects does not necessarily remove the individual fixed effects in count panel data. This will happen only if the individual fixed effects are related to the individual parameter of overdispersion in a very specific way" (66). To address this issue, an alternative is to run a conventional negative binomial model with dummy variables reflecting the cross-sectional heterogeneity (Allison and Waterman, 2002). This is the unconditional fixed effects estimation, and is a direct estimation of the fixed effects instead of conditioning them out in the likelihood function.

The concern with conducting a conventional negative binomial model with dummy variables to account for the panel nature is that it may produce inconsistent estimates. As Hilbe (2007) acknowledges, there is evidence that the unconditional negative binomial will underestimate the standard errors when there are a large number of fixed effects. The general rule of thumb is that if there are more than 20 cross-sectional units, one should use the conditional fixed effects estimation due to the "incidental parameters problem". This is a problem, first defined by Neyman and Scott (1948), where the potential bias increases with each additional panel (Hilbe, 2007). Fortunately, the lease and sale models in this analysis only have 6 and 5 fixed effects, respectively.

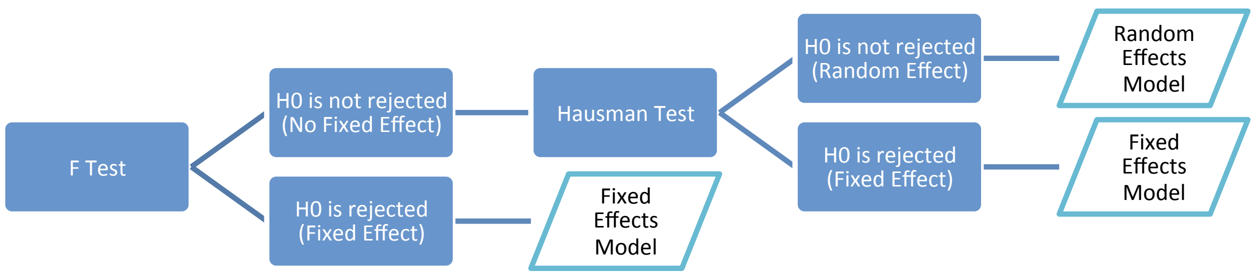
To incorporate the panel nature of the data, I choose to estimate the conventional negative binomial regression model with direct estimation of the fixed effects by including dummy variables for the states. Both the sale and lease models were estimated in the same fashion.

5.2.2B. Total Volume and Total Dollar Value Models

The other two econometric models in this analysis are the total volume of water transferred and the total dollar value expended in the water market each year. Again, the analysis is broken up between sales and leases and incorporates the panel nature of the data. The total volume model and the total dollar value models are not balanced panels, so the number of observations differs across states and the type of the transfer. The statistical software used in this analysis is able to handle unbalanced data (Cameron, 2007). Essentially, these models aim to understand the factors that contribute to higher levels of activity (as defined by the total volume and the total dollar value), given that there is at least one transaction in each year and state. I follow Park's (2010) procedure to determine the model specification.

Before following Park's procedure, I must conduct an initial specification test to check for endogeneity. Endogeneity may be a problem when using the weighted average price and percentage of the total volume transferred for environmental purposes (percent volume environemental variable) as regressors for the total volume and the total dollar value if these values are simultaneously determined. As before, I use the regression procedure of the Hausman test to check for endogeneity (Wooldridge, 2002). The suspected endogenous variables (weighted average price and percent volume environmental) are regressed on the proposed instruments using OLS and the residuals are saved. The second stage of the procedure calls for another ordinary least squares regression in which the market activity variables (total volume and total dollar value) are regressed on the endogenous variables, the exogenous variables, and the residuals. Again, a significant parameter estimate on the predicted residuals suggests that the errors from the endogenous variable are related to the errors in the market activity equation, therefore suggesting that the variable is endogenous. For both variables, I use the same instruments as had been done in the transaction models. In all four models (total volume and total dollar value for sales and leases), the parameter estimates for the weighted average price variable are not significant, suggesting that two-stage least squares is not necessary. In three of the four models, the parameter estimates for the variable measuring the percent volume environmental are not significant. The only model in which the parameter estimate is significant is the total dollar value sale market. However, in order to maintain consistency in the modeling, I choose not to use the two-stage least squares estimation technique for the total dollar value sale model. Accounting for the endogeneity is this model is an area for future research.

FIGURE 20. PANEL MODEL SPECIFICATION FOR TOTAL VOLUME AND TOTAL DOLLAR VALUE MODELS



After determining if there is endogeneity, the first specification test I conduct is the F test for the fixed effects model. The fixed effects model assumes that the unobserved u_i are correlated with one or more of the right hand size variables. When running a fixed effects model in STATA 12, the software reports the correlation between u_i and the fitted values $(x_{it}*\hat{\beta})$. A high correlation suggests that a fixed effects model should be run instead of a random effects model. However, the F test is more conclusive. Below are the correlations for both models in the sale and lease markets.

TABLE 22. CORRELATION AND F-TEST FOR TOTAL VOLUME AND TOTAL DOLLAR VALUE MODELS

	Corr (Ui, Xb)	**F Test**	**Prob>F**
	Total Volume Model		
Lease	-0.90	F(5,101)=10.22	0.000
Sale	-0.89	F(4,103)=0.81	0.519
	Total Dollar Value Model		
Lease	-0.92	F(5,101)=4.71	0.001
Sale	-0.094	F(4,103)=1.69	0.158

The F test (or Wald Test) for fixed effects is conducted by fitting the least squares dummy variable model (Park, 2010). Then I conduct a joint F test of the null that all of the dummy variables are equal to zero. If the F test is significant we can reject the null and use the fixed effects model specification. As can be seen in the table above, in both lease models we can reject that the random effects model is a better specification for the lease market. This, however, is not the case in the sale market. In both models, we cannot reject the null for the sale market.

I use the Hausman test to determine whether to use the random effects or fixed effects model specification for the sale market in both the total volume and total dollar value models. The null hypothesis in the Hausman test states that the error is uncorrelated with the x variables. If the null is rejected, then only the fixed effects model is consistent (Park, 2010). If the null is not rejected, either of the models can be run. Using STATA's canned procedure for the Hausman test I receive the following results:

TABLE 23. HAUSMAN TEST FOR FIXED VS. RANDOM EFFECTS

	Chi2 (4)	Prob> Chi2
Total Volume-Sales	3.09	0.5435
Total Dollar Value- Sales	10.07	0.0392

According to these results, the total dollar value sales model requires fixed effects estimation. Even though we cannot reject the null for the total volume sales model, I choose to continue with fixed effects estimation for consistency across the models and based on theory. In this thesis, I aim to *explain* market activity levels, not to *predict* the activity levels outside of the sample. For these reasons, I choose to model the panel data using fixed effects.

5.2.3 Description of Variables and Expected Signs

The variables used in all 6 models are presented in this section along with their expected signs. For convenience, the table below summarizes the variables briefly with more detailed definitions following. While the variables do not change drastically between models, they did have to be re-scaled to account for the difference in magnitudes of the dependent variable. For the transaction models, the variables had to be re-scaled to accommodate the small magnitude of the dependent variable. Those variables that had to be re-scaled will be noted in the variable descriptions.

TABLE 24. VARIABLE DESCRIPTIONS AND EXPECTED SIGNS

Variable Name	**Description**	**Expected Sign**
Weighted_Avg_Price	Annual average price by state weighted by volume (2010 dollars)	+/ -
Income_Annual	Annual state income (2010 dollars)	+

SP12_Sept	Standard precipitation index value for previous 12 months in the month of September	-
SP12_Lag1	Standard precipitation index value for previous 12 months in the month of December, lagged 1 year	-
Farm_Net_Cash_Income	Annual farm net cash income by state (2010 dollars)	-
Avg_Lease_Length	Simple annual average of lease length.	-
Percent_Volume_Env	Percentage of total volume designated for an environmental purpose end use.	+/-
Percent_Volume_Muni	Percentage of total volume designated for a municipal purpose end use.	+/-
Percent_Count_Env	Percentage of total number of transactions designated for an environmental purpose end use.	+/-
Percent_Count_Muni	Percentage of total number of transactions designated for a municipal purpose end use.	+/-
State_Population	Annual state population	+

Weighted_Average_Price: The weighted average price was the average price ($/AF) of all of the transactions in each state and year weighted by the total volume transferred in that year and state. Average lease prices and sale prices were calculated separately. Due to the balanced panel in the transaction models, where years with zero transactions are still included in the models, the weighted_average_price was calculated for those years using the average of the 4 consecutive weighted average prices (2 prior and 2 after). The expected sign of price on all 6 models is ambiguous. On the one hand, we could expect the sign to be positive as price is a signal of water scarcity and an increasing price would suggest a more active water market. However, we could also think of price in the traditional sense where we would expect that as prices increase the quantity demanded decreases. This variable was used in all models and I tested for endogeneity using the Hausman regression procedure. The variable was not endogenous in all 6 models.

Income_Annual: The Income_Annual variable is the annual state personal income. State personal income is defined as “the income received by all person from all sources” (BEA, 2012). This measure provides a framework for analyzing the relative economic conditions in each state over time. Income data comes from the Bureau of Economic Analysis website (BEA, 2012). State personal income was adjusted for inflation using the Consumer Price Index for 2010 from the Bureau of Labor Statistics (BLS, 2012). The state personal income is measured in billions of dollars in all models. The expected sign on this variable is positive, as we would expect that a healthy economy would increase water market activity.

SP12: The standard precipitation index was used to account for drought conditions within the state over the year. The SP12 was used, meaning that the average precipitation over the last twelve months was compared to the average precipitation from the entire record. The historic record is based on the precipitation from 1895 to the latest month with available data. The index ranges from (-3 to 3) where negative values represent drier than normal conditions and positive values represent wetter than normal conditions (NCDC, 2007). Two different "lags" were used in this analysis. For the lease models, I use SP12_Sept which in essence created a 3-month lag. The SP12 value in September compares the precipitation for the 12 month period from September the previous year to the current September. For the sale models, I chose a longer lag to account for the fact that sales (permanent transfers) take longer to negotiate and implement than temporary transfers. I suspect that sales are pursued when there are longer periods of drought. The amount of time chosen for the lag in the sales models is one year, or SP12_Lag1. The expected sign of this variable is negative. As weather conditions become more wet, there is less demand for the use of water acquisitions, therefore decreasing the water market activity.

Farm_Net_Cash_Income: This variable is the net returns earned from the production of goods and services in the agricultural sector minus the net rental value of farm operator dwellings. Farm income data comes from the Economic Research Service (ERS, 2012). The farm income was also adjusted for inflation using the Consumer Price Index for 2010 from the Bureau of

Labor Statistics (BLS, 2012). For all models, this variables is measured in thousands of dollars. The expected sign of this variable is negative. Since a majority of the transfers are transferring water out of agriculture, it makes sense that if the farmer is experiencing high net cash income then they would be less interested in leasing or selling water.

Avg_Lease_Length: This variable is the average length of leases within a state and a year (distribution of average lease length across states and time available in Appendix I). A large majority of the leases are only 1 year in length (87% of the sample). Colorado and Washington are the exceptions with only 55% and 56%, respectively, of the lease lengths equal to 1 year (see Appendix I for details on frequency of lease lengths). The other lease lengths for Colorado occur at 25 and 40 years, and the lease lengths for Washington are 10 years. The expected sign for this variable is negative because we expect that as the lease length is longer, there is less demand for water transactions; therefore decreasing the market activity.

Percent_Volume_Env and Percent_Volume_Muni: This variable measures the percentage of the total volume that is purchased for an environmental and municipal purpose, respectively. The ambiguous sign is due to the differences between the sale and lease market. Based on the literature, we expect that an increase in the percentage in volume for environmental purposes would increase the volume transferred through a lease, and not necessarily increase the volume transferred in the sale markets. Opposite from the percent_volume_env variable, we expect the percent_volume_muni variable to be negative in the lease models and positive in the sale models. I use the percentage for each respective end use, as opposed to the raw figure, to decrease the likelihood of endogeneity in the model. I also test for endogeneity in the total volume and total dollar value models (for both sales and leases). In 3 of 4 models, the variable was determined to not be endogenous.

Percent_Count_Env and Percent_Count_Muni: These variables are very similar to the variables presented above, but instead of the percentage of the total volume, this variable calculates the percentage based on the total number of transactions. We expect the same differences between the sale and lease markets to be present in these variables as well. Again, the percentage was used as opposed to the raw figure and the variable was tested for endogeneity. The variable was not endogenous in the transaction lease market model, but was determined to be endogenous in the transaction sale market model.

Population: Although this variable is not used in the estimation of the six models due to collinearity with the annual_income variable, I use this variable as an instrument in the Hausman test procedure. The population is the entire state population at an annual timescale lagged two years to account for the changing demographic. The annual state population was obtained from the Census Bureau Website (Census Bureau, 2012). The expected sign on this variable is positive due to potentially increasing demand for water.

5.4 RESULTS

To the extent possible, the same variables were used across the three models measuring market activity in both the sale and lease markets to promote consistency and allow for comparison across the models. Comparisons can easily be made across the market activity models in each respective type of transfer (sales and leases). However, it is important to note that comparisons across the sale and lease markets are not as straightforward. This is due to the fact that there are different states represented in each dataset, with only three states present in both sale and lease market analyses.

Table 25 contains the summary statistics of the three different measures of market activity for both sales and leases at an annual timescale. This table provides data for the entire period (1987-2010) and for the states used in each analysis. The data not used in the sale and lease analysis is not present in the table. As shown in the figure, Arizona and Nevada were not included in the lease market analysis and Idaho, Oregon, and Washington were not included in the sale market analysis.

TABLE 25. ANNUAL SUMMARY STATISTICS, 1987-2010

	AZ	CA	CO	ID	NV	NM	OR	WA
Leases								
min no. trans		5	1	0		0	0	0
median no. trans		32	5	2		3	3	1
mean no. trans		36	7	4		4	6	1
max no. trans		89	21	39		15	62	4
min total volume		48,153	20	0		0	0	0
median total volume		471,067	20,425	28,174		23,157	9,173	659
mean total volume		510,590	26,322	132,267		26,935	41,017	3,297
max total volume		937,528	153,451	846,199		99,262	497,029	28,002
min total dollar value		1,009,215	366	0		0	0	0
median total dollar value		57,479,008	1,269,437	326,044		815,385	298,607	14,168
mean total dollar value		73,802,468	2,955,581	4,423,934		2,110,800	8,489,407	296,990
max total dollar value		229,929,430	36,387,953	38,171,315		9,934,829	176,399,092	3,177,176
Sales								
min no. trans	0	0	27		1	0		
median no. trans	6	6	64		15	3		
mean no. trans	6	5	64		14	4		
max no. trans	13	14	106		36	13		
min total volume	0	0	1,399		24	0		
median total volume	9,463	13,767	4,169		3,217	547		
mean total volume	13,060	40,367	15,559		6,791	1,737		
max total volume	50,269	483,005	219,022		32,058	9,082		
min total dollar value	0	0	5,286,000		73,098	0		
median total dollar value	7,191,572	24,507,334	41,976,554		12,064,395	1,271,499		
mean total dollar value	14,846,355	36,932,644	42,514,480		40,821,639	2,605,009		
max total dollar value	54,410,257	218,648,313	129,162,629		203,266,830	11,894,979		

5.4.1 Lease Models

I estimate the lease models using the statistical software STATA 12. For all lease models, the analysis includes data from 1989 to 2010 for the following states: California, Colorado, Idaho, New Mexico, Oregon, and Washington. Whereas the transaction model is a balanced panel (there are the same number of observations for each state), the other two market activity level models are not balanced panels for methodological simplicity. In the total volume and total dollar value models, there are fewer transactions due to lack of activity in certain years.

For the transaction models, I estimate the unconditional fixed effects model by using a conventional negative binomial model and include the fixed effects by using dummies to represent the states. In order to interpret the coefficients from the negative binomial regression I follow convention and interpret the parameter estimates in terms of the incidence rate ratio (IRR) or rate ratios (Hilbe, 2011). The rate at which events occur is called the incidence rate (STATA Annotated Output Negative Binomial Regression, 2012) and the parameter estimates can be expressed in this way by exponentiating the coefficients. The results of the lease model are presented below.

TABLE 26. TRANSACTION LEASE MODEL RESULTS

N= 132
LR chi2(11) = 137.42 Prob > chi2 = 0.0000

	IRR	Std. Err.	P>|z|
Weighted_Average_Price ($/AF)	1.001	0.001	0.147
Avg_Lease_Length	1.029	0.019	0.114
Percent_Count_Env	**3.521*** **	1.000	**0.000**
Annual_Income (in billions)	**1.002** **	0.001	**0.020**
Farm_Net_Cash_Income (in thousands)	1.000	0.000	0.985
SP12_Sept	0.931	0.081	0.411
CA	0.883	1.005	0.913
ID	1.179	0.396	0.623
NM	0.645	0.216	0.190
OR	0.815	0.253	0.509
WA	**0.201*** **	0.070	**0.000**
Intercept	**2.606*** **	0.832	**0.003**

*** significant at 1%, ** significant at 5%, * significant at 10%

Referring only to the variables that are statistically significant, we can see that a one percent increase in the percentage of transactions that are for an environmental purpose result in 3 times as many transactions. From this result, we can see that water acquisitions for environmental purposes are a large part of the lease market. Additionally, there are is a slight increase (less than 1% increase) in transactions when the state's annual income increases by $1 billion. Finally, we can see that the number of lease transactions is 80% less if they occur in Washington as opposed to in Colorado.

Continuing to the other lease models, the dependent variable in the total volume model is the total volume of water transferred each year in a state and the dependent variable in the total dollar value model is the annual total dollar value expended by state. The results of these analyses are conditional on the fact that at least one transaction has occurred in that year.

The results of the lease total volume model and total dollar value model are presented in Table 27. Both models were estimated using the command xtreg, fe in STATA 12 whose purpose is to handle panel data. Due to the elimination of the years with no water transfers, the number of observations in these models is 113.

TABLE 27. TOTAL VOLUME AND TOTAL DOLLAR VALUE LEASE MODEL RESULTS

	N= 113
Number of Groups	6
Min. Observation per Group	15
Avg. Observation per Group	18.8
Max. Observation per Group	22

	TOTAL VOLUME MODEL		TOTAL DOLLAR VALUE MODEL	
Variable	**Parameter Estimate**	**P>|t|**	**Parameter Estimate**	**P>|t|**
Weighted_Average_Price ($/AF)	56.5	0.469	**66,316.36*** **	**0.000**
Annual_Income (billions)	116.92	0.338	-805.13	0.976
SP12_Sept	-14,086.11	0.254	**-5,639,907.00** **	**0.038**
Farm_Net_Cash_Income (thousands)	**-49.86*** **	**0.001**	**-11,014.12*** **	**0.001**
Percent_Volume_Env	**62,343.49* **	**0.063**	-4,188,631.00	0.564
Avg_Lease_Length	-1,066.98	0.635	-557,526.20	0.258
Intercept	**234,422.70*** **	**0.000**	**49,100,000*** **	**0.000**
	F(6,101)= 2.73		F(6,101)= 5.54	
	Prob >F= 0.0168		Prob >F= 0.0001	

*** significant at 1%, ** significant at 5%, * significant at 10%

The results of the total volume lease model suggest that the profitability in the farm sector and the share of water transferred for environmental purposes significantly affect the total volume of water transferred. As expected, as farm net cash income increases, the total volume of water transferred decreases. When farm net cash income increases by $1,000, the total volume of water transferred decreases by almost 50 acre-feet of water. The positive and significant sign on percent_volume_env suggest that the environmental uses are a large component of the lease market. An increase of 1% in the volume transferred for environmental purposes results in a total volume increase of water of more than 60,000 acre-feet (0.4% of the total volume transferred).

In the lease total dollar value model, weighted_average_price is positive and significant. This result shows that as the price per acre-foot increases, the total dollar value expended on water acquisitions increases. SP12_Sept and Farm_Net_Cash_Income are negative and significant. Both of these make intuitive sense. As the state experiences wetter conditions, there is a significant decrease in amount of activity in terms of the total amount spent on water acquisitions. As with the total volume activity model, the total dollar value model also exhibits decreasing activity in the lease market when there is an increase in farm_net_cash_income.

5.4.2 Sale Models

I also estimate the sale models using the statistical software STATA 12. For all sale models, the analysis includes data from 1987 to 2010 for the following states: Arizona, California, Colorado, Nevada, and New Mexico. Again, whereas the transaction model is a balanced panel (there are the same number of observations for each state), the other two market activity level models are not balanced panels. In the total volume and total dollar value models, there are fewer transactions due to lack of activity in certain years. Over the 24-year period and five states, there were only 6 times in which there were no water acquisitions.

For the sales transaction model, I estimate the unconditional fixed effects model using dummies to incorporate the panel nature of the data. Following the lease model, the interpretation is presented in terms of incidence rate ratios. The results of the sale transaction model are presented below.

TABLE 28. TRANSACTION SALE MODEL RESULTS

N= 120

LR chi2(10) = 168.05 Prob > chi2 = 0.0000

	IRR	Std. Err.	P>|z|
Weighted_Average_Price ($/AF)	1.000	0.000	0.426
Percent_Count_Env	0.891	0.484	0.832
Percent_Count_Muni	1.172	0.270	0.490
Annual_Income (in billions)	**1.002*** **	0.001	**0.000**
Farm_Net_Cash_Income (in thousands)	1.000	0.000	0.376
SP12_Lag1	1.048	0.068	0.468
AZ	**0.099*** **	0.021	**0.000**
CA	**0.009*** **	0.011	**0.000**
NV	**0.274*** **	0.075	**0.000**
NM	**0.079*** **	0.018	**0.000**
Intercept	**38.616*** **	11.680	**0.000**

*** significant at 1%, ** significant at 5%, * significant at 10%

The transaction sale model shows that there are significant differences between the base state (Colorado) and the other states. In the sale market, Colorado dominates in terms of the number of transactions. The closest competitor to Colorado is Nevada, but even then, Nevada has almost 82% fewer transactions than Colorado. Similar to the lease transaction model, the state annual income is slightly positive and significant.

The results of the two other market activity econometric sale models are presented below. The table includes both the total volume and total dollar expended models for the sale market. I estimate these models using the same fixed effects panel procedure in STATA 12.

TABLE 29. TOTAL VOLUME AND TOTAL DOLLAR VALUE SALE MODEL RESULTS

	N= 114
Number of Groups	5
Min. Observation per Group	21
Avg. Observation per Group	22.8
Max. Observation per Group	24

	TOTAL VOLUME MODEL		TOTAL DOLLAR VALUE MODEL	
Variable	**Parameter Estimate**	**P>|t|**	**Parameter Estimate**	**P>|t|**
Weighted_Average_Price ($/AF)	-1.06	0.333	**3,500.78*** **	**0.000**
Annual_Income (in billions)	**-105.23** **	**0.035**	**-71,132.13** **	**0.049**
SP12_Lag1	-2,612.69	0.597	**-8,863,057** **	**0.015**
Farm_Net_Cash_Income ($)	6.22	0.293	-5,301.30	0.217
Percent_Volume_Env	8,375.85	0.689	8,468,907	0.578
Percent_Volume_Muni	-16,872.94	0.170	1,870,212	0.833
Intercept	**48,575.45** **	**0.045**	442043.7	0.980
	F(6,103)= 1.68 Prob >F= 0.1336		F(6,103)= 5.65 Prob >F= 0.0000	

*** significant at 1%, ** significant at 5%, * significant at 10%

While the total dollar value model performs well in terms of the F-test, the total volume model does not. Based upon the F-test of the sale total volume model, I cannot say that all of the coefficients are different from zero. For this reason, I will not analyze the results of this model, but they are included Table 29 for reference.

Consistent with the lease market, the total dollar value model finds that a $1 increase in the weighted_average_price increases the total dollar value expended in the sale market by just over $3,500. This variable is positive and significant at the 1% level, but is of much smaller magnitude than in the lease market. The inclusion of weighted average price does not necessarily create circularity in the model because the dependent variable is an interaction between the volume of water purchased and the price per volume paid for each transaction. Although there is a link, the link is not direct enough to cause circularity in the model. An increase in the weighted average price does not necessarily increase the total dollar value spent because the volume purchased could be significantly lower. The drought indicator variable, similar to the lease market, is negative and significant as expected. Surprisingly, state annual income is negative and significant suggesting that as the state personal income increases less money is spent on water acquisitions in the sale market. One explanation for this could be that the less money is spent on water acquisitions and more money is spent on water infrastructure.

Interestingly, the total dollar value models (for both sale and lease) are the only models in which drought conditions are significant factors in the activity of the market. However, this is consistent with previous literature that concluded that prices of water transfers are influenced by drought conditions. Wetter conditions lead to a decrease in the amount of money expended for water acquisition. This most likely occurs for two reasons: any decrease in the price of the water (due to decreasing scarcity) and any decrease in the amount of water transferred. Individually, we can't conclude that wetter conditions lead to smaller quantities of water transferred (there is not statistical significance), but the combination of the price and volume seem to have an effect on the total dollar value spent on water acquisitions.

In order to make comparisons across the models, I present the statistically significant variables for all models in the table below.

TABLE 30. SUMMARY OF SIGNIFICANT VARIABLES ACROSS ALL MODELS

	Transaction Model	**Volume Model**	**Dollar-Value Model**
Estimation Technique	Unconditional fixed effects negative binomial	Panel fixed effects	Panel fixed effects
Lease Market Significant Variables	Percent_Count_Env (+) Annual_Income (+) WA (-)	Farm_Net_Cash_Income (-) Percent_Volume_Env (+)	Weighted_Average_Price (+) SP12_Sept (-) Farm_Net_Cash_Income (-)
Sale Market Significant Variables	Annual_Income (+) AZ (-) CA (-) NV (-) NM (-)	Annual_Income (-)	Weighted_Average_Price (+) Annual_Income (-) SP12_Lag1 (-)

Market activity related to environmental purposes is obviously more active in the lease market than in the sale market, as demonstrated in the transaction and total volume analyses. In both cases, an increase of transactions or volume for environmental purposes results in a significant increase in the number of transactions and the total volume. Another consistent result in the lease market is that as farm net income increases, the market activity (as defined by the total volume of water and the total dollar value expended) decreases. Intuition supports this result as we expect that farmers would be less interested in leasing water when they are experiencing high net cash income. Although this is also seems to be true in the sale market, the farm net cash income variables were not significant in the sale markets and are therefore not a driving factor. We expect this to be this case as farm net cash income is a variable capturing the short-term profitability of the farm, not the long-term.

In the sale market, the state annual income is significant in all three market activity models. However, the signs change depending on the measure of market activity; in the transaction model, an increase in the state's annual income increases the number of water transfers. However, in the total volume model and the total dollar value model an increase in the state's annual personal income results in a decrease in the amount of water transferred and the amount of money spent on water acquisitions. These results could suggest that although growth has necessitated more transfers, they are of smaller volumes and result in fewer dollars expended for water acquisitions.

CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 SUMMARY AND POLICY IMPLICATIONS

This thesis presents results on two different aspects of the problem of securing water for water-dependent ecosystems. It addresses the first issue of valuing the ecosystem service benefits of water-dependent ecosystems by conducting a contingent valuation analysis in the Colorado River Delta, Mexico. In order to contribute further to the discussion of water management in the Colorado River, this thesis analyzes the economic value of water for recreation in the Delta and the value that visitors place on water for a healthy Delta ecosystem. By demonstrating that the protection of the Delta's ecosystems has tangible benefits for the community and that the community values healthy ecosystems, we can influence and support decision-makers when they are determining the appropriate allocation of scarce Colorado River resources.

Based upon a survey sample of 584 (mostly local) respondents, I calculate the median willingness-to-pay (WTP) for entrance to five different recreational sites in the Colorado River Delta. The respondents were asked how much they would be willing-to-pay via an entrance fee in order to guarantee an adequate amount of water to sustain a healthy and vibrant ecosystem in the Delta. The results calculate the median WTP of visitors to Campo Baja Cucapah and Campo Mosequeda, well-facilitated sites along the Hardy River, to be $168 pesos ($13 USD) per car per entry. The WTP of visitors to Morelos Dam, San Felipito, and the Cienega de Santa Clara is $97 pesos ($7 USD) per car per entry.

It is important to note that although this thesis determines that value of the Delta via the median WTP, not all of the values or ecosystem benefits are captured in this analysis. Use value is captured due to the fact that all of the respondents were physically at the recreation site at the time of the survey. Some non-use values, such as existence value, may have been captured due to the wording of the scenario and the WTP question. However, other non-use values, such as bequest values, were certainly not captured as there was no mention of protecting the Delta ecosystem for future generations. Additionally, it is important to acknowledge that there are numerous other ecosystem service benefits that were not captured in this analysis. The primary benefit measured in this analysis was the recreational benefits, but the Delta provides other ecosystem service benefits such as water quality improvements through the riparian vegetation along the river and the wetlands, as well as supporting services such as nutrient cycling. Therefore, it is important to acknowledge that this analysis only captures a partial measure of the value of ecosystem benefits that the Delta provides.

The results suggest that the visitors to these five locations in the Colorado River Delta value the Delta's water-dependent ecosystem and the recreational opportunities that they provide. Understanding the value that people place on a healthy Delta ecosystem provides additional information and allows decision-makers to see the benefits of protecting freshwater and riparian ecosystems. The inclusion of the non-market benefits that these ecosystems support into decision-making provides impetus to use water markets to secure water to protect, maintain, or restore these ecosystems.

The second aspect of this thesis addresses questions relating to the use of water markets to transfer water from one place or user to another. This section of the thesis analyzes the activity of Western U.S. water markets by conducting six different econometric models. By understanding the factors that influence periods and locations with higher water market activity, we may be able to gain insight into the strategies that could be employed to secure water for water-dependent ecosystems.

Using water transfer data from the *Water Strategist*, I analyze the fluctuations in annual activity of the water market across several Western states. To analyze this, I use three different measures of market activity: 1) the number of transactions, 2) the total volume of water transferred, and 3) the total dollar value expended on water acquisitions. Due to the systematic differences between sales and leases of water, I model these types of water transfers separately.

The lease market analyses include data from California, Colorado, Idaho, New Mexico, Oregon, and Washington for the period from 1989 to 2010. These states and the range of years were selected because they had enough water transfers for all three econometric analyses. The sales market, on the other hand, included data from Arizona, California, Colorado, Nevada and New Mexico from 1987-2010. Only three states (California, Colorado, and New Mexico) are present in both the sale and lease markets.

The results of the market activity analysis emphasize that the factors influencing levels of water market activity vary depending on the definition used to define market activity. When the number of transactions is the measure used to define market activity, the state annual income variable is significant in both the sale and lease models. This transaction model also shows the extreme variance between the level of activity in terms of transactions between the states, especially in the sale market. Colorado, the base, has significantly more transactions than Arizona, California, Nevada, and New Mexico. When the level of activity is measured by the total volume, the variables that become significant in the lease market are the profitability in the farm sector and the share of water transferred for environmental purposes. Finally, when measured by the total dollar value expended on water acquisitions, the weighted average price and drought variable are significant factors in both the sale and lease models. These two variables have the expected signs, with an increase in the price resulting in increased dollars spent on water acquisitions and wetter drought conditions resulting in decreased activity in terms of the total dollar value expended.

The results of the transaction analysis also suggest that the water market is a supply-side dominated market. This is evident when looking at the relationships between price/AF and the market activity, net farm income and market activity, and the relationship between drought conditions and market activity. For a majority of the models, as the price per acre-foot of water increases the market activity also increases. This would suggest that demand is relatively inelastic as the demand for water does not change as the price increases. Additionally, in a majority of the models, as the net farm income increases, the market activity decreases. This result suggests that the market activity decreases potentially as a result in a shortfall of supply. In this case farmers may not be interested in joining markets and therefore there is less water available for transfers. Lastly, the conclusion that market activity decreases during wetter periods suggests that in wet periods there is less demand, potentially as a result of adequate supplies of water. These three phenomena suggest that water markets in the western U.S. are supply-side dominated.

Although some conservation groups prefer to secure water for ecosystems in perpetuity, the lease market is more active in environmental purchases of water. In terms of the number of transactions, the share of transfers for an environmental purpose is a significant determinant in the number of transactions that occur. This seems to suggest that water for the environment has secured a significant position within the lease market in terms of the number of transactions. However, if the goal would be to increase the volume of water for ecosystems, special attention should be paid to the agricultural sector. The results suggest that higher net cash incomes at the farm level decrease the volume transferred. Environmental organizations seeking to secure water for ecosystems could target farmers and use innovative short-term leases to ensure that farmers are compensated and larger volumes of water could be transferred to environmental purposes at the times of year when water is the most needed for flows and specialized environmental needs.

6.3 Contributions

This thesis contributes to the literature by providing a two-fold analysis related to challenges in securing water for ecosystems. First and foremost, it provides insight into the value of the water-dependent Delta ecosystem to the visitors who frequent there. Although based upon a previous study by Rivera and Cortés with assistance from Carrillo-Guerrero, this study broadened the scope of the valuation to include more recreational sites within the Delta and focus specifically on the WTP for a guaranteed source of water to support the health of the Delta ecosystem. Secondly, this thesis provides a unique analysis of the activity of western U.S. water markets. Whereas previous studies have focused almost entirely on individual transactions, this study analyzes the market as a whole by aggregating up to a state and annual timescale. Additionally, this thesis is unique in that it considers three different definitions to analyze water market activity. In doing so, it utilizes several different econometric models.

6.4 Future Work

Referring to the contingent valuation analysis in the Colorado River Delta, future work could involve conducting an analysis using the travel cost methodology. The survey captures the respondents' primary residence and the distance traveled to each recreation site could be calculated. Using this information, one could conduct a travel cost analysis to determine the respondents' WTP based upon the revealed preference method instead of the stated preference method.

Additionally, an econometric analysis could be conducted on the second, follow-up willingness-to-pay question. The second question, presented in the payment card elicitation format, asked the maximum that the respondent was willing to pay per car per entry in order to ensure that the Delta has an adequate amount of water to sustain a healthy and vibrant ecosystem. This study presented the results of the dichotomous choice WTP question, but one could also conduct an analysis on the payment card maximum WTP question. Finally, for comparison, one could conduct the contingent valuation analysis by adjusting for "yea-sayers" in a different manner – such as by assuming that yea-sayers would say Yes to their Maximum WTP amount and proceeding with the analysis accordingly.

Referring to the water market activity analysis, additional work could be done to accommodate issues that were not addressed in this analysis. First and foremost, in order to maintain consistency among estimation techniques across the six models, this thesis did not address the endogenous variable that was present in two of the models. Additional work could be done in the transaction and total dollar value sale market models in order to address the endogeneity from the percent environmental variables. Secondly, additional analysis could be done to determine the effect of previous years' average lease length on current market activity. One would expect that as average lease lengths in previous years become longer, there would be less water available for transfer in subsequent years. For this reason, it could be fruitful to examine the effects on market activity when average lease length is lagged by one or two years.

Future work could also be done to understand the interaction between the number of transactions and the total volume of water transferred. We would expect that as the number of transactions increases, the total volume of water also increases and potentially vice versa. This phenomenon could potentially be modeled simultaneously, where the individual transaction model and volume model would be estimated individually, and then run jointly in a simultaneous model.

Another area of research interest is the relationship between sales and leases. An analysis could be conducted at a macro-economic scale to understand the interaction between sales and leases. Again, the sale and lease models would be estimated individually and then run jointly in the simultaneous model.

Furthermore, additional work could be done to understand the factors contributing solely to environmental purposes. This thesis analyzes water market activity as a whole, with the inclusion of a variable measuring water for environmental purposes. A more in-depth analysis could be conducted on a sub-sample of this one, where one could determine the factors contributing to higher levels of environmental water activity.

APPENDIX A: CONTINGENT VALUATION SURVEYS (ENGLISH AND SPANISH VERSIONS)

Colorado River
Tourism Activity in the Colorado River Delta Recreational Areas

Name of interviewer ___________________________________
Date: ___________ Start time: ____________

Good morning (afternoon), we are conducting a survey to learn about certain characteristics of visitors to the Colorado River Delta. The information that you provide will help us to improve conservation of the environment and natural resources for the benefit of the people and wildlife. This survey is voluntary, anonymous, and confidential. If you choose to participate, we would greatly appreciate it.

Section 1: General information about this visit and past visits

We will start the survey by asking about today's visit and then continue with questions regarding your typical visits to this site in the past.

1. What is your place of residence (town and state)?
____

2. On today's trip, including yourself, how many people are in your party? ______________

3. On this trip, how many vehicles were used to transport your entire party? ________________

4. On this trip, how long have you spent or think you will spend at this recreational site?

_________ (total # of hours on this **day** trip)
OR
_________ (total # of nights on this **multiple-day** trip)

5. What have been the main reasons for your visit to the area today?(*Maximum of two: mark with 1 and 2 in order of importance for the two most relevant; 1 is the most important*)

Activity	**1**	**2**		**Activity**	**1**	**2**
a) Spend time together				f) Bird watching		
b) Picnic				g) Swimming		
c) Walk around				h) Sport fishing		
d) Hunting				i)Required for work		
e) Aquatic Activities (boating, jet skiing,				j) Other (specify):		

water skiing)						

6. In your opinion, what should the minimum depth be of the river for you to do the activity you indicated as the most important reason? ________ meters/feet *(please circle one)*

7. If you knew that today's water depth would be less than the minimum depth you answered in question #6, would you still have visited this site? Y / N *(please circle one)*

8. Please choose the top two reasons you came specifically to this site today, as opposed to other nature sites:

a) Close to residence
b) Easy to access
c) Restaurants and stores are nearby
d) Good facilities- bathrooms, picnic tables, etc.
e) Quantity of water
f) Quality of water
g) Abundance of vegetation for shade
h) Abundance of wildlife
i) Other (specify): ______________________________ _________

Now we will ask questions about past visits to this site.

9. In a typical year, how often do you come to this site? *(skip to question #10 if they answer "a")*

a) This is my first trip.
b) Less than 1 time a year
c) 1 time a year
d) 2-5 times a year
e) 6-10 times a year
f) More than 10 times a year

a. When you visit this site, on average, how long do you stay?

_________ (average # of hours on **day** trips)

OR

_________ (average # of nights on **multiple-day** trips)

b. What year was your first visit to this site? __________________

c. Do you remember if you have seen portions of the Colorado River dry from lack of water inflows?

YES (in what year? ___________) NO

d. We've already asked about the reason for your visit today, but thinking back on all other visits, what activities do you like to do when you come to this site (mark all the options that apply)?

a) Picnic
b) Spend time together
c) Fish
d) Swim
e) Walk around
f) Bird-watch
g) Hunt
h) Other (specify)

e. What do you feel is the best time of year to visit this site to do the activities mentioned above?

a) Dec-Feb	b) Mar-May	c) Jun-Aug	d) Sept-Nov	e) Holidays (Semana Santa, Christmas, etc.)

If there are other specific times when you like to visit (Ex. during hunting season), please specify:

____

10. What characteristics of this site, if any, prevent you from coming more often?

Motive	**Mark**	**Motive**	**Mark**
a) Lack of activities		e) Lack of water	
b) Distance		h) Too many people	
c) I prefer other sites		i) Bad wáter quality	
d) I did not know of this site		j) Other	

11. In a typical year, what other outdoor nature areas do you visit? (*Ex. La Rumorosa, El Bosque de la Ciudad o Golfo de Santa Clara*)

Section 2. Use and conservation of the ecosystem

To continue, we are going to ask a series of questions, which will be taken into account for when a possible conservation plan for the area is designed.

12. Within the past two years, have you heard or read about the protected area of the Delta (la Reserva de la Biosfera del Alto Golfo de California y Delta del Río Colorado)? Y / N *(please circle one)*

13. Within the past two years, have you heard or read about the global attention that has been focused on Colorado River Delta for its flora y fauna? Y / N *(please circle one)*

14. On a five point scale *(with 1 being most important and 5 being least important and 3 being neutral)*, please indicate how important you think it is to:

a. designate a secure supply of water for the environment, so that the water level is adequate to maintain the health of the river corridor.

Most important | | | | Least important

1	2	3	4	5

b. take part in conservation efforts in order to maintain habitat for native species.

Most important | | | | Least important

1	2	3	4	5

Section 3. Preferences about the Colorado River

In recent decades, portions of the Delta's rivers and wetlands have dried due to lack of water flows. Conservation groups, local communities, and visitors are concerned that inadequate flows are harming the flora and fauna of the region. Without adequate flows, the health of this ecosystem is threatened, and visitors and local communities face declining recreation benefits and livelihoods.

People who value this ecosystem want to ensure that there are adequate amounts of water to sustain a healthy and vibrant Delta ecosystem and sustain the benefits it provides for visitors and local communities. Funds for securing adequate water could be generated through various sources: one of these sources could be entrance fees collected at the main entrances of recreation sites such as the one you are visiting today.

Now, we ask you a series of questions regarding a possible entrance fee. In answering, please assume that the fees will be collected and managed by a non-profit trust responsible for securing water to sustain a healthy ecosystem. Please think carefully about your response and keep in mind that you would need to reduce expenditures on other items in order to contribute.

15. Which of the following options would you prefer (choose one)

c) Pay [X] pesos per car/entry to this site and the Colorado River would be guaranteed to have adequate amounts of water to sustain a healthy and vibrant ecosystem, and the benefits it provides.

d) Do not pay for entry to the Colorado River, and have no assurance of water to help sustain the ecosystem. (sometimes there could be more water, sometimes less, as they release water from the United States).

16. If you had to pay, what is the **maximum** you would pay per car/entry to this site in order to ensure that it has an adequate supply of water to sustain a healthy and vibrant ecosystem? *(please hand the separate payment card sheet to respondent and record their answer below)*
______ $/car (per visit)

a. If you answered zero to the previous question, or left the space blank, please check the **one** reason below that best explains why you answered this way:
_____ Our party cannot afford to pay the entrance fee.
_____ Any amount I pay would be too small to make an impact.
_____ I do not think the deterioration to the Delta's health is urgent.
_____ I can go to other locations to enjoy nature.
_____ Water for the Colorado Delta should be acquired at no cost to me.
_____ Local people will be unfairly burdened by paying for entrance.
_____ I do not trust that the money would be handled correctly.
_____ I need more information/time to answer this question.
_____ Other, please specify ____

Section 4. Demographic information

17. Age: ________________

18. Feminine / masculine

19. Marital status _______________

20. How many people depend on your income _______ children ______ adults (including yourself)

21. Occupation _________________

22. Highest level of education:

a) None
b) Elementary school
c) Middle school
d) High school
e) University
f) Higher education

23. Select the category for the total annual income of your household economy

___ less than $20000 per year
___ between $21000 and $40000 per year
___ between $41000 and $60000 per year
___ between $61000 and $80000 per year
___ between $81000 and $100000 per year
___ between $101000 and $125000 per year
___ between $126000 and $150000 per year
___ between $151000 and $175000 per year
___ between $176000 and $200000 per year
___ More than $200000 per year

Any comments you would like to make: ____________________

Thank you very much for your participation and have a good day.

16. If you had to pay, what is the **maximum** you would pay per car/entry to this site in order to ensure that it has an adequate supply of water to sustain a healthy and vibrant ecosystem?

0	5	10	15	20	25	30
35	40	45	50	60	70	80
90	100	110	120	130	140	150

Other amount if not listed: ________________________

Río Hardy
Actividad Turística en Zonas Recreativas del Delta del Río Colorado

Nombre del encuestador: ____________________
Fecha: ______ Hora de inicio: ______

Buenos días (tardes), nos encontramos realizando una encuesta con el fin de conocer ciertas características de los visitantes del Delta del Río Colorado. La información que usted nos proporcione ayudará a mejorar la conservación del ambiente y los recursos naturales para beneficio de la población y de la vida silvestre. Esta encuesta es voluntaria, anónima y confidencial. Si usted decide cooperar con nosotros se lo agradeceremos mucho.

Sección 1: Datos generales sobre esta visita y visitas pasadas

Comenzaremos la encuesta con preguntas sobre su visita de hoy y después continuaremos con preguntas sobre sus visitas anteriores a este sitio.

1. ¿Cuál es su lugar de residencia (poblado, ejido, colonia o cuidad **Y** estado)? ______________

2. En el viaje de hoy, ¿cuántas personas están en su grupo, incluyéndolo(a) a usted? ____

3. En este viaje, ¿cuántos vehículos fueron utilizados para la transportación de todo el grupo? __

4. En este viaje, ¿cuánto tiempo ha pasado usted o piensa pasar en este sitio recreativo?

______ (# total de horas en este viaje de **un día**)
O
______ (# total de noches por este viaje de **varios días**)

5. ¿Hoy, cuáles han sido los motivos principales de su visita al área? (Señalar máximo dos: marcar con 1 y 2 en orden importancia los dos más relevantes; 1 el más importante)

Actividad	**1**	**2**		**Actividad**	**1**	**2**
f) Convivencia				f) Observación de aves		
g) Día de campo				g) Natación		
h) Pasear en la zona				h) Pesca deportiva		
i) Cacería				i) Por cuestiones de trabajo		
j) Actividades acuáticas (ski, jetski, pasear en lancha)				j) Otra (especificar):		

6. A su juicio, ¿cuál sería la profundidad mínima que debería tener el río, para que usted pudiera realizar la actividad que indicó usted como el motivo más importante de su visita?
__________ metros / pies (*por favor señale uno*)

7. Si supiera usted que la actual profundidad del agua sería menor a la profundidad que nos dijo en la pregunta #6, ¿aún así habría visitado este sitio?
Sí / No (*por favor señale uno*)

8. Por favor, elija los dos motivos principales por los cuales vino usted específicamente a este sitio en vez de ir a otros lugares de la naturaleza:

a) Cerca de su casa
b) Fácil acceso
c) Restaurantes y tiendas cerca
d) Instalaciones adecuadas – baños, ramadas, etc.
e) Cantidad del agua
f) Calidad del agua
g) Abundancia de vegetación para sombrear
h) Abundancia de la vida silvestre
i) Otro (especifique): ______________________________

Ahora le haremos preguntas sobre sus visitas pasadas a este sitio.

9. Durante el año, ¿qué tan seguido viene a este sitio? (si la respuesta es "a", ve a pregunta #10)

a) Es mi primera visita
b) Menos de una vez por año
c) Una vez por año
d) 2 a 5 veces por año
e) 6 a 10 veces por año
f) Más de 10 veces por año

a. Cuando visita este sitio, en promedio ¿cuánto tiempo se queda?

_______ (# promedio de horas por viajes de **un día**)

O

______ (# promedio de noches por viajes de **varios días**)

b. ¿En qué año fue su primera visita a este sitio? __________________

c. ¿Recuerda si ha visto usted partes del río secas por falta de agua?

SÍ (¿en qué año?______) NO

d. Ya le preguntamos sobre el motivo de su visita hoy, pero pensando de sus visitas anteriores, ¿qué actividades le gusta hacer cuando viene a este sitio? *(señale todas las opciones que aplican)*

i) Día de campo
j) Convivir
k) Pescar
l) Nadar
m) Pasear por la zona
n) Ver y escuchar aves
o) Cazar
p) Otro (especificar)

e. ¿Cuando piensa usted que es la mejor época del año para visitar este sitio ya hacer las actividades que mencionó anteriormente?

a) Dic-Feb	b) Mar-May	c) Jun-Ago	d) Sept-Nov	e) Días festivos (Semana Santa, Navidad, etc.)

Si hay otras épocas específicas en que le gusta visitar el sitio, por favor díganos (Ej. durante la temporada de cazar): ____________________

10. ¿Qué características del sitio, si las hay, le impiden venir más seguido?

Motivo	**Marcar**	**Motivo**	**Marcar**
d) Falta de actividades		e) Falta de agua	
e) Distancia		h) Demasiada gente	
f) Prefiere otro sitios		i) Agua de mala calidad	
d) No lo conocía		j) Otro	

11. En el año, ¿qué otros sitios al aire libre visita usted? *(Ej. La Rumorosa, El Bosque de la Ciudad o El Golfo de Santa Clara)*

Sección 2. Uso y conservación del ecosistema

A continuación vamos a hacerle una serie de preguntas, pues nos queremos tomarlo en cuenta a la hora de diseñar un posible plan de conservación de la zona.

12. Dentro de los dos últimos años, ¿ha oído o leído sobre la zona protegida Reserva de la Biosfera del Alto Golfo de California y Delta del Río Colorado?
Sí / No (*por favor señale uno*)

13. Dentro de los dos últimos años, ¿ha oído o leído sobre la atención que en el mundo se ha enfocado en el Delta del Río Colorado por su flora y fauna?
Sí / No (*por favor señale uno*)

14. En una escala del 1 al 5 (donde 1 es lo más importante, y 5 lo menos importante, y 3 neutral), por favor indique qué tan importante piensa que es:

a. Asegurar un suministro de agua para el medio ambiente, de forma que el nivel de agua sea suficiente para mantener la salud ambiental del corredor del río.

Mas importante — Menos importante

1	2	3	4	5

b. Participar en esfuerzos de conservación con el fin de mantener hábitat de especies nativas.

Mas importante — Menos importante

1	2	3	4	5

Sección 3. Preferencias sobre el Delta del Río Colorado

En las últimas décadas, parte de los ríos y humedales del Delta se han secado debido a la falta de agua. Algunos grupos de conservación, comunidades locales y visitantes están preocupados de que la falta de agua está dañando la flora y fauna de la región. Sin flujos suficientes de agua, la salud de este ecosistema está amenazada y tanto los visitantes como las comunidades locales se enfrentan a la diminución de beneficios recreativos y en sus vidas.

Las personas que valoran este ecosistema quieren asegurar que hay cantidades suficientes de agua para mantener el ecosistema del Delta saludable y lleno de vida además de mantener los beneficios que provee a visitantes y comunidades locales. Para lograr esto se pueden obtener fondos para asegurar que haya agua suficiente, los fondos se podrían generar de diversas formas: una de ellas podría ser el pago de una tarifa a la entrada del sitio en cada una de las entradas principales de los sitios recreativos como el que está visitando hoy.

Ahora le vamos a hacer una serie de preguntas con respecto a un posible precio de la entrada. En su contestación, por favor asuma que las entradas serán colectadas y administradas por un fideicomiso sin fines de lucro responsable de asegurarse de que haya agua en los sitios para mantener un ecosistema saludable. Por favor piense con cuidado su respuesta y tome en cuenta que necesitaría reducir sus gastos en otras cosas para poder pagar la entrada.

15. ¿Cuáles de las siguientes opciones preferiría? (elija uno)

a) Pagar (X) pesos por carro/entrada a este sitio y asegurar que el río tendrá garantizada el agua para mantener un ecosistema saludable y lleno de vida, así como otros beneficios que provee.

b) No pagar la entrada a este sitio y no tener la garantía de habrá agua en el río para mantener el ecosistema (a veces podría haber más agua, a veces menos, conforme se suministre el agua de los Estados Unidos).

16. Si tuviera que pagar, ¿cuánto es lo máximo que pagaría por carro/entrada a este sitio con el fin de asegurar que haya un suministro suficiente de agua para mantener un ecosistema saludable y lleno de vida? (darle al encuestado la hoja con las cantidades y escribir aquí abajo su respuesta)
________ $/carro (por visita)

a. Si contestó cero a la pregunta anterior o dejó un espacio en blanco, por favor seleccione de abajo el motivo que mejor explica su respuesta:
____ Nuestro grupo no puede pagar la entrada.
____ Cualquier cantidad que pague sería muy pequeña para tener un impacto.
____ No creo que el deterioro de la salud del Delta sea importante.
____ Puedo visitar otros lugares para disfrutar de la naturaleza.
____ No debería de pagar yo el costo del agua para el Delta del Río Colorado.
____ Es una carga injusta que la gente local tendría que pagar la entrada.
____ No confío en que el dinero será manejado correctamente.
____ Necesito más información/tiempo para contestar esta pregunta.
____ Otro, por favor especifique ____

Sección 4. Datos Demográficos

17. Edad: ________________

18. Femenino / masculino

19. Estado civil _______________

20. ¿Cuántas personas dependen de su ingreso? _______ niños ______ adultos (contándolo a usted)

21. Ocupación _________________

22. Último grado de escolaridad completado:

g) Ninguno
h) Primaria
i) Secundaria
j) Preparatoria
k) Universidad
l) Maestría

23. Seleccione la categoría de total de ingresos anuales en su hogar

___ menos de $20,000 por año
___ entre $21,000 y $40,000 por año
___ entre $41,000 y $60,000 por año
___ entre $61,000 y $80,000 por año
___ entre $81,000 y $100,000 por año
___ entre $101,000 y $125,000 por año
___ entre $126,000 y $150,000 por año
___ entre $151,000 y $175,000 por año
___ entre $176,000 and $200,000 por año
___ más de $200,000 por año

Algún comentario que quiera hacer:

Muchas gracias para su participación y que tenga un buen día.

16. Si tuviera que pagar, ¿cuánto es lo máximo que pagaría por carro/entrada a este sitio con el fin de asegurar que haya un suministro suficiente de agua para mantener un ecosistema saludable y lleno de vida?

0	10	15	20	25	30	35
40	45	50	60	70	80	90
100	125	150	175	200	250	275
300	325	350	375	400	450	500

Otra cantidad si no se incluye: ________________________

APPENDIX B: ENUMERATOR TRAINING AGENDA

AGENDA
Delta Recreation Survey Training
March 29, 2012

Locations Surveyed:

- Cienega de Santa Clara (CSC)
- Campo Mosqueda (CM)
- Campo Baja Cucapah (CBC)
- Presa Morelos (PM)
- San Felipito (SF)

Dates Administered:

The survey will be administered over the Holy Week weekend (April 6-9).

Supplies:

- Surveys (5 different versions for each site)
  - CSC-100 surveys
  - CM- 200 surveys
  - CBC- 200 surveys
  - PM- 150 surveys
  - SF- 100 surveys
- Pens
- Map of the Delta for EACH enumerator (needs to show the area defined as the Delta, as well as the locations of all sites, and the Colorado and Hardy Rivers)
- Tally sheet for EACH enumerator for EACH day to mark the number of surveys completed and the number of non-participants.

Important Information about the Surveys:

- Clothing sin logos/lemas.
- Each survey will have a unique ID number in the top right hand corner. This ID number should be present on ALL pages of the survey. The ID number designates where the survey should be administered. CSC must be administered at the Cienega, CM at Campo Mosqueda, etc. It is very important that the survey is administered at the correct place because there are different versions of the survey.
- Please encourage respondents to answer ALL questions and carefully record every answer. This is extremely important because if the question is not answered/recorded, the entire survey could potentially be thrown out of the study. Even information that doesn't seem important, like the date, please record it. It may be a variable in the analysis.

- These questions have been carefully worded to avoid biasing the results, so please stick to the wording as closely as possible.

Visitor Contact:

At the beginning of each day, and at each site, begin a tally sheet. It needs to have your name, the date, the time you begin they surveys, the time you end, and the beginning and end numbers of the surveys conducted.

- Approach all visitors over the age of 18. Multiple individuals from one party can respond to the survey.
- Introduce the survey using the prompt given and ask if they would be willing to participate.
  If no, thank them and discreetly note their response on the tally sheet.
  If yes, note the visitor's willingness to participate on the tally sheet.
- Make sure that the survey ID number matches the location of the survey.
- Administer the survey, carefully recording the answers and encouraging the respondent to answer all questions. Possible wording, "We would be very grateful if you would complete the entire survey. We understand that you may be in the middle of your trip, but the answers can help us understand how these areas can better serve recreationists.
- Thank the visitors for agreeing to participate and wish them an enjoyable trip.

Survey Questions:

1. For open ended questions, such as this one, we want to have every enumerator recording the answer in a consistent way. Ejidos should be designated as Ej. ___________, colonias should be designated Col. ___________, etc.
2. Make sure that the respondent is including themselves.
3. This question is designed specifically for large parties.
4. Please only fill out one of these sections. It is either a day trip or a multiple-day trip. It's important to note that the multiple-day trip refers to the number of *nights*, not the number of days. We want to capture the over-night visitors.
5. Please put a check mark or an "X" under the 1 column for the most important/main reason they came. Put a check mark or an "X" under the 2 column for the second reason. Please ONLY mark the top two, and be sure to rank them.
6. Don't forget to circle which measure of unit the respondent answered in. This is a free answer for the respondent, so they can literally answer anything. If they don't think there is a minimum depth for the activities that they came to do, they are welcome to answer "0".
7. Please circle the response. Remember that someone else will be inputting the data into the computer, so please make it clear how the respondent answered.
8. Select only two reasons- do not need to rank.
9. If the person answers "a" to this question, you can skip to question #10. If not, please ask #9a-#9e.
   a. We are asking for averages here. If they do not remember, remind them that we are talking about all past visits and we want to know how long they stay on average.
   b. Please record in YYYY format. If they say, 10 years ago, clarify that they meant around 2002 and record that value.

c. “Dry” at the Cienega means any shallow area that has dried out. It could be along the shore or it could be in areas that act as intermittent lagoons. “Dry” in the in the rivers means cracked earth (no water at all), or no flowing water (it can be muddy or have portions with standing water). If they have seen the site “dry”, please record the year that they recall seeing it.
d. Please mark all answers that apply. They are allowed to enjoy all activities if they want. Please specify if they have another activity that they enjoy doing.

10. Respondents can have multiple answers to this question. Poor water quality could be in terms of odor, clarity, cleanliness. If they have another reason, please specify.
11. We are trying to ask what other recreation sites that are “competing” with these sites. Ask the question first, and if they are having trouble coming up with an area then you can give the examples listed.
12. The next two questions are designed carefully to understand if people are aware of the Delta’s importance. Follow the wording as shown on the survey.
13. Follow the wording on the survey.
14. Please make sure to explain that 1 is the most important, 5 is the least important and 3 is neutral. It’s imperative that no one get confused about the scale.
15. Section 3 is the most important part of the survey. Please make sure to read the paragraphs in their entirety and follow the wording as closely as possible. The respondent has two choices: 1) they are willing to pay the amount for entry or 2) they prefer to not pay for entry.
16. For this question, the enumerator will read the question aloud and then hand the last sheet of the survey to the respondent to respond to the question. The last sheet is a payment card where the respondent can choose from a list of values for the maximum that they’d be willing to pay. Although the enumerator will read the question aloud to the respondents, please have the respondents mark the sheet themselves. Once the respondent has marked the sheet themselves, please record their response on the blank in #16.

    If the respondent answered “0” for #16, they need to answer part 16a. Read from the selection of responses and have the respondent select the ONE reason that explains why they chose that value.
17. Complete the rest of the survey as indicated.
18. Record any comments or suggestions the respondent has.

APPENDIX C: SURVEY CHECKLIST (ENGLISH AND SPANISH VERSIONS)

DELTA RECREATION SURVEY CHECKLIST

- Did you remember to dress in a neutral manner and avoid wearing shirts with slogans?
- Have you started the Tally Sheet?
- Have you verified that the surveys you are about to administer are the correct survey for the location?
  - Cienega de Santa Clara (CSC)
  - Campo Mosqueda (CM)
  - Campo Baja Cucapah (CBC)
  - Presa Morelos (PM)
  - San Felipito (SF)
- Are you contacting all visitors over the age of 18?
- Are you using the entry paragraph written for you and asking if they would be willing to participate?
  - If they answer no, are you thanking them and discreetly noting their response on the tally sheet?
  - If they answer yes, are you noting the visitor's willingness to participate on the tally sheet?
- Administering surveys.
  - Did you follow the wording of the survey as closely as possible?
  - Did you read #16 to respondents and have them mark the payment card sheet (last page) themselves? Did you record the answer in the blank provided in #16?
  - Did you carefully record ALL answers, making sure they are clearly marked?
- Did you record ALL comments or suggestions made by the respondent?
- Did you thank the visitors for agreeing to participate and wish them an enjoyable trip?
- At the end of the day, did you complete the tally sheet?
- Did you take note any problems or frequently asked questions? If so, please e-mail Ashley at akerna@email.arizona.edu or tell Edith.

Thank you for being a part of this project! We appreciate your hard work!

Lista para la Encuesta de la Recreación de Delta

- ¿Te acordaste de vestir en una manera neutral y sin llevar una camisa con logos/lemas?
- Cuando llegaste al sitio de la entrevista, ¿empezaste a contestar/llenar la hoja de recuento?
- ¿Verificaste que las encuestas son las correctas para el sitio?
    - Cienega de Santa Clara (CSC)
    - Campo Mosqueda (CM)
    - Campo Baja Cucápa (CBC)
    - Presa Morelos (PM)
    - San Felipito (SF)
- ¿Haz estado contactando a todos los visitantes mayores de edad (mayor de18 años)?
- ¿Estás usando el párrafo de introducción y preguntando si quieren participar?
    - <u>Si la repuesta fue no que no quieren participar</u>, ¿le agradeciste por su tiempo y discretamente apuntaste su respuesta y la razón (si dio razón para no participar) en la hoja de recuento?
    - <u>Si la respuesta fue sí</u>, ¿marcaste/llenaste la hoja de recuento con esta respuesta?
- La administración de las encuestas.
    - ¿Seguiste el texto/vocabulario de la encuesta lo más cerca posible?
    - ¿Les leíste la pregunta #16 a los encuestados y los hiciste marcar la hoja con la tarjeta de pago (en la última página)? ¿Escribiste la respuesta en el espacio en la pregunta #16?
    - ¿Marcaste con cuidado TODAS respuestas y verificaste que están marcadas clara y correctamente?
- ¿Escribiste todos los comentarios o sugerencias de los encuestados?
- ¿Les agradeciste por su participación y les deseaste un viaje agradable?
- Al final del día, ¿completaste la hoja de recuento?
- ¿Tomaste notas de los problemas o las preguntas más frecuentes? Si notaste algunos/as, *por favor* mándame un e-mail a akerna@email.arizona.edu o di Edith.

¡Gracias por su apoyo! ¡Nosotros apreciamos su trabajo duro!

APPENDIX D: ENUMERATOR TALLY SHEET

Recreación del Delta Hoja de Recuento

Locación: ________________________

Nombre del Encuestador: ____________________________ **Fecha: _____________________**

Hora de Empezar: ____________ **Numero de la Primera Encuesta: _________________**

Hora de Terminar: ____________ **Numero de la Última Encuesta: __________________**

Participantes	**Los que no participaran**
(Ejemplo: ~~||||~~)	Negó (nota motivo cuando es posible)

APPENDIX E: DESCRIPTION OF CATEGORICAL VARIABLES

Annual Income	
1	< $40,000
2	$41,000-$80,000
3	$81,000-$125,000
4	$126,000-$175,000
5	$176,000-$200,000
6	> $200,000

Number of Visits	
1	It's my first visit.
2	Less than once per year.
3	One time per year.
4	2-5 times per year.
5	6-10 times per year.
6	More than 10 times per year.

Level of Education	
1	None
2	Elementary School
3	Junior High School
4	High School
5	University
6	Masters

APPENDIX F: NUMBER OF TRANSACTIONS AND VOLUME TRANSFERRED BY CLIMATE DIVISION

Number of Transactions by Climate Division

State	Climate Division (CD)	No. of Transactions	Total No. of Transactions	% in CD of total	Where??	No. of Sales	No. of Leases
AZ	1	3		1.4%		3	0
AZ	2	3		1.4%		2	1
AZ	3	13		5.9%		7	6
AZ	5	5		2.3%		4	1
AZ	6	135		**61.4%**	Phoenix	74	61
AZ	7	61	220	**27.7%**	Tucson	51	10
CA	1	10		1.0%		0	10
CA	2	59		6.0%		11	48
CA	4	92		9.3%		17	75
CA	5	362		**36.8%**	Grasslands WD, Stanilaur River, Stockton, Kern, San Joaquin, Tulare Lake, Westlands, Tipton, Lower Tule River, Eagel Field, Bakersfiel, Panoche	25	337
CA	6	205		**20.8%**	Central LA Basin, West Coast Basin, Bellflower, Somerset Mututal, Downey, Chino	22	183
CA	7	257	985	**26.1%**	Imperial Valley, Mojave	55	202
CO	1	85		5.0%		41	44
CO	2	64		3.8%		34	30
CO	4	1538		**91.1%**	Denver, Boulder, Ft. Collins,-Loveland, Erie, Windsor, Greeley, Moregan, Evans, Arora, Berthoud	1451	87
CO	5	1	1688	0.1%		1	0
ID	4	9		6.9%		0	9
ID	5	67		**51.5%**	Boise, Farmers Coop, Payette, #63	8	59
ID	7	50		**38.5%**	Twin Falls, Jerome, Milner Dam, #1	12	38
ID	9	3		2.3%		3	0
ID	10	1	130	0.8%		1	0

NV	1	306		**91.9%**	Washoe County- Reno, Sparks, Warm Springs Valley, Carson City	302	4
NV	2	2		0.6%		2	0
NV	3	3		0.9%		2	1
NV	4	22	333	6.6%		21	1
NM	1	5		2.7%		5	0
NM	2	8		4.3%		4	4
NM	4	23		12.4%	San Francisco Basin, Southwest	23	0
NM	5	125		**67.6%**	Albuquerque, Heron Reservoir	39	86
NM	6	1		0.5%		1	0
NM	7	22		11.9%		18	4
NM	8	1	185	0.5%		1	0
OR	1	10		6.0%		2	8
OR	2	6		3.6%		1	5
OR	3	42		**25.1%**	Rogue River, Evans Creek, Sucker Creek	8	34
OR	5	1		0.6%		0	1
OR	6	28		16.8%	Umatilla, Hermiston, Willow Creek, John Day, Hood River	7	21
OR	7	78		**46.7%**	North Unit ID, Klamath Lake, Wickup, Deschutes	3	75
OR	8	1		0.6%		0	1
OR	9	1	167	0.6%		1	0
WA	2	1		2.3%		0	1
WA	3	6		14.0%	Alderwood WD, Olympia, Lacey	5	1
WA	4	3		7.0%		2	1
WA	6	11		**25.6%**	Teanaway, Methow	1	10
WA	7	1		2.3%		0	1
WA	8	21	43	**48.8%**	E. Columbia Water Bank, Roza ID, Walla Walla	7	14

Volume Transferred by Climate Division

State	Climate Division (CD)	Volume by CD	Total Volume	% in CD of total	Where??	Volume of Sales	Volume of Leases
AZ	1	15,000.00		0.2%		15,000.00	0.00
AZ	2	11,064.00		0.1%		10,972.00	92.00
AZ	3	18,031.75		0.2%		16,240.75	1,791.00
AZ	5	1,260,228.50		15.6%		60,228.50	1,200,000.00
AZ	6	6,485,137.76		**80.2%**	Phoenix	183,189.58	6,301,948.18
AZ	7	297,264.40	8,086,726.41	**3.7%**	Tucson	27,803.40	269,461.00
CA	1	136,838.38		1.0%		0.00	136,838.38
CA	2	1,787,588.88		13.5%		402,454.88	1,385,134.00
CA	4	813,713.00		6.2%		74,275.00	739,438.00
CA	5	6,130,960.08		**46.4%**	Grasslands WD, Stanilaur River, Stockton, Kern, San Joaquin, Tulare Lake, Westlands, Tipton, Lower Tule River, Eagel Field, Bakersfiel, Panoche	293,790.00	5,837,170.08
CA	6	3,514,546.05		**26.6%**	Central LA Basin, West Coast Basin, Bellflower, Somerset Mututal, Downey, Chino	82,094.62	3,432,451.43
CA	7	839,311.00	13,222,957.39	**6.3%**	Imperial Valley, Mojave	116,188.00	723,123.00
CO	1	369,919.37		36.8%		9,732.36	360,187.01
CO	2	31,926.13		3.2%		7,665.46	24,260.67
CO	4	603,306.09		**60.0%**	Denver, Boulder, Ft. Collins,-Loveland, Erie, Windsor, Greeley, Moregan, Evans, Arora, Berthoud	356,022.00	247,284.09
CO	5	2.10	1,005,153.68	0.0%		2.10	0.00
ID	4	456,812.93		13.6%		0.00	456,812.93
ID	5	1,906,618.10		**56.6%**	Boise, Farmers Coop, Payette, #63	173,911.00	1,732,707.10
ID	7	988,887.58		**29.3%**	Twin Falls, Jerome, Milner Dam, #1	3,995.08	984,892.50
ID	9	14,018.00		0.4%		14,018.00	0.00
ID	10	3,100.00	3,369,436.61	0.1%		3,100.00	0.00
NV	1	182,182.45		**70.0%**	Reno, Sparks, Warm Springs Valley, Carson City	120,331.45	61,851.00

NV	2	162.00		0.1%		162.00	0.00
NV	3	44,229.00		17.0%		9,229.00	35,000.00
NV	4	33,707.56	260,281.01	13.0%		33,259.56	448.00
NM	1	661.65		0.1%		661.65	0.00
NM	2	80,691.60		11.7%		1,281.60	79,410.00
NM	4	6,678.29		1.0%	San Francisco Basin, Southwest	6,678.29	0.00
NM	5	542,744.60		**78.9%**	Albuquerque, Heron Reservoir	17,233.77	525,510.83
NM	6	92.00		0.0%		92.00	0.00
NM	7	56,580.41		8.2%		15,070.96	41,509.45
NM	8	680.40	688,128.94	0.1%		680.40	0.00
OR	1	8,201.74		0.8%		591.00	7,610.74
OR	2	428,680.00		42.1%		600.00	428,080.00
OR	3	64,379.29		**6.3%**	Rogue River, Evans Creek, Sucker Creek	12,884.99	51,494.30
OR	5	15,805.00		1.6%		0.00	15,805.00
OR	6	66,124.48		6.5%	Umatilla, Hermiston, Willow Creek, John Day, Hood River	2,461.42	63,663.06
OR	7	408,722.27		**40.1%**	North Unit ID, Klamath Lake, Wickup, Deschutes	759.19	407,963.08
OR	8	9,798.00		1.0%		0.00	9,798.00
OR	9	17,700.00	1,019,410.78	1.7%		17,700.00	0.00
WA	2	941.28		0.9%		0.00	941.28
WA	3	11,417.33		11.1%	Alderwood WD, Olympia, Lacey	9,417.33	2,000.00
WA	4	1,296.98		1.3%		1,295.45	1.53
WA	6	28,465.59		**27.7%**	Teanaway, Methow	5,310.00	23,155.59
WA	7	920.00		0.9%		0.00	920.00
WA	8	59,547.22	102,588.40	**58.0%**	E. Columbia Water Bank, Roza ID, Walla Walla	7,436.22	52,111.00

APPENDIX G: ENDOGENEITY RESULTS

Regression Procedure of Hausman Test for Endogeneity

1. **1st Stage Regressions**
   Lease: regress **weighted_lease_price** SP12 SP12_Lag1 state_population
   Sale: regress **weighted_sale_price** SP12 annual_income state_population

   Lease: regress **percent_count/volume_env** SP12 SP12_Lag1 state_population
   Sale: regress **percent_count/volume_env** SP12 annual_income state_population

2. **Predict Residuals**

3. **2nd Stage Regressions**
   Include the suspected endogneous variable, residuals, and exogenous variables in structural equation.

4. **Test Significance of Residuals Weighted Lease Price**

	Transaction Model *P>|z|*	**Total Volume Model** *P>|t|*	**Total Dollar Value Model** *P>|t|*
Lease	0.290	0.760	0.936
Sale	0.230	0.435	0.232

5. **Test Significance of Residuals Percent Environmental**

	Transaction Model *P>|z|*	**Total Volume Model** *P>|t|*	**Total Dollar Value Model** *P>|t|*
Lease	0.451	0.997	0.968
Sale	0.047	0.847	0.000

Appendix H: Number of Transactions by Year and State (In analysis)

Number of Sale Transactions

y	AZ	CA	CO	NV	NM
1987	8	2	27	16	13
1988	6	0	29	10	7
1989	0	0	36	17	5
1990	2	7	59	8	4
1991	1	1	68	2	5
1992	1	2	62	1	10
1993	2	14	67	6	6
1994	7	0	54	1	9
1995	11	2	76	4	0
1996	5	1	79	1	5
1997	2	2	95	3	2
1998	2	1	80	5	0
1999	5	10	106	22	2
2000	9	5	99	19	1
2001	8	11	73	20	2
2002	4	6	53	20	2
2003	8	10	71	23	1
2004	11	5	84	22	2
2005	8	8	65	23	2
2006	6	12	62	36	4
2007	13	7	48	29	3
2008	11	7	49	22	1
2009	7	10	42	13	1
2010	4	7	43	4	4

Number of Lease Transactions

y	CA	CO	ID	NM	OR	WA
1987	n/a	n/a	n/a	n/a	n/a	n/a
1988	n/a	n/a	n/a	n/a	n/a	n/a
1989	18	4	1	3	0	1
1990	16	2	2	0	0	0
1991	35	2	0	4	0	1
1992	39	1	2	3	0	2
1993	13	3	1	2	0	1
1994	27	5	0	5	2	0
1995	29	8	2	1	2	0
1996	32	1	2	0	2	3
1997	23	2	2	1	6	0
1998	21	4	0	1	2	1
1999	43	8	2	8	2	0
2000	22	7	3	3	3	3
2001	57	10	0	7	7	4
2002	75	8	3	4	6	1
2003	62	13	3	4	5	2
2004	46	3	5	0	3	2
2005	53	10	10	15	10	2
2006	25	10	6	12	62	1
2007	36	19	39	1	9	0
2008	46	21	8	3	6	3
2009	32	11	3	11	9	0
2010	89	5	11	1	9	1

APPENDIX I: LEASE LENGTH DESCRIPTIVE STATISTICS

Frequency of Length of Lease by Individual Transaction

Length of Lease	CA	CO	ID	NM	OR	WA
Less than 1 yr	0	5	2	0	1	2
1	809	88	94	82	111	15
1.3	1	0	0	0	0	0
2	6	2	0	3	1	0
3	2	0	4	2	2	2
4	0	0	0	0	1	0
5	5	3	0	1	13	0
8	2	0	0	0	0	0
9	0	0	0	0	0	0
10	9	2	0	1	4	8
15	4	1	0	0	0	0
17	0	1	0	0	0	0
19	0	0	0	3	0	0
20	0	0	0	1	0	0
23	1	0	0	0	0	0
25	9	23	0	1	1	0
29	0	0	0	0	1	0
30	5	2	1	0	0	0
35	1	1	0	0	0	0
40	1	31	0	0	7	0
Total	855	159	101	94	142	27

Variability of Average Lease Length Variable

y	CA	CO	ID	NM	OR	WA
1989	1.00	1.00	1.00	1.00	0.00	1.00
1990	1.88	1.00	1.00	0.00	0.00	0.00
1991	1.00	1.00	0.00	14.50	0.00	1.00
1992	1.03	1.00	1.00	1.00	0.00	1.00
1993	1.08	0.28	0.33	1.00	0.00	1.00
1994	1.00	0.68	0.00	1.00	13.00	0.00
1995	1.00	19.00	0.63	1.00	3.00	0.00
1996	1.75	1.00	1.00	0.00	1.00	1.00
1997	3.22	8.00	1.00	1.00	1.67	0.00
1998	4.43	1.00	0.00	3.00	1.00	1.00
1999	4.19	1.00	1.00	1.00	1.00	0.00
2000	1.02	18.14	1.00	7.33	0.70	1.67
2001	1.75	13.40	0.00	1.29	2.50	2.96
2002	1.32	28.88	1.00	1.00	4.00	10.00
2003	2.16	29.38	1.00	3.25	8.80	6.50
2004	1.09	1.33	2.60	0.00	15.00	5.50
2005	1.34	12.70	1.00	1.40	5.80	1.00
2006	2.36	8.80	5.83	1.00	1.27	0.00
2007	1.25	10.47	1.00	25.00	6.22	0.00
2008	2.63	15.14	1.00	1.33	3.33	10.00
2009	1.22	12.45	1.00	1.00	6.22	0.00
2010	1.57	13.80	1.00	1.00	13.22	10.00

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