San Francisco Public Utilities Commission:

Economic Impact Analysis:
Water Supply Reduction

November 23, 2005

Public Financial Management

Two Logan Square
Suite 1600
Philadelphia, PA 19103
215 567-6100 phone
215 567-4180 fax

50 California Street
Suite 2300
San Francisco, CA 94111
415 982-5544 phone
415 982-4513 fax

In conjunction with:

TXP

1310 South 1st Street
Suite 105
Austin, TX 78704
512 328-8300 phone
512 462-1240 fax

Stratus Consulting

1881 Ninth Street
Suite 201
Boulder, CO 80302
303 381-8000 phone
303 381-8200 fax

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Background and Methodology

In October 2005, the San Francisco Public Utilities Commission (SFPUC) requested that Public Financial Management (PFM) analyze the potential economic impact of water rationing on San Francisco and the suburban users' service area. As a result of the history of periodic droughts in Northern California and the Sierra Nevada, these impacts have been previously studied. This analysis, developed in conjunction with economists from TXP and Stratus Consulting, draws on that earlier work – with updates and certain methodological adjustments applied to incorporate more recent economic data.

This study relies on the relationships between water usage and economic output (elasticities) established in prior studies from surveys of representative water users, and applies these relationships to the latest available data regarding the size of the commercial and manufacturing base for San Francisco and the suburban service area. As a result, the analysis generates estimates of how across-the-board reductions of water availability would impact economic output, measured in dollars of lost output annually.

Key Findings

We have estimated the direct impact of 10%, 15%, 20%, 25% and 30% reductions in water availability on the manufacturing and commercial sectors as follows, using 2002 dollars (the most recent year for which sufficiently detailed economic data is available):

Reduction in Direct Economic Activity Associated With Different Levels of Reduced Water Supply on Selected Sectors of the SFPUC Service Territory Economy ($Millions)

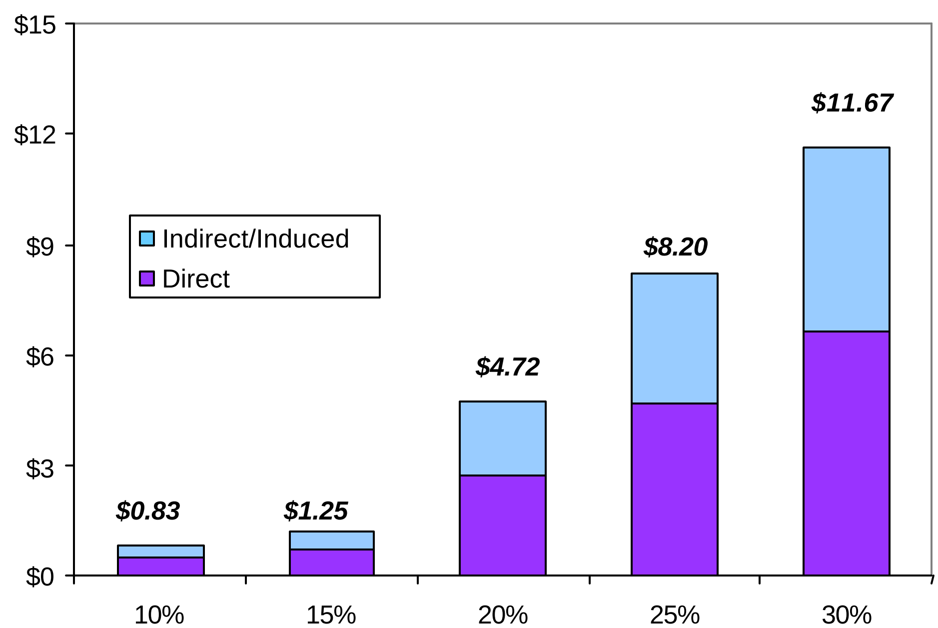
Manufacturing Sectors	**10%**	**15%**	**20%**	**25%**	**30%**
Food/Kindred Products	$119.1	$178.6	$442.6	$706.6	$970.7
Stone/Clay/Glass	$28.3	$42.5	$54.7	$67.0	$79.2
Industrial Machinery	$2.5	$3.8	$5.1	$6.4	$7.6
Electronic Components	$101.2	$151.8	$511.5	$871.1	$1,230.8
Communications Equip	$108.3	$162.4	$299.2	$436.0	$572.8
Aerospace/Trans Equip	$0.0	$0.0	$69.7	$139.4	$209.2
Measuring/Controlling	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial Sectors					
Grocery Stores	$0.0	$0.0	$125.9	$251.9	$377.8
Eating & Drinking Places	$0.0	$0.0	$380.2	$760.5	$1,140.7
Real Estate	$32.7	$49.1	$171.7	$294.4	$417.1
Hotels	$34.0	$51.0	$223.4	$395.8	$568.2
Laundries	$21.5	$32.3	$62.5	$92.7	$122.9
Hospitals	$35.5	$53.3	$361.0	$668.8	$976.5
TOTAL	$483.2	$724.8	$2,707.7	$4,690.6	$6,673.4

Depending on the level of water reduction, the potential direct impact in 2002 could have ranged from nearly $500 million to almost $6.7 billion. The payment made by an out-of-town visitor to a hotel operator is an example of such a direct economic effect.

In addition, these direct effects would move through the regional economy, causing additional economic loss. These "ripple" effects are technically referred to as the indirect and induced impacts, and are captured through the use of a regional input-output model. For example, satisfying the demand for an overnight stay will require the hotel operator to purchase additional cleaning supplies and services. These downstream purchases affect the economic status of other local merchants and workers. Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects. Both the hotel operator and the cleaning supplies outlet experience increased income from the visitor's stay. Induced effects capture the way in which this increased income is, in turn, spent in the local economy.

The following chart shows the direct and total (direct, indirect, and induced) impacts estimated for each reduced water supply scenario.

Direct and Total Economic Impacts Due to Reduced Water Supply on Selected Sectors of the SFPUC Service Territory Economy ($Billions)



As one would expect, these results are highly non-linear: Decreases in water availability yield proportionately larger decreases in economic output. As water availability decreases, more and more businesses reach a tipping point that requires them to reduce their business activities.

Caveats

1. Hardening of Demand

The relationships between water availability and economic output were established during the last major drought, prior to the utilization of many technical innovations and behavioral changes that reduced economic reliance on water. This means that additional reductions in water usage may be more difficult to achieve, and that the results of this study may be understated. A more accurate and up-to-date analysis would require new user surveys to establish more clearly the current relationships between water availability and economic output.

2. Absence of Policy Response
This study assumes no effort to manage water usage through the setting of policies, other than a simple across-the-board reduction. In the real world, policies would be adopted that would seek to strategically managed water usage. These policies would lessen the impact of reduced water availability.

3. Drought Duration
This study estimates the impact of reduced availability at specified levels for a one-year period. Further analysis would be necessary to determine the impact of a longer period of reduced water availability. At the same time, it is important to note that the levels of supply reduction analyzed would not likely be reached until an extended period of drought had already occurred.

4. Seasonality
The seasonal demand pattern for water is not taken account of in this study. This pattern in fact may present opportunities for future policies that could mitigate the impacts indicated here.

5. "Other" Economic Impacts
This study addresses the commercial and manufacturing sectors of the economy, which are believed to be the most water-intensive. It does not address a variety of other sectors thought not to be as water-dependent. Likewise, while residential impacts have a value further addressed in Appendix 5, no economic impact is calculated for residential rationing. Future studies would need to address the relationships between water availability and outputs in these sectors in order to quantify them.

Conclusions

The economic impact of reduced water supply could be significant, with the potential for multibillion dollar economic loss. At the same time, the total potential economic impact (again, estimated to range from slightly less than $1 billion to just under $11.7 billion, depending on the scenario) represents a relatively modest share of the region's overall economy. To put these figures in context, total economic activity in the SFPUC service territory for 2002 is estimated at $272.8 billion (and $451.7 billion for all of Alameda, San Mateo, Santa Clara and San Francisco counties).

Further, however successful this study may be in predicting the impact of rationing on economic output, the implication of such impact on the infrastructure investment decisions by the SFPUC will be inherently less clear. The SFPUC, like all policy-making bodies, must make its investment decisions in a context of competing and changing priorities, and limited overall investment capacity.

One cannot simply compare the cost of a desired investment to the projected economic cost of not making that investment in the event of adverse conditions. Further, the fact that a negative consequence may occur when a particular decision is made *not* to invest does not automatically mean that the earlier decision was wrong. Rather, each potential investment must be viewed in the larger context of all of the public objectives and potential investment decisions faced by the policymakers.

In the case of a large organization with multiple objectives such as the SFPUC, such choices will hopefully be better informed by this study, but the study itself should not mechanistically drive a particular policy choice.

Acknowledgements

The authors wish to thank the many officials at the SFPUC and BAWSCA who have assisted in compiling data and information for this analysis, as well as the authors of prior studies whose work forms the basis for this study. We wish to especially thank Millicent Bogert for her continuous support and availability throughout the course of the work.

Introduction

Local government decisions about the allocation of scarce resources can have wide-ranging economic impacts. For example, the symbiotic relationship between convention facilities, typically built and operated by local government, and the hospitality industry is very clear. Perceptions regarding public safety can serve to influence business location decisions. Infrastructure investments and quality also strongly impact economic activity. In many cases, however, such impacts are not carefully considered or understood.

Scarcity of water is a reality throughout much of the western United States. Therefore, the relationship between the availability of water and business output has been more carefully analyzed than many other areas of public sector resource allocation. A number of studies over the last twenty-five years have attempted to describe and analyze with considerable detail the relationship between the amount of water available and various economic outputs.

Some of these studies have focused on the Bay Area. Although the Bay Area often experiences long periods without water shortages, droughts inevitably occur. Past droughts have created a real-world opportunity to better understand the impact of water shortages on economic output, and have resulted in policy experimentation. The last major drought, in the late 1980's and early 1990's, yielded a number of economic impact studies, and provided a range of policy efforts to manage shortages. These studies provide very valuable data and analysis regarding the relationship between water availability and economic output. However, we know that this relationship is always subject to change.

First, the economic base itself changes. Some sectors increase while others shrink. The sensitivity of some sectors to water availability may itself change due to changes in technology. Changes in the cost of other economic inputs, such as labor, influence the shifts in the relative importance of various sectors. For instance, it is generally understood that, over the last fifteen years, much labor-intensive manufacturing has moved off-shore. These changes may, in turn, affect the demand for water.

Second, the relationships between water availability and output may change fundamentally as a result of behavioral and policy changes that occurred during previous shortages. Previous economic studies have noted, but have not precisely measured, this phenomenon known as the "hardening of demand." In lay terms, this simply means that the easy solutions may have already been exhausted. An obvious example is that most of the region's older toilets have been replaced with low-usage models. The result of this hardening of demand is that additional reductions in water usage are incrementally more difficult and expensive to achieve unless and until new water conservation technologies emerge.

This Study

The San Francisco Public Utilities Commission (SFPUC) is currently studying the engineering and cost implications of large-scale improvements to the Bay Area water system. Given the region's history of periodic drought, policymakers felt that it also made sense to update the earlier analyses of the impact of water availability on economic output. This study builds on prior studies by updating the profile of the service area's economic base, updating the output elasticity of water by industry, calculating the impact of reduced water supply by industry, calculating the total economic impact of reduced water supply, and reviewing existing and potential approaches to mitigate negative economic impacts.

This work relies largely on secondary sources, and does not provide detailed analyses of sub-regions. Additional analysis may be helpful that is based on updated primary research, that details impacts by industry and region further, and that focuses on measuring the potential impacts of particular policy approaches.

A very wide range of policy responses is possible. It is no surprise that output elasticity will vary by industry. Therefore, policy responses will have to attempt to balance fairness and equity with the variable impacts of rationing decisions. The better the predictability of industry responses, the better that policymakers will be able to articulate a balanced and workable policy.

Investment Decisions and Policy Impacts

However successful this study may be in predicting the impact of rationing on economic output, the implication of that impact on the investment decisions by the SFPUC in infrastructure will be inherently less clear. The SFPUC, like all policy-making bodies, must make its investment decisions in a context of competing and changing priorities, and limited overall investment capacity.

One cannot simply compare the cost of a desired investment to the projected economic cost of not making that investment in the event of adverse conditions. Further, the fact that a negative consequence may occur when a particular decision is made *not* to invest does not automatically mean that the earlier decision was wrong. Rather, each potential investment must be viewed in the larger context of all of the public objectives and potential investment decisions faced by the policymakers. In the case of a large organization with multiple objectives such as the SFPUC, such choices will hopefully be better informed by this study, but the study itself should not mechanistically drive a particular policy choice.

General Background

The Drought of 1987-1992

In 1987, a drought began in the Bay Area that would eventually have a profound impact on the region's water rationing management, conservation, and the development of alternative sources of water supply. In fact, the impact of the drought is largely responsible for much of the research focused on the economic impact of drought scenarios on the Bay Area.

Over the course of the six year drought, SFPUC, faced with severe shortfalls in water supply and depleted reserves, implemented a series of rationing measures to limit consumer demand. During this period mandatory rationing protocols were enacted that yielded reductions in water use ranging from 25% to 45% (Retail Water Shortage Allocation Plan: 2001).

The process started in 1988, when a second straight year of poor run-off from the Tuolumne River and dwindling reservoir levels would require reduction of pre-drought consumption levels. This led the SFPUC to adopt a number of new policies for retail customers. First, the SFPUC instituted mandatory rationing on all indoor and outdoor water uses. To enforce this policy, the SFPUC also developed a set of calculations for determining excess water use and the associated fines. The range of fines varied from 2 times the water rate, for over use just above the defined allotment, to a charge of 10 times the regular water rate for use well above defined limits. (Retail Water Shortage Allocation Plan: 2001).

In response to the reduction in the water supply, many retail customers implemented plumbing devices engineered to reduce water consumption, such as low-flow toilets, low-flow shower heads and faucet aerators. Other than limiting water through conservation, the only other recourse for customers was to contact the SFPUC's rationing unit to request a water allotment modification. To receive a modification of water allotment, a customer had to demonstrate an increase in household occupancy, increased levels of business, achieved water reductions resulting from past conservation activities or medical necessity just to receive consideration by the unit. Throughout the drought, the rationing unit received 131,000 such requests for modified allocations.

The rationing unit was also responsible for monitoring excessive water use. Audits were performed on homes that surpassed their allotment of water. The audits were usually conducted to identify leaks; however, the identification of continued excessive use of water without consideration given to the rationing allotment was met with the installation of a flow restrictor to limit water intake. These customers were also charged for the installation and removal of the flow restrictor.

By 1991, water levels in the Hetch Hetchy Water System and local reservoirs were in such a depleted state that the SFPUC declared an intent to require 45% reductions in water use for its retail customers. However, the end of the drought permitted the SFPUC to avoid implementing the reduction.

By 1992, the final year of the drought, water rationing had limited water intake to 214 MGD, a 25% reduction in daily consumption levels compared to the pre-drought water intake level of 285 MGD (SFPUC, Hetch Hetchy Power and Water Company: 1993).

The impact of the drought continued even past the rationing stages, as residents and businesses implemented water saving devices and conservation techniques to both improve the reliability of available water and to reduce the costs associated with reduced water supplies and water price increases. Even with the large economic growth that occurred between 1990 and 2000, water consumption levels have not increased above pre-drought water consumption levels.

Legislation and Inter-Agency Agreements

One of the important and relevant policy documents is the Interim Water Shortage Allocation Plan adopted in October 2000. This agreement was required by the Master Water Sales Agreement. The agreement establishes a process that does not penalize customers for water conservation by establishing calculations that reflect a customer's ability to minimize water demand. The agreement between the SFPUC and the wholesale customers outlines the process for water allocation in the event of a future water reduction up to 20%. If rationing levels surpass the 20% level, both the SFPUC and the wholesale customers must meet to negotiate how to manage the allocation process.

The agreement establishes the SFPUC as the responsible agency for monitoring water levels and making a determination that the plan be enacted. While the SFPUC has the authority to make the determination for the necessity of rationing, the plan requires that the SFPUC demonstrate that the projected water demand for the coming year surpasses the available supply of water. In making this assessment, the SFPUC must consider stored water supplies, projected run-off, water acquired from non-SFPUC sources, and reservoir levels. Once a determination is made to implement rationing protocols, the SFPUC is instructed to notify the customers, determine whether rationing will be voluntary or mandatory, and if mandatory, set a schedule of excess water use fees.

The Bay Area Water Users Association, the organization representing the interests of the wholesale customers, is responsible for the calculating the amount of water that should be distributed to each wholesale customer. This function was transferred to the Bay Area Water Supply and Conservation Association (BAWSCA) as the result of legislation enacted in 2002. The legislation articulated that the new association would perform the same function as BAWUA in addition to being a regional water district with additional powers to oversee water system improvements.

The Interim Water Shortage Allocation Plan also establishes the process that allows suburban customers to bank water credits and transfer water supplies. In addition, the plan articulates a process for debiting excess water use from the allotment of water for the following month.

The credit process allows customers to bank unused amounts of water for future use. The plan also allows customers, with banked water credits, to voluntarily transfer the water credits to other customers. The debit process is a similar process in that debits are carried over to the next month. If customers exceed the monthly allotment of water, the excess amount is charged to the following month. If debits remain in the account at the close of the year, the customer is charged an excess water fee for the remaining owed amount.

In December of 2001, the Retail Water Shortage Allocation Plan was published as a companion document to the Interim Water Shortage Allocation Plan. The Purpose of the Retail Plan was to outline the water allocation plan clearly for retail customers.

The SFPUC wanted to ensure that retail customers understood the processes and protocols that would be enacted in the event of a water shortage.

In addition to the Interim Water Shortage Agreement, in 2002 a series of legislative changes were enacted that impact water system management. In order to address future financing concerns and needed improvements for effective water management, three propositions were approved on the San Francisco Ballot:

- **Proposition A** approved $1.6 billion dollars in revenue bonds for capital improvements to address the functioning and reliability of the Hetch Hetchy Water System. Proposition A also stipulated that the upgrades would be repaid by water customers. The Proposition also allowed funds to be used to fund water alternatives and water conservation programs.

- **Proposition E** transferred voters' right to approve the use of bonds to fund capital projects. The approval for issuing revenue bonds shifted to the Board of Supervisors, requiring a two-thirds vote of approval. In addition, Proposition E allows the SFPUC to set rate increases given independent review and a rate study.

- **Proposition P** created the Revenue Bond Oversight Committee which provides checks and balances to ensure that Propositions A and E are implemented properly and processes going forward are closely scrutinized.

In addition to these local measures, also in 2002, three bills related to the region's water resources management were passed in the California State Legislature:

- **AB 1823**, referred to as the Wholesale Regional Water System Security and Reliability Act, requires San Francisco to assess the current state of the water system, to provide a capital improvement program to upgrade the system, to develop an emergency response plan for water provision in the event of a catastrophe, and a method for distributing water equitably among all current customers.

- **AB 2058** established BAWSCA as a local water district, representing the interests of all parties receiving SFPUC supplied water. BAWSCA consists of the 28 wholesale customers served by the SFPUC. The rationale for the creation of the agency was to protect the health safety, and economic well being of the 1.7 million suburban customers purchasing water indirectly from SFPUC through the wholesale customers. The legislation's intent was for BAWSCA to advocate for its members' interest in the improvements to the water system. In addition, the legislation required the members of BAWSCA to raise money to help fund improvements to the water system.

- **SB 1870** created the financing mechanism, the San Francisco Bay Area Regional Water System Financing Authority, to undertake capital improvement projects. The authority is authorized to issue revenue bonds and use the proceeds from revenue bond sales to fund capital improvement projects. In addition, the authority is the responsible agency for accessing state and federal grants, loans and other financial assistance.

Water Consumption Trends

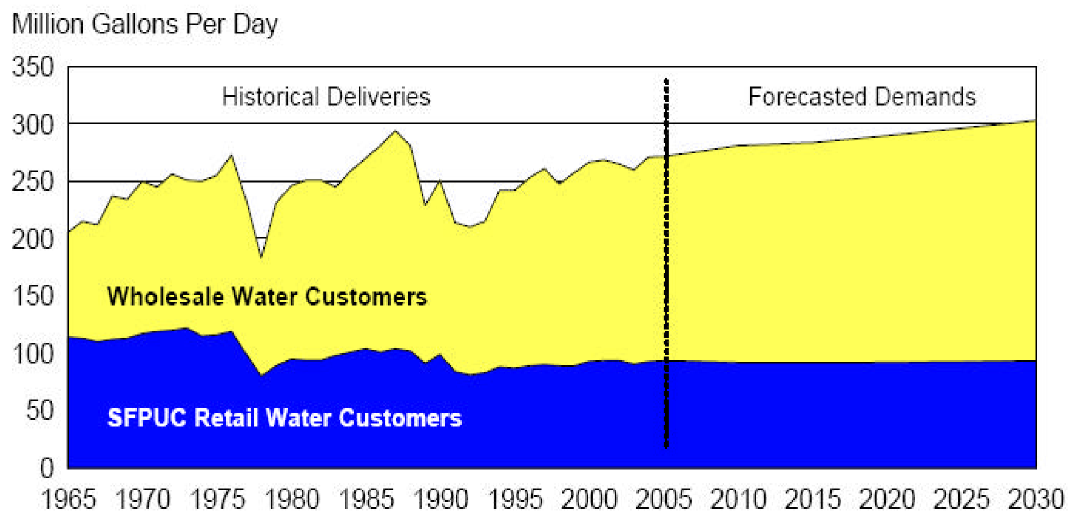
Different reports and studies present varying Bay Area water consumption patterns based on the period covered, the section of the service area described, and the sectors being described, which makes direct comparison of water consumption data difficult. Given these caveats, some broad themes emerge.

Information on how water is distributed between San Francisco retail customers and the suburban wholesale customers is fairly consistent across sources, with San Francisco retail customers consuming approximately one third of the Regional Water System Supply and the suburban customers consuming the remaining two-thirds. The use of Regional Water System water provided by the SFPUC is proportionate to population levels being served, with San Francisco also accounting for about a third of the population served by the Regional Water System.

In 1970, San Francisco customers consumed 117 million gallons per day (MGD); by 1990 consumption levels had been reduced to 99 MGD, and in the year 2000 water consumption decreased to 93.6 MGD (IWRP Presentation). BAWSCA, which reported that water consumption in the late 1990s equaled pre-drought water consumption levels, stated FY 2001/ 2002 demand was reduced by 3.5% (BAWSCA).

The demand among suburban customers has grown steadily during the period following the drought; whereas, the San Francisco trend has remained relatively flat. The figure displayed below, drawn from the *Draft 2005 Urban Water Management Plan* developed by the SFPUC, shows the divergent path for the two groups beginning shortly after the 1987-1992 drought ended.

Total San Francisco Water Demands



San Francisco residents and suburban customers also share some similarities in water use by sector with residential customers (single family and multi-family units combined) using more water than the commercial sector and industrial sector.

One other important note about water consumption is that water use is not evenly distributed by month. There are variations in water use based on the season, with the heaviest consumption of water typically occurring between the months of June and September. However, there are also seasonal sub-trends depending on the use of water. For instance, indoor water use increases during the winter months, while business patterns show that water usage increases in the summer as production cycles pick up during the summer months.

Hardening of Demand

Throughout the literature, the term “hardening” is used repeatedly with regard to the region’s demand for water. Hardening of demand refers to the reduced availability of water alternatives or conservation techniques used to offset diminishing water supplies. More simply stated, residents and businesses are less likely to absorb the impact of future water reductions as they have exhausted many of the technologies to minimize the impact of water shortages. There are other options available for further conserving water; however, the cost of these options might not create enough benefit to support implementation.

The acceptance of conservation techniques usually begins with a simple cost benefit analysis to determine if the costs of implementing a technology are exceeded by the benefits produced by the technology. In terms of conservation technology, users are more likely to implement technologies that cost them little to implement, but produce savings in terms of costs avoided. After the implementation of the most cost-effective conservation techniques, further water supply shortages may need to occur before users will consider the next tier of conservation options, which are generally more expensive or disruptive.

The 1987-1992 drought created concern regarding the reliability of the water supply among business management and the potential consequences this trend could have on production. Businesses turned to conservation techniques to ensure that water needed for production processes was maximized to its fullest potential.

In the manufacturing sector, overall water usage was reduced quickly to ensure that available water supplies were limited to the most critical production operations. Manufacturers reduced overall water consumption by 25% between 1987 and 1992, with most of the savings occurring in the first year (MHB: 1994). Conservation reductions for manufacturers declined over time as the cost of options became increasingly more expensive. It appears that manufacturers are quick to implement water usage reduction strategies as long as the cost of implementation does not outweigh the benefit added to production.

The commercial sector also achieved significant reductions in water usage in response to the impact of the drought and associated water supply reductions. Between 1987 and 1992, commercial industries reduced water consumption by 29%. Most of the commercial savings have been achieved by plumbing retrofits and the adoption of landscape conservation techniques.

Projected Water Consumption

The SFPUC estimates that water consumption in San Francisco will not increase in future years, projecting that in the year 2030 water demand will be 93.4 MGD. Officials believe that the ongoing impact of plumbing code changes will have an impact of reducing demand by 10.3 MGD by the year 2030. This reduction is accounted for in the 2030 estimate (SFPUC: 2004). This reduction through conservation will offset water demands driven by growth, and overall water consumption levels will remain at the same level as today.

The trend for projected water consumption for the suburban customers does not mirror the trend for San Francisco retail customers. In the year 2030, SFPUC has projected 324 MGD of water is needed to meet system demand of the suburban customers. This represents an increase of approximately 19% over the current water consumption level of 282 MGD (SFPUC: 2004). The plumbing code changes are estimated to reduce usage by 25.4 MGD. (This impact is included in the 324 MGD.)

The difference between the trends for San Francisco County and suburban customers is based largely on expansion potential. San Francisco County is mostly built out, which will limit the number of additional new households that can add to the water demand. The three suburban counties still have developable space and it has been projected that both population levels and the number of households will continue to increase significantly over the next few decades.

In addition to developing projections, the SFPUC has taken an active role in water consumption management planning. Through a combination of promoting conservation, sponsorship of forums to discuss water source alternatives, and interagency cooperation, the SFPUC is actively seeking solutions to improve the reliability of water. In 2005, SFPUC has sponsored a number of workshops to discuss alternative methods for increasing reliability in the water supply and creating system redundancies in the event of an emergency.

The SFPUC has also created partnerships with BAWSCA to ensure that system plans do not negatively impact the region. In 2005, the SFPUC, in conjunction with BAWSCA, produced studies on water use and projected demand among wholesale customers to inform the development of plans to improve the water system.

The SFPUC has also maintained a relationship with a number of State, Federal and local agencies, and has been active in the CALFED program. This team of nearly two dozen state and federal agencies is working together to address water quality issues and supply reliability. While this is a statewide focus, a CALFED subgroup was formed to focus on Bay Area specific water concerns. Recently, for example, the CALFED program funded a project examining the feasibility of blending or exchanging source waters among Bay Area water utilities to improve water quality.

Prior Studies on the Impact of Water Reduction

Since the 1987-1992 Drought, a number of studies have been commissioned to study the impact of service disruption and rationing on the region. While the overall goal has been to measure regional economic impact, the sector(s) studied and definition of "impact" used has varied from one study to the next. Our analysis is focused on the commercial and manufacturing sectors, under the assumption that the impact of water supply reduction these non-residential sectors will produce the majority of any direct economic impact on the region. Issues related to the "value" associated with residential water loss are addressed in Appendix 5.

To help guide the development of our analysis, we reviewed multiple research projects focusing specifically on the Bay Area and water impacts. Below, we list some of the methodologies and associated limitations with the leading examples of such prior research. A more comprehensive list of past studies reviewed and other reference materials is included as Appendix 4. In addition, similar studies from Southern Nevada and Tampa were reviewed, and are summarized in Appendix 2.

Cost of Industrial Water Shortages, 1991

While the 1987-1992 drought was still impacting much of California, a study was conducted to review the impact of water reduction on two major manufacturing centers, the Bay Area and Southern California. The study's objective was to determine industrial water use patterns, the extent of adopted conservation strategies, the potential for production losses and employment reductions under water reduction scenarios of a 15% seasonal reduction (April-November) and a 30% year-long water reduction scenario, and to assess the potential for further conservation.

The study design in 1991 used a survey to gather data from manufacturers. The survey focused on manufacturing industries that would be most affected by water rationing policies. These industries would be likely candidates for large economic losses in the event of a water reduction, high volume water users with large employment bases. A stratified sampling method was selected using sampling fractions to account for variation in employment size by industry. Using data obtained from the surveys, elasticity values were assigned to each industry. Then, applying these elasticities, Spectrum Economics estimated the impact of water reduction on manufacturing firms.

Under the 15% scenario, the economic impact on the Bay Area Region and Southern California was estimated at $3.8 billion. For this scenario, no findings specific to the Bay Area were presented. If a multiplier is added to account for secondary economic impacts on dependent industries and employment, the economic impact increased to $6.4 billion.

The 30% reduction scenario was found to have a direct economic impact on the Bay Area Region and Southern California of $11.8 billion, and a $20 billion impact when the multiplier is included to account for impact of dependent industry. For the 30% reduction scenario, Spectrum did identify the portion of economic loss that can be directly attributed to the Bay Area (albeit defined to include counties outside of the SFPUC service territory. This Bay Area economic impact was estimated at $4.4 billion, accounting for just over one third of the overall impact. Applying the multiplier to account for indirect losses, the economic impact on the Bay Area rose to $7.4 billion.

A key limitation with the findings of the Spectrum analysis for the purposes of our current study is timing. The study is not only 14 years old, but it was conducted during the drought, which may have impacted survey responses. In addition, since the drought, the region's manufacturing industry has changed both in terms of water conservation and management and the general composition of industry. Other limitations include the service area studied and low survey response rates. The results of the Spectrum analysis combine results from the Bay Area and Southern California region in some of the analyses, and define the Bay Area differently from the SFPUC service territory. Further, our interest extends beyond this study's exclusive focus on the manufacturing sector to encompass major commercial activities such as the regions hospitality industry.

The Economic Impact of Water Delivery Reductions on the San Francisco Water Department's Commercial and Manufacturing Customers, 1994

A more comprehensive analysis of the potential impacts of mandatory reductions in Bay Area water supply was undertaken by Dr. Philip McLeod for MHB Consultants in 1994 (McLeod). This study expanded on the Spectrum report done in 1991 by specifically including San Francisco County, as well as measuring the economic impact on both the commercial and manufacturing sectors of the economy.

Given apparent divergence in water-use patterns between the Bay Area and other U.S. urban communities, McLeod surveyed local commercial and manufacturing businesses to obtain region-specific data. The survey was designed using a stratified random sample approach targeting (through over-sampling) high water-use and large employers. The instrument was sent to 304 manufacturing facilities and 709 commercial facilities, with 30% of the manufacturers and 13% of the commercial facilities responding. Information was solicited regarding water-use patterns by detailed function (production, landscaping, etc.), costs incurred to reduce consumption, and conservation policies and procedures that had already been implemented. The survey also inquired about each firm's response to water shortage (at different levels of reduced availability), their observed reaction to price increases and their perceived need for water reliability.

Based on the primary information gathered through the survey process, McLeod performed two calculations designed to capture the impact of reduced water availability. The first, the "welfare loss" methodology, is a common approach to estimating the impact of reduced supplies and higher commodity prices. Per McLeod, "the formula is simply the average of before and after prices times the change in quantity." Under this approach, the consumer will be forced to "pay more for less," and assumes that the market for water is sufficiently freely competitive that "those with a high value for the commodity will be able to displace those willing to pay less." The calculations that follow indicated that a 15% reduction in the water supply would create a welfare loss of $35 million per year and a 30% reduction would yield a $218 million per year impact. The manufacturing sector takes an $11 million loss under the 15% scenario, and an $80 million loss for the 30% scenario. The impact for the commercial sector would be $24 million and $140 million respectively.

There are significant limitations to using this approach, as McLeod recognizes. "In using welfare loss as an estimate of economic impacts… one must assume that suppliers (i.e. water utilities) have total flexibility to set prices, no legal encumbrances, and, most importantly, that there are no additional social impacts from displacing low value customers. These assumptions may be valid for concert tickets, but not for municipally supplied water."

An alternative approach, the "66 production loss" method, solicited information regarding the impact of forced water reduction on economic activity. Respondents were asked "if your water supply is reduced by a certain percentage, what will be the corresponding percentage impact on your production (economic activity). The following table provides the results at two levels; a 15 and 30 percent reduction. The data represents the marginal impact of a one percentage point reduction in water availability, i.e., the production elasticity. For example, the study finds that a 15 percent cutback in water available will prompt Food & Kindred Products manufacturers to reduce production by 6.9 percent (15 * 0.46). Similarly, a 30 percent reduction yields production loss of 37.5 percent (15*0.46) + (15*2.04).

Using the above relationships, the direct economic impact of a 15% and 30% reduction in water supply was estimated for 1994 at $583 million and $4.9 billion, respectively. This finding does not include the ripple effects through the regional economy of this direct loss, which were not measured.

Reduction in Direct Economic Activity Associated With Different Levels of Reduced Water Supply on Selected Sectors of the SFPUC economy (%)

Manufacturing Sectors	**10%**	**15%**	**20%**	**25%**	**30%**
Food/Kindred Products	4.6%	6.9%	17.1%	27.3%	37.5%
Stone/Clay/Glass	6.7%	10.1%	13.0%	15.9%	18.8%
Industrial Machinery	0.4%	0.6%	0.8%	1.0%	1.2%
Electronic Components	1.9%	2.9%	9.6%	16.4%	23.1%
Communications Equip	1.9%	2.9%	5.3%	7.7%	10.1%
Aerospace/Trans Equip	0.0%	0.0%	3.4%	6.7%	10.1%
Measuring/Controlling	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial Sectors					
Grocery Stores	0.0%	0.0%	2.2%	4.4%	6.6%
Eating & Drinking Places	0.0%	0.0%	7.8%	15.6%	23.4%
Real Estate	0.4%	0.6%	2.1%	3.6%	5.1%
Hotels	1.5%	2.3%	9.9%	17.5%	25.1%
Laundries	9.2%	13.8%	26.7%	39.6%	52.5%
Hospitals	0.6%	0.9%	6.1%	11.3%	16.5%

Hetch Hetchy Water and the Bay Area Economy, 2002

This study, conducted by the Bay Area Economic Forum, assesses the impact of a water supply reduction resulting from a catastrophic earthquake. The Hetch Hetchy Water System crosses five different fault lines, and this study analyzed the potential impact of a 7.9 magnitude earthquake on the San Andreas Fault Line and a 7.1 magnitude earthquake on the Hayward Fault Line.

Using the results provided in an engineering study commissioned in 2000, the Bay Area Economic Forum applied per capita daily usage and rates with available quantity assumptions given an earthquake to determine willingness to pay values. The study found that the San Andreas scenario would have an economic impact of $28.7 billion, and the Hayward scenario would have an impact of $17.2 billion. The study also identifies costs associated with fire loss occurring as a result of an earthquake, causing an additional $10.7 billion impact in the San Andreas scenario and a further $5.8 billion loss in the Hayward scenario.

While the results of this study are certainly important regarding timely capital improvement projects and the study does measure the impact of a reduction in water supplies, the focus of the study is fundamentally different in that the magnitude and duration of the assumed earthquake-related impact would be wholly distinct from a drought impact. While droughts can be monitored in advance and would not result in near-total supply interruption, an earthquake has a sudden, unpredictable nature, and a severe event could dramatically disrupt water service. Accordingly, the results include scenarios that are improbable given in a drought scenario, such as fire losses due to unavailable supply for fire suppression.

An Economic Evaluation of the Water Supply Reliability Goal in the SFPUC Water System Improvement Plan, 2005

The focus of this BAWSCA-commissioned study was water supply reliability for the Water Systems Improvement Plan. The lead analyst, William Wade (formerly of the 1991 Spectrum team), argues that the 80% reliability goal fails to recognize the impact of water supply reductions on the region and that further investment in the improvement of water supplies is far less costly than economic losses resulting from production cutbacks. In doing so, he recommends adjusting the water reliability percentage from 80% back to the 90% reliability level.

To support the argument, the study compares Value in Shipment data for manufacturing industry in Alameda County, San Mateo County and Santa Clara County for 1990 and 2001. The data indicates that the value in shipments, during this time period, nearly quadruples, from $56.3 billion to $207.3 billion. The Wade study replicated a methodology employed by a 1991 study using manufacturing industry specific water elasticity and value in shipment data to calculate the impact of a 15% and 30% water supply reduction on the manufacturing industry. However, the study updates the Value in Shipment analysis using data for 2001.

A major concern regarding this study is that the projected value of shipments is much larger than the actual data reported in the 2002 Economic Census for the suburban counties. As a result, even if one were to accept all other components of the analysis, the actual impact of water reductions on the manufacturing sector would be considerably smaller than indicated in this report.

With this significant caveat, it may be noted that this analysis found that production losses would fall between $2.5 billion with a 10% water supply reduction and $7.5 billion per year for a 20% reduction in the water supply. Wade adds that these estimates are conservative since they are based on 1991 elasticity value when conservation options and water alternatives were not yet completely instituted, and notes that the impacts reported do not reflect secondary impacts on businesses that rely on the impacted industry or lost sales and revenues to support local government.

Other limitations of this study for the purposes of our analysis include the study's exclusion of the commercial sector, its focus on suburban counties without San Francisco, and its reliance on elasticity values derived from the 1991 study.

In addition to data and methodological concerns, Wade's argument that an estimated, potential economic loss justifies a public investment of equivalent size in order to prevent that loss, merits close scrutiny. Although citizens and policy makers may well wish to make investments in order to avoid negative economic impacts, public investment decisions require comparison of many alternative investments and policy approaches which have varying economic and political consequences. In other words, even if one course of action might theoretically avoid potential losses of greater cost, there may be even better strategic alternatives available and/or even more compelling demands for limited financial resources.

Summary of Prior Bay Area Studies

Study	Sector/Geography	Objective	Findings	Limitations Relative to Current Analysis
Cost of Industrial Water Shortages Spectrum Economics, 1991	Bay Area and Southern California Manufacturing Sector (Note: the Bay Area findings include two counties not served by the SFPUC)	To determine industrial water use patterns, the extent of adopted conservation strategies, the potential for production losses and employment reductions under water reduction scenarios of a 15% summer – seasonal reduction and a 30% year long water reduction scenario, and to assess the potential for further conservation	For the 30% reduction scenario, direct Bay Area economic impact was estimated at $4.4 billion. Applying a multiplier to account for indirect losses, the economic impact $7.4 billion.	No Bay Area specific estimates for 15% reduction scenario, with Bay Area definition different from SFPUC service territory. Study period predates significant changes in industry composition and conservation practices. Focus on manufacturing only.
The Economic Impact of Water Delivery Reductions on the San Francisco Water Department's Commercial and Manufacturing Customers, MHB (McLeod), 1994	Bay Area Commercial and Manufacturing Sectors	To determine economic impact on commercial and manufacturing sectors	Using the production loss method, the economic impact of a 15% reduction was $583 million and a 30% reduction was $4.9 billion.	While study period reflects some conservation practices adopted during 1987-1992 drought, regional industry composition has changed significantly since 1994.
Hetch Hetchy Water and the Bay Area Economy Bay Area Economic Forum, 2002	All Sectors of the Bay Area	To study the economic impact of water supply interruptions from a 7.9 magnitude earthquake on the San Andreas Fault line and a 7.1 magnitude earthquake on the Hayward fault line.	San Andreas scenario would have economic impact of $28.7 billion, and the Hayward scenario would have an impact of $17.2 billion. In addition, associated fire loss would have impacts of $10.7 billion and $5.8 billion, respectively.	Drought scenario with rationing varies dramatically from severe supply disruption in a major earthquake scenario.
An Economic Evaluation of the Water Supply Reliability Goal in the SFPUC Water System Improvement Plan Wade, 2005	Bay Area Suburban County Manufacturing Sector	To compare economic losses against water rationing plan of 80%	10% water reduction results in $2.5 billion economic impact, 20% reduction is $7.5 billion.	Estimates partially based on erroneous economic data, and relies on 1991 elasticities. Study focuses on manufacturing sector only. Study focuses on suburban counties only.

In the analysis that follows, we use the relationships between water availability and economic output established in the McLeod study, and apply these findings to the manufacturing and commercial sectors of the economy in the SFPUC service area. This allows us to estimate the economic losses that would be created at successively higher levels of water reduction, absent policy intervention.

The analysis of percentage reduction in economic activity calculated by McLeod can be combined with data on the size of the economy in the SFPUC service territory to estimate the direct impact on the local economy. This exercise is somewhat challenging, in that there is not a source of information on the relevant economy that is both current and reflects the industry-specific production elasticity estimates developed by McLeod.

The 2002 Economic Census does provide a high level of industrial data at the county level, and, therefore, is used as the base data for the analysis.[1] ZIP Code level information on total employment from the 2002 County Business Patterns dataset was used to refine the estimate of economic activity within the SFPUC service territory. Based on this information, 100 percent of San Francisco and San Mateo Counties are included, along with 48.0 percent of Santa Clara and 33.4 percent of Alameda. The following table delineates the estimates of total 2002 SFPUC economic activity in each applicable sector.

Estimated 2002 Economic Activity in the SFPUC Service Territory in Selected Industries($Billions)

Manufacturing Industries	**Sales/Receipts/Shipments**
Food/Kindred Products	$2.59
Stone/Clay/Glass	$0.42
Ind Machinery	$0.64
Electronic Components	$5.33
Communications Equip	$5.70
Aerospace/Trans Equip	$2.08
Measuring/Controlling	$1.71
Commercial Industries	
Grocery Stores	$5.72
Eating & Drinking	$4.87
Real Estate	$8.18
Hotels	$2.27
Laundry	$0.23
Hospitals	$5.92

Applying the potential percentage losses in the previous table on page 17 against data above yields the following direct impacts by sector.

[1] There were several cases where data for specific industries was suppressed at the county level due to confidentiality concerns. In these instances, estimates were developed using state-level ratios applied against available county information.

Reduction in Direct Economic Activity Associated With Different Levels of Reduced Water Supply on Selected Sectors of the SFPUC Service Territory Economy ($Millions)

Manufacturing Sectors	**10%**	**15%**	**20%**	**25%**	**30%**
Food/Kindred Products	$119.1	$178.6	$442.6	$706.6	$970.7
Stone/Clay/Glass	$28.3	$42.5	$54.7	$67.0	$79.2
Industrial Machinery	$2.5	$3.8	$5.1	$6.4	$7.6
Electronic Components	$101.2	$151.8	$511.5	$871.1	$1,230.8
Communications Equip	$108.3	$162.4	$299.2	$436.0	$572.8
Aerospace/Trans Equip	$0.0	$0.0	$69.7	$139.4	$209.2
Measuring/Controlling	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial Sectors					
Grocery Stores	$0.0	$0.0	$125.9	$251.9	$377.8
Eating & Drinking Places	$0.0	$0.0	$380.2	$760.5	$1,140.7
Real Estate	$32.7	$49.1	$171.7	$294.4	$417.1
Hotels	$34.0	$51.0	$223.4	$395.8	$568.2
Laundries	$21.5	$32.3	$62.5	$92.7	$122.9
Hospitals	$35.5	$53.3	$361.0	$668.8	$976.5
TOTAL	$483.2	$724.8	$2,707.7	$4,690.6	$6,673.4

Depending on the level of water reduction, the potential direct impact in 2002 could have ranged from just over $483 million to $6.7 billion. The payment made by an out-of-town visitor to a hotel operator is an example of a direct effect, as would be the taxi fare that visitor paid to be transported into town from the airport.

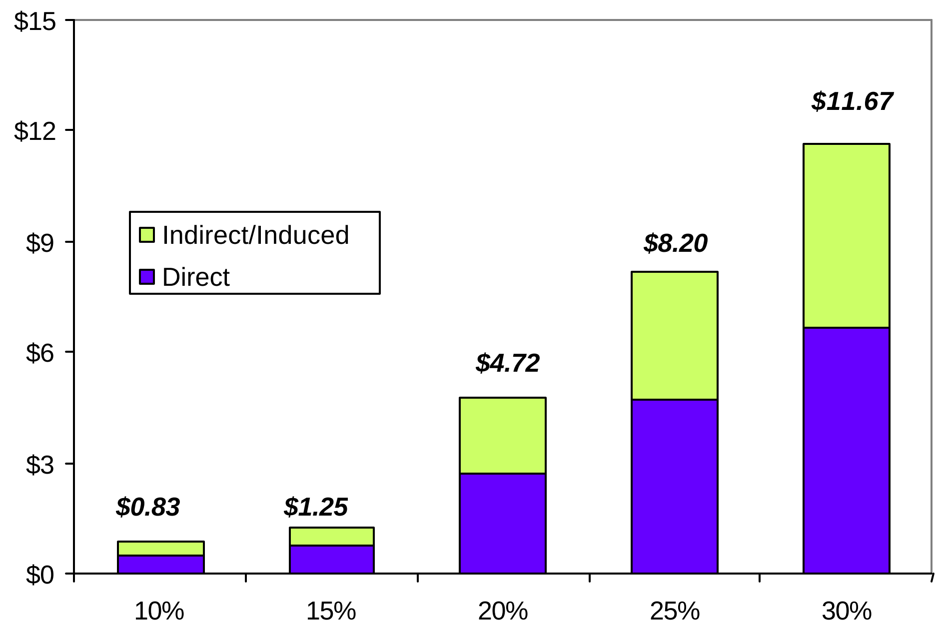
In addition, these direct effects would move through the regional economy, causing additional economic loss. These "ripple" effects are technically referred to as the indirect and induced impacts, and are captured through the use of a regional input-output model.[2] By way of illustration, indirect effects are production changes in backward-linked industries cause by the changing input needs of directly affected industries – typically, additional purchases to produce additional output. Satisfying the demand for an overnight stay will require the hotel operator to purchase additional cleaning supplies and services, for example, and the taxi driver will have to replace the gasoline consumed during the trip from the airport. These downstream purchases affect the economic status of other local merchants and workers.

Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects. Both the hotel operator and taxi driver experience increased income from the visitor's stay, for example, as do the cleaning supplies outlet and the gas station proprietor. Induced effects capture the way in which this increased income is, in turn, spent in the local economy.

[2] *For this study, a customized version of the Bureau of Economic Analysis (BEA) RIMS model of the four-county area was used to measure the total economic impacts. The unique multiplier for each individual sector (which ranged from 1.33 to 1.98) listed above was applied to that industry's estimated direct loss. For example, the economic activity multiplier for Hotels in this area is 1.72, meaning that for every dollar lost (or gained) directly, an additional $0.72 in impact ripples through the regional economy.*

The following charts show the direct and total (direct, indirect, and induced) impacts for each reduced water supply scenario.

Direct and Total Economic Impacts Due to Reduced Water Supply on Selected Sectors of the SFPUC Service Territory Economy ($Billions)



Detailed Total Economic Impacts Due to Reduced Water Supply on Selected Sectors of the SFPUC Service Territory Economy ($Millions)

	10%	15%	20%	25%	30%
Agriculture, forestry, fishing, and hunting	$5,515.1	$8,272.7	$26,487.4	$44,702.1	$62,916.8
Mining	$395.1	$592.6	$983.9	$1,375.2	$1,766.6
Utilities	$3,101.8	$4,652.7	$17,209.6	$29,766.6	$42,323.6
Construction	$2,502.7	$3,754.0	$16,327.9	$28,901.8	$41,475.7
Manufacturing	$434,869.9	$652,304.8	$1,746,056.8	$2,839,808.9	$3,933,560.9
Wholesale trade	$26,563.9	$39,845.8	$140,873.4	$241,900.9	$342,928.5
Retail trade	$15,849.6	$23,774.3	$230,008.4	$436,242.4	$642,476.4
Transportation and warehousing	$13,382.2	$20,073.3	$79,041.1	$138,009.0	$196,976.8
Information	$18,506.3	$27,759.4	$116,861.7	$205,964.1	$295,066.4
Finance and insurance	$28,800.7	$43,201.0	$179,858.5	$316,516.0	$453,173.5
Real estate and rental and leasing	$82,055.0	$123,082.4	$490,942.6	$858,802.8	$1,226,663.0
Professional, scientific, and technical services	$31,758.0	$47,636.9	$179,859.9	$312,082.9	$444,305.9
Management of companies and enterprises	$20,916.3	$31,374.4	$105,923.2	$180,472.0	$255,020.7
Administrative and waste management services	$12,113.1	$18,169.6	$79,708.3	$141,246.9	$202,785.6
Educational services	$3,334.8	$5,002.2	$22,078.1	$39,154.0	$56,229.8
Health care and social assistance	$50,501.4	$75,752.2	$458,192.1	$840,632.0	$1,223,072.0
Arts, entertainment, and recreation	$3,125.3	$4,688.0	$22,381.2	$40,074.4	$57,767.6
Accommodation and food services	$44,631.4	$66,947.1	$672,096.6	$1,277,246.0	$1,882,395.4
Other services	$33,519.1	$50,278.6	$136,202.6	$222,126.5	$308,050.4
Total Economic Impact	**$831,441.4**	**$1,247,162.1**	**$4,721,093.3**	**$8,195,024.5**	**$11,668,955.7**

Key Findings:

The economic impact of reduced water supply could be significant. Depending on the scenario, the total potential economic impact is estimated to have ranged from slightly less that $1 billion to just under $11.7 billion. To put these figures in context, total economic activity in the selected sectors in the SFPUC service territory for 2002 is estimated at $45.7 billion, while estimated reported activity for all industries in the SFPUC territory that year was $208.0 billion (the reported total for Alameda, San Mateo, Santa Clara and San Francisco counties was $344.5 billion).[3]

The results of the study are based, however, on information that is dated – at least, in part. While the analysis employs reasonably current data on the local economy (suggesting that there probably has been relatively little structural change since), the relationship between non-residential water supply and economic activity is more than 10 years old. In general, McLeod's research is the most thorough and recently-available information on the impact of reduced water availability on given industries in the Bay Area. However, the information is dated, and it is certainly possible that some or all of these relationships may have changed.

Complicating the situation is the fact that there is no clear indication of bias in either direction. On the one hand, demand may have "hardened" (as discussed earlier) in the intervening years, which would suggest that the production elasticities might understate non-residential users sensitivity to reduced water supply. On the other hand, changes in patterns of production (reflecting new technology, an evolving product mix, enhanced business processes, etc.) could well diminish sensitivity levels, which would in turn suggest that elasticities are over-stated. On balance, therefore, this uncertainty suggests that these findings should be viewed as reflecting an order of magnitude, rather than a precise accounting.

The impact of a mandatory reduction in water supply is sensitive to the level of constrained supply. McLeod's research reveals that many industries sensitivity to reduced levels of water supply grows as the constraint increases, and that for many there is likely a "tipping point" at which their operations are either significantly impacted or no longer viable.

These findings are simplified for illustration. In modeling of this type, a number of simplifying assumptions normally are made, such as that the duration of the impacts lasts for exactly one year (in order to match up with reported data on economic activity), all firms within a given sector react homogenously (which obviously is not true in reality), etc. Appropriate practice is to attempt to balance these assumptions so as not to significantly bias the findings. For example, there are likely to be some modest direct impacts in the sectors of the economy that are not explicitly included in the analysis (although these industries were selected as being water-intensive at the time of the original McLeod study), but they could well be offset by reality of firm's ability to dynamically adapt to reduced water availability which is not captured in this static analysis.

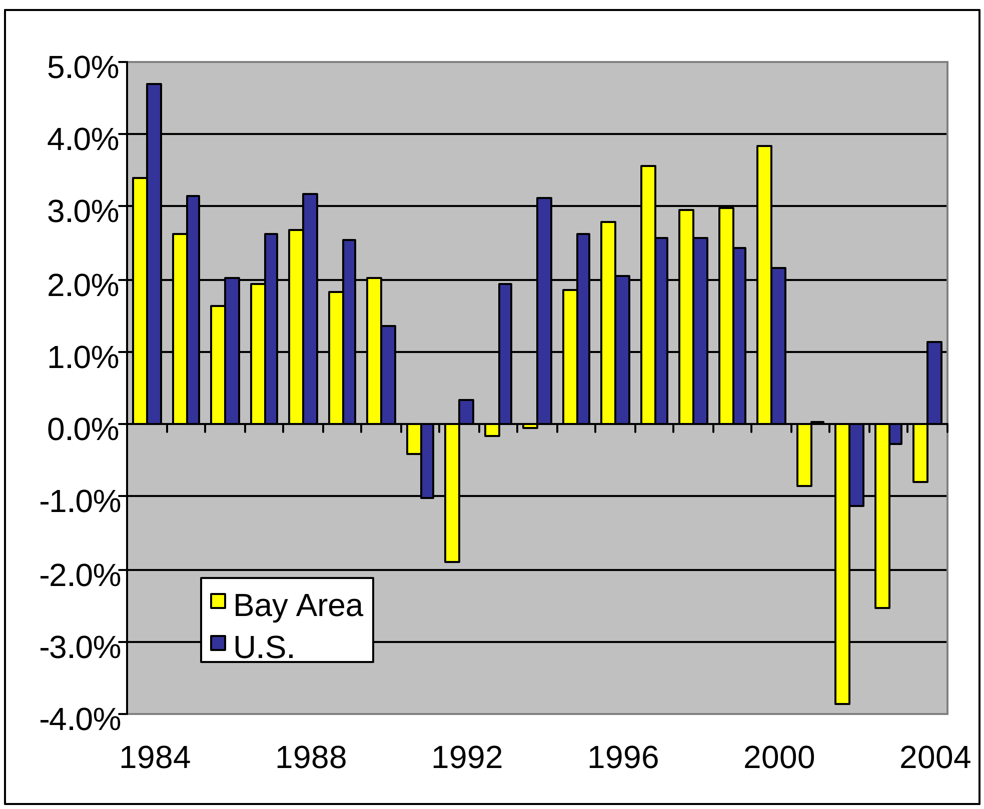
The timing, range, and scope of policies and procedures implemented to achieve overall system-wide water reduction goals could potentially mitigate much, if not all, of this potential economic impact. This analysis is conducted in a policy vacuum, assuming no other change than across-the-board reductions in

[3] The base data again is drawn from the 2002 Economic Census, which does not report data at the county level for Mining, Construction, Utilities, Transportation & Warehousing, Finance & Insurance, and the Management of Companies/Enterprises. Nationally, these industries comprised 23.7 percent of 2002 economic activity, suggesting that the total economy of the SFPUC region was approximately $272.8 billion and the four-county region totaled $451.7 billion that year.

water supply. The SFPUC and the suburban agencies would obviously enact a variety of policies designed to manage and mitigate the impacts of reduced supply. Also, private businesses would react to reduced supply by utilizing changes in technology, techniques and behavior, all of which could substantially mitigate economic impacts.

Other factors in the regional economy may have an even greater impact than water supply reduction, as was seen during the 1987-1992 drought. While this most recent major drought undoubtedly had a significant impact on Californian's lives – shifting patterns of water consumption for both residents and businesses throughout the region – measuring the impact on the local economy is complicated by the fact that the drought did not occur in a vacuum. Over that same period, the national economy endured a mild recession, which certainly had an impact on the Bay Area, and it is clear that national (as well as international) trends tend to greatly influence the performance of the local economy. The net effect is that, though the job base in the San Francisco-Oakland-Fremont MSA fell in the early 1990s (see chart), it would be inappropriate to ascribe this loss entirely to the influence of the drought. In fact, well into the drought in 1990, the Bay Area economy was still growing at a faster rate than the nation's economy overall. It should also be noted that the Bay Area economy was affected negatively by the Loma Prieta earthquake, which occurred in October of 1989. As a result, estimates of the impact of droughts tend to be done based with an "all other things being equal" caveat, which is seldom the case in the real world.

Wage & Salary Employment Growth in the U.S. and the San Francisco-Oakland-Fremont MSA (annual change)



Conclusions and Areas for Further Inquiry

The economic impact of reduced water supply could be significant, with the potential for multibillion dollar economic loss. At the same time, the total potential economic impact (again, estimated to range from slightly less than $1 billion to just under $11.7 billion, depending on the scenario) represents a relatively modest share of the region's overall economy.

Due to the accelerated timeframe for this analysis, more specific impacts – and opportunities to manage these potential events toward more favorable outcomes – have not been fully evaluated. To further understand these issues and associated policy options, the following are among the potential areas for further inquiry:

1) **Update the demand elasticity values with new, original survey research to account for hardening of demand that has occurred over the past decade as a result of water demand reduction efforts and conservation activities.** Given the time constraints of the project, the current analysis used demand elasticity values derived shortly after the drought that may be more forgiving regarding the nonresidential sector response to water reductions. Also important, an updated survey might address impacts associated with shifting to alternative supplies from high quality Hetch Hetchy water.

2) **Introduce duration of a potential water reduction to the calculation of regional economic impact.** The present analysis only accounts for a single-year economic impact; however, duration of a drought would most likely increase the magnitude of economic impact. The Southern Nevada study (see Appendix 2), which modeled the duration of recovery from an interruption in regional growth, indicated that duration would increase the magnitude of the impact exponentially.

3) **Measure economic impact of water reduction with greater precision.** Our measures of economic impact are aggregated from industry specific data. It is clear from the analysis that economic impact is not spread evenly across all businesses. The industries that are most affected by a water reduction can be identified. Regions, where these industries are located, could face more significant economic impacts than their neighbors. Inclusion of economic sectors outside of the manufacturing and commercial sectors would also permit more precise more policy considerations.

4) **Measure the seasonal impact of water reductions.** The economic impact of water reductions is not evenly distributed across months. Patterns of water use reveal that heavy periods of water use during the year can be identified by sector, and more specifically, by industry. This information could be used to target specific strategies to mitigate the magnitude of economic impact on industries most likely to affect the regional economy.

5) **Study incentives and price mechanisms that will achieve needed water reductions with the least economic impact to the region.** Our review of rationing plans (see Appendix 3) suggests that little action is being taken within the industry to calibrate

rationing plans so as to mitigate economic impacts. With the ability to target the time of year and the type of industry most vulnerable to water reductions, rationing plans might be able to adjust rationing percentages to achieve needed water usage reductions without creating economic hardships on the region or water customers. As the 2009 expiration of the SFPUC Interim Water Shortage Allocation Plan approaches, there may be opportunities to develop positive incentives for the next version of this agreement.

6) **Evaluate potential for transaction based water credit sales among large retail water users.** The current system of banking water credits and water transfers among wholesale customers could be applied to develop a transaction based system for large water users. Under this possible approach, large retail customers might sell water credits to other retail customers in need of increased supplies above defined allotments. The concept is to create incentives for both parties, with one party receiving financial reward and the other gaining the benefit of a valued input for business processes. This process creates both an incentive to conserve for those desiring financial reward and reduces risk of output losses among those industries most dependent on water. Overall, water would be allocated equitably, but it would be redistributed based on the market value the customer places on the water.

By recognizing specific industries affected by water reductions, the time of year when water reductions are most likely to exacerbate economic impacts, and the sub-regions and sectors most likely to be impacted by a drought, the SFPUC can develop a balanced rationing plan that minimizes overall regional economic loss.

Formulation and analysis of policy alternatives aimed at mitigating the impacts of reduced water availability would permit the SFPUC and suburban agencies to be more prepared when the next drought occurs. A wide range of alternative strategies could be considered, and it will be important to work closely with representatives from the commercial and manufacturing sectors while balancing considerations of equity and fairness. It will likely be easier to craft an updated strategy at this point than waiting until the next drought occurs.

Hetch Hetchy Background

History

Much like current issues that Bay Area stakeholders are addressing with regard to reliable water supply, officials in the late nineteenth century investigated a number of possibilities to increase the water supply to the growing regional population. After reviewing a number of potential water sources, city engineers recommended importing water from the Tuolumne River as the best solution to increase the supply of water to San Francisco. The system was assessed as superior to alternative water sources for a number of reasons, including the quality of the water, freedom from existing legal claims, and hydro-electric power possibilities.

A number of setbacks occurred with regard to gaining permission to supply water from the Tuolumne River as a result of local political changes and the denial of requests for rights to the river handed down by the Federal Government; however, the search for reliable water became a priority again with the occurrence of a catastrophic natural disaster. The 1906 earthquake and resulting fire demonstrated the weakness of the existing water supply. Public officials again focused on the urgent need for a reliable source of water.

In 1906, Congress granted limited permission for the rights to supply water using the Tuolumne River. Four years later, an overwhelming number of San Franciscans voted in support of a $45 million bond issue to construct the Hetch Hetchy System (SFPUC History: The Sierra Nevada: Website), and in 1913, the United States Government enacted the Raker Act which allowed for the construction of the Hetch Hetchy Water System and the importing of water from the Sierra Nevada Mountains. The actual construction of the system was begun in 1914 and completed in 1934. The system includes a 167 mile gravity-based system of dams, reservoirs, treatment plants, pump stations, tunnels, pipelines and valves that collects snow melt and the resultant Tuolumne River run-off and delivers the water to the Bay Area from the Hetch Hetchy Reservoir in the Sierra Nevada.

Beyond the engineering complexity of the Hetch Hetchy Water System, there is one very important attribute of the water supplied from the Sierra Nevada region: its purity. The purity of the water is a precious attribute to industries which use water in their production process. Hetch Hetchy water requires little to no pretreatment to remove contaminants harmful to the production process and the purity of water also determines the quantity of water needed in the production process. The end result is that more pure water results in reduced costs associated with the purchase of water as an input, the pretreatment of water to reduce contaminants, and the quantity of wastewater that requires disposal. Each of these cost reducing factors makes the Hetch Hetchy water supply very valuable to industrial customers requiring water in the production process.

Management and Service Area

The San Francisco Public Utility Commission (SFPUC) is responsible for the management of the Regional Water System. The SFPUC is part of the City and County government serving San Francisco, California. It is responsible for providing water, waste water services, and municipal power to approximately 770,000 retail customers. In addition, the SFPUC supplies water under contractual agreement to 28 wholesale customers serving retail customers in parts of Alameda County, Santa Clara County and San Mateo County. With the inclusion of retail customers served by the wholesale water agencies, the SFPUC manages a water system that serves 2.4 million customers in the Bay Area (California State Auditor: 2000).

The revenues generated from water sales are the primary source of annual funding for the water delivery system. The Commission's final budget for fiscal year 1999-2000 indicates that 76 percent of the funds to operate the City Distribution and Water Supply and Treatment divisions will come from retail rates charged to San Francisco customers and wholesale rates charged to suburban customers (California State Auditor: 2000). Proceeds from the sale of bonds are used to support capital improvement projects needed to maintain the system.

While the system serves San Francisco and wholesale customers in parts of three surrounding counties, the SFPUC is exclusively governed by the City and County of San Francisco. The leadership of the Commission, five commissioners and the Commission's general manager are directly appointed by the Mayor of San Francisco. Each appointed commissioner serves a term of four years.

The City Board of Supervisors and the voters of San Francisco have also had a role in the governance of the water supply as both of these groups have the ability to affect management decisions made by the Commissioners. Historically, the decision to increase water rates and to use bond proceeds to fund new capital projects required the approval of voters through ballot questions. For instance, in 1998, the voters passed a proposition that prevented the Commission from raising water rates until July 1, 2006, except in the case of emergency (California State Auditor: 2000). However, in 2002, a number of changes were made as a result of approved ballot measures that would directly impact the future management of the SFPUC and the governance of the Hetch Hetchy Water System. As further described in the primary body of this report, approval authority for the use of bond revenues and water rate increases shifted from the voters of San Francisco to the San Francisco Board of Supervisors and multiple oversight functions were created to review bond financing, water and wastewater rates and oversee the implementation and financing of capital projects.

Reliance on the Regional Water System

There are key differences with regard to reliance on the Regional Water System between San Francisco County and the counties supplied with water by the wholesale customers. There are varying levels of dependence on the Regional Water System among each of the wholesale customers. San Francisco County relies on the Regional Water System, of which 85% comes from Hetch Hetchy, with the remaining 15% supplied by water imported from the Alameda and Peninsula watersheds and a small percentage supplied by groundwater (California State Auditor: 2000). Overall, San Francisco imports 97% of its water and the remaining 3% of water supplied is produced from groundwater.

Considered in the aggregate, wholesale customers have had fairly consistent patterns of reliance on Hetch Hetchy water and alternative water sources. The largest supply of water for wholesale customers is SFPUC supplied Hetch Hetchy water which accounts for 67% of overall water supply, followed by groundwater (15%); other sources (15%), local surface water (2%), and local water (1%) (BAWSCA: Website).

The pattern of water usage among the San Francisco retail customers and the suburban customers is also fairly consistent. In 2001-2002, the San Francisco customers consumed 84 MGD or about a third of the Regional Water System's imported water, leaving the remaining two-thirds, or 170 MGD for the suburban customers. More recent projections suggest that the usage relationship among the two groups was not changed.

Dependence upon the Hetch Hetchy water supply varies by wholesale customer, with some customers relying completely on SFPUC supplied water, while other wholesale customers require SFPUC produced water for less than half their overall water supply.

- Fifteen of the wholesale customers are completely dependent on the Regional Water System;
- Five customers are between 80% and 99% dependent;
- Five are between 60% and 79% dependent ;
- and four customers are less than 50% dependent on water supplies from the Regional Water System. (SFPUC: 2004)

Wholesale customers acquire their remaining water supply from groundwater, recycled water, water conservation and supplies from the State Water Project and other local water system imports. In 2001, the wholesale customers produced 272 MGD through a combination of water sources of which approximately 170 MGD was purchased from the SFPUC.

Projected Growth

Demographic trends and economic indicators can provide an approximation of regional growth. Much of the literature focused on the impact of water reductions on the Bay Area Economy identifies key indicators used to measure trends in population, water consumption and business activity. Comparing data across studies has limitations based on the time period studied, the source of the data and the definition of indicators, and the methods used for performing projections to predict future patterns.

One measure used to determine demand is the overall population served by the SFPUC. The SFPUC has used population as an indicator in some of its recent reports to predict future demand. In a 2005 report, projecting future suburban customer water use, the SFPUC reported that the 2001 population served by the suburban customers was approximately 1,623,560, and the projections indicate the population will increase to 1,933,829 by 2030, a 19% increase. Data from the State of California, Department of Finance, also show that population increases have occurred in each of the four counties served by the SFPUC. Between 1990 and 2003, the population increases are as follows:

- Alameda County (17%);
- Santa Clara County (15%);
- San Mateo County (10%); and
- San Francisco County (9%).

The trend in population growth between 1990 and 2003 and the SFPUC projection of population growth through 2030 suggest that the increasing regional population will have an impact on water demand if overall water supplies and management techniques are held constant.

In addition to population growth, the number of households is another indicator used to approximate the potential demand on water supplies. Like Bay Area population trends, the literature shows an increase in the housing stock from the early 1990's through the year 2005. The SFPUC projections indicate a continuation of this trend.

In 1990, the number of single family households was 1,028,814. By 2005, the number has increased to 1,254,007, and projections estimate the number of single family housing units will reach 1,509,771 by the year 2030. The trend and projection for multi-family residences follow the same pattern (SFPUC: 2004).

While population certainly affects the magnitude of demand for water, economic factors also play an important role. Certain manufacturing processes and other industrial and commercial activities (e.g., hotels) generate particularly large water demand relative to population-driven household use.

Measures of economic activity include employment numbers and the value of goods produced or sales achieved. In 2005, the SFPUC reported data that suggests that employment levels will increase in the region.

- San Francisco County recorded the number of employed persons in the year 2000 at 634,430, increasing to 656,480 by the year 2005. In 2030, SFPUC projects that 795,400 persons will be employed in the County of San Francisco (SFPUC: 2004).
- In 2030, the suburban service area will employ 1,488,566 persons, a 31.3% increase over the 2001 level of 1,134,097 persons (SFPUC: 2004).

The research reviewed did not indicate a projection for production values; however, below, we gathered some basic descriptive information from the US Bureau of the Census, which includes indicators for manufacturing and retail sales.

While the data presented in the table is far from conclusive, it suggests that great attention should be given to the collection of key performance indicators for regional demographics and economic activity. The aggregate data gathered from the US Census Bureau does not give a clear indication that projections will proceed in a linear direction.

Furthermore, some of the data listed in the table suggest that growth will not continue at the same pace as had occurred between 1990 and 2000. After the year 2000, the similarities in the trends across counties begin to disappear.

Selected Bay Area Indicators
US Bureau of the Census: County Demographic and Household Profiles

Population, US Census				
	1990	2000	2004 (2)	
Alameda	1,279,182	1,443,741	1,455,235	
San Francisco	723,959	776,733	744,230	
San Mateo	649,623	707,161	699,216	
Santa Clara	1,497,577	1,682,585	1,685,188	
No. of Households, US Census				
	1990	2000		
Alameda	479,518	523,366		
San Francisco	305,584	329,700		
San Mateo	241,914	254,103		
Santa Clara	520,180	565,863		

US Bureau of the Census: Fact Finder, County Level Information; Economic Census: County Level Information

Manufacturing, Value in Shipments, Economic Census				
	1992	1997	2002	
Alameda	17,011,000	22,337,780	29,632,054	
San Francisco	5,268,000	3,978,945	3,589,122	
San Mateo	5,596,000	6,690,069	8,304,922	
Santa Clara	47,458,000	72,528,275	47,110,263	
Retail, Sales, Economic Census				
	1992	1997	2002	
Alameda	9,685,000	12,404,947	16,512,174	
San Francisco	6,379,000	6,795,006	8,883,316	
San Mateo	6,190,000	7,335,405	9,017,029	
Santa Clara	13,181,000	16,673,573	20,035,462	

US Bureau of the Census: County Business Pattern Information (1)

Number of Establishments, County Business Pattern Data				
	1993	1997	2000	2003
Alameda	33,574	34,770	36,391	36,706
San Francisco	30,013	31,481	31,406	29,244
San Mateo	18,729	19,740	20,407	19,453
Santa Clara	39,862	43,374	45,655	43,738
Non-farm Paid Employees, County Business Pattern Data (3)				
	1993	1997	2000	2003
Alameda	501,857	576,640	655,730	625,672
San Francisco	487,834	516,816	555,647	522,391
San Mateo	291,869	319,674	372,908	323,302
Santa Clara	777,418	892,535	999,519	855,608
Annual Payroll, County Business Pattern Data				
	1993	1997	2000	2003
Alameda	14,615,563	20,596,825	28,627,936	28,571,099
San Francisco	16,811,193	21,708,569	31,060,972	29,116,420
San Mateo	9,877,409	12,892,965	22,916,966	17,885,798
Santa Clara	28,862,163	42,277,883	76,783,213	54,506,062

(2) County data for Alameda County, San Mateo County and Santa Clara County represent the entire County. The data is not limited to the SFPUC service area. Population data for 2004 based on estimates
(3) Employment measurement in County Business Pattern Report refers to non-farm, paid employees.

The table presents a few key issues that need further review, before accepting the projections presented in earlier studies.

- Population growth increased significantly between 1990 and 2000; however, 2004 population estimates suggest that population numbers may level in the coming years.
- Between 1992 and 1997, Value in Shipments for manufacturing industries increased for Alameda County, San Mateo County and Santa Clara County. The magnitude of the increase for the three counties varied significantly. San Francisco manufacturing industry has shown a lower value with each reported economic census. The 2002 data show that Value in Shipments only increased for 2 of the four counties served by the SFPUC. San Francisco continued to decline, and Santa Clara had a $25 million reduction in the value of shipments between 1997 and 2002.

- Retail Sales have increased for all four counties when comparing 2002 to 1997 Economic Census data and 1997 to 1992 economic census data.
- County Business Pattern data reveal that by 2003, the number of establishments, number of non-farm paid employees and annual payrolls for non-farm paid employees have leveled or declined for all four counties.

While not directly comparable to data reported in the study, the data listed above suggest that attention should be given to current baseline data before accepting available projections in the literature. Many of the water management plans and rationing policies are based on an assessment of future conditions, and these assessments generally come in the form of projections using baseline data and a set of assumptions for projecting future values. The data are consistent over the past decade in stating that there was generally increasing growth in the region that could impact future water supplies; however, more recent data suggest that population may be leveling off and economic growth may be shifting from one sector to another. This has important implications for drought management policy, conservation programs, and projects focused on identifying alternative water supplies as the magnitude of growth is a key factor the development of a plan to increase the reliability of water supplies.

Conservation Data and Practices

Since the late 1980s, conservation has been one of the region's primary water management strategies. Whether the driving force is environmental protection, business decisions based on cost reduction, or a strategy to increase the reliability of water supplies, many residents and businesses have actively worked to implement conservation techniques. At the same time, most customers will assess the benefit of a given conservation option against the cost to implement the option. The data support this practice as many of the conservation options implemented to date have involved changes to the plumbing code. Plumbing code changes are widely accepted as the cost of implementation is minimal and the modifications result in measurable reductions in water use.

Since the early 1990s, a number of changes to the plumbing code have been made by way of ordinances requiring the adoption of certain water conserving devices or compliance with defined practices for use. These ordinances have required a number of changes including installation of water saving toilets and urinals, the update of commercial buildings with retrofit devices and compliance with requirements for landscaping.

In addition, acceptance of conservation strategies has been supported by offering rebate incentives for the purchase of more efficient devices and the discounting of water prices for those customers implementing conservation devices. The incentive approach has achieved positive results with 95% of residential customers having signed affidavits through 2001 attesting to the implementation of water conserving devices (Retail Water Shortage Allocation Plan: 2001).

The SFPUC has long been a proponent of water conservation practices; in 1991, the SFPUC became a signatory to the *Memorandum of Understanding Regarding Urban Water Conservation* in California. By signing the MOU, SFPUC committed to the implementation of a number of conservation best management practices including plumbing retrofits, landscape conservation strategies, educational programming, conservation pricing and system audits.

Water consumption results prove that these strategies can significantly reduce water consumption. The SFPUC has projected that conservation activities related to the plumbing code will account for 10 MGD in water savings by 2030. The SFPUC has also identified more aggressive conservation options that could achieve an additional 4 MGD.

Prior Studies on the Economic Impact of Water Reduction: Southern Nevada and Tampa Bay

In addition to reviewing Bay Area specific studies, the project team reviewed two studies based on water shortage impact studies in Tampa Bay, Florida, and the Southern Nevada region. The purpose of reviewing these studies was to determine the type of methodology used in water impact studies for other locales and to determine if similar findings were derived in the assessment of economic impact.

The Impact of a Growth Interruption in Southern Nevada, 2004

The purpose of the Southern Nevada study was to replicate and update findings reported in an earlier report titled, "The Impact of a Water Imposed Interruption of Growth in the Las Vegas Region". This 1992 study, conducted by Hobbs, Ong and Associates concluded that a water disruption that sudden change made in the normal growth pattern for the region would cause large and undesirable fiscal and social impacts. The goal of the current study, including involvement of Public Financial Management on the core project team, was to update findings, but with a slightly different approach. Instead of specifying the nature of the impact, Hobbs, Ong and Associates decided to treat the cause of the interruption as an unspecified impact, assessing the impact of any change that would alter normal growth in the region.

By not defining the actual impact interrupting the growth pattern in the region, the first assumption in the methodology used is that regardless of the nature of the impact, the results will have similar impacts. Using forecast data from the Center for Business and Economic Research at the University of Nevada, Las Vegas and the Office of the State Demographer, the project team was able to set baseline values that were used to measure a series of impacts across sectors when their model of service interruption was applied. In addition, they used a widely accepted source for multiplier data that is used in conjunction with economic forecast.

After determining baseline values, the team developed a model for determining the effect of service interruption. A decision was made to study the impact on the construction industry as they hypothesized that the construction industry would likely be the most directly affected industry. The next step taken was the creation of a four part model, including an assumption of a three year impact, three scenarios for the severity of the impact measures by a 10% reduction, a 30% reduction and a 65% reduction; an assumption that the duration of time to recover would be ten years; and three scenarios for recovery defined as rapid recovery, moderate recovery and failure to recover.

Due to the voluminous number of findings, only the upper and lower bounds are reported for a couple key indicators, though it should be mention that for each level of severity results were produced based on each recovery model. In essence there are nine sets of results, including direct economic impact, indirect economic impact, direct fiscal impact, and population impact. In addition, to give context to the impacts reported, the study derives its measure from a regional source of economic data referred to as IMPLAN. The Implan model listed Clark County's economic output in 2000 dollars at $88 billion. This figure represents the value of output produced, not the actual sale of output.

Under the 10% interruption scenario, the project team found that the direct economic impact assuming a rapid recovery was $7.1 billion dollars over a fourteen year period (addition of 3 year impact duration added with ten year recovery assumption) and the failure to recover model resulted in $36.5 billion dollars. If the indirect losses are included in the 10% interruption scenario, the rapid recovery impact climbs to $10.0 billion dollars and the failure to recover increases to $72.2 billion. Using the 65% interruption scenario, the direct economic impact for the rapid recovery model is $48.3 billion and the failure to recover scenario results in an economic impact of $87.2 billion. By including indirect losses the numbers increase to $68.1 billion for a rapid recovery and $209.4 under the failure to recover model. Given these results, the overall findings for the impact of a growth interruption are significant even under the best case scenario of a rapid recovery from a ten percent interruption impact.

Impact of a Growth Interruption on Clark County (1)

Percent Impact	Recovery Model	Includes Indirect	Economic Impact in Dollars (in billions)	Percent of Clark County Total Output
10%	Rapid	No	$7.1	0.6%
10%	Rapid	Yes	$10.0	0.8%
10%	Failure	No	$36.5	3.0%
10%	Failure	Yes	$72.2	5.9%
65%	Rapid	No	$48.3	3.9%
65%	Rapid	Yes	$68.1	5.5%
65%	Failure	No	$87.2	7.1%
65%	Failure	Yes	$209.4	17.0%

(1) Economic impact values reported reflect impacts over a 14 year recovery period.

The major difference between this study and our SFPUC analysis, other than the locale, is that the Nevada study focuses on one industry and measures the ripple effect of impact by using multipliers. Our analysis is focused on economic impact as it applies to individual commercial and manufacturing categories and at the aggregate level. However, we see parts of the Southern Nevada as the next steps that might be taken to build on the current SFPUC economic analysis. The Southern Nevada study measures economic impact by the duration of the impact and multiple recovery models, in addition to the severity of impact.

Tampa Bay Water, 1999

In response an agreement reached in 1998 which reduced current water productions at existing wellfields from an annual average of 158 MGD to 121 MGD by January 1, 2003, Tampa Bay Water commissioned a study to assess the value of water that could be produced by new facilities suggested in the Master Water Plan.

In the development of their model, Oscher decided to use a calculation that measures the value of water in terms of end use. This is a different approach from the majority of studies that measure impact in terms of economic losses measured by lost sales or revenues as a result of reduced production. Using current water demand and price estimates and forecasting these values using a linear trend the team developed demand estimates.   The demand estimates were than applied to a calculation of value, using a range of demand elasticity values to account for the sensitivity of value calculations to small changes in demand elasticity values. The calculations of value were made to determine the price customers were willing to pay for increased value created with additional supplies.

Oscher Consulting concluded that based on the value added through additional water supplies, Tampa Bay Water could expect to charge more for water which would allow the capital costs of building new water producing facilities to be repaid in an eight year time frame. The basis of the conclusion is that the value of added water for uses valued by consumers would allow price to be adjusted accordingly to pay for the increased value created.

The goal of this Tampa Bay study was fundamentally different from the SFPUC analysis we are presenting in that the objective of this study was to measure the value of creating additional water supplies; whereas, our focus is to measure the economic impact of a reduction of water supplies on production outputs. It would be erroneous to assume that the value associated with a consumer's willingness to pay can be equated with the value lost as a result of reduced production. In fact, another study, *Economic Impacts of the Tampa Bay Water Master Water Plan*, focused on the economic impact on Tampa if the water facilities were not constructed, and estimated that the region would lose $5.7 billion dollars in Gross Regional Product. While of interest, it is clear that the results should not be compared to the current SFPUC study.

Drought Management Policies

A review of multiple drought management contingency plans identified a number of techniques that can be used to address reduced water supply levels. The drought management activities outlined in the SFPUC Interim Water Shortage Allocation plan were cross referenced with the techniques used in other locales to assess the overall comprehensiveness of the Interim Water Shortage Allocation Plan and to determine if there are other available techniques that could be considered. The Interim Water Shortage Allocation Plan is not viewed by SFPUC to be a complete drought management plan although it does contain some elements of that. It is important to note that, for the SFPUC, drought management policies must be crafted as appropriate to fit both its retail and wholesale roles.

We reviewed a report produced by the U.S. Environmental Protection Agency (EPA), which summarized the water conservation programs of 17 different locations, of varying size, that implemented water management plans to avoid the consequences resulting from unreliable water levels. Each of the locations reviewed had developed plans in response to regional growth, drought conditions, inadequate water supplies resulting from a lack of natural resources or expensive capital improvements. While the plans are not strict water rationing plans, the techniques used for conservation are aimed at water demand management, which is applicable to drought management.

In addition, we reviewed drought management contingency plans for Fort Worth, TX; Mesa, AZ; Peoria, AZ; Southern Nevada; and the Monterey Peninsula Water Management District, CA to examine whether rationing plans in other locales offered any promising management practices that might be incorporated by the SFPUC. We have included a summary table that identifies strategies used by each locale. The presence of an "X" means that they have a program meeting the condition listed at the top of the chart. Blank cells do not represent the lack of the program, a blank cell only represents that the literature did not refer program meeting the requirement. It is quite possible that some of these locations employ strategies not marked on the table.

In viewing the following table, one should note that whereas drought management is more focused on short-term management, conservation is aimed at long-term supply and demand.

Elements of Water Demand Reduction and Drought Management Plans, By Location

Location	Public Education	Seasonal Management	Management by Price	Plumbing Code Modification	Plumbing Retrofit Program	Rebate/ Cost-Sharing Incentives	Water Surveys/ Audits	Mandatory Landscape Conservation	Customer-Specific Water Conservation Plans	System Leak Detection	Housing/ Building Development Management	Water Reclamation	Mandatory Rationing
Conservation to Reduce System Demand													
Albuquerque, NM	X	X	X	X	X	X	X	X	X				
Ashland, OR			X			X	X			X			
Cary, NC	X		X			X	X	X	X		X	X	
Gallitzin, PA										X			
Gilbert Arizona	X		X							X		X	
Goleta, CA	X		X		X		X						X
Houston, TX	X		X		X		X			X			
Irvine Ranch, CA			X							X			
Massachusetts Water Resources Authority	X		X	X	X				X	X			
Metropolitan Water District of Southern California	X			X	X	X	X						
New York City, NY	X				X	X	X			X			
Phoenix, AZ	X	X	X	X	X		X				X		
Redwood City, CA	X		X		X	X	X		X	X			X
Santa Monica, CA	X		X	X	X	X	X	X					
Seattle, WA	X	X	X	X	X	X				X			
Tampa, FL	X		X	X	X	X			X				
Wichita, KS*													
Barrie, Ontario					X	X							
Drought Management Plans													
Location	**Stages**	**Voluntary Stages**	**Mandatory Stages**	**Management by Price**	**Pricing Stages, Residential**	**Pricing Stages, Non-Residential**	**Defined Rationing Percentages**	**Exemptions**	**Regulations by Sector**	**Moratorium on New Connections**	**Seasonal Management**	**Outdoor Restrictions**	**Sector Rotation**
Fort Worth, TX	X	X	X				X	X				X	X
Mesa, AZ	X	X	X	X					X	X		X	
Monterey Peninsula, CA	X	X	X	X			X		X			X	X
Peoria, AZ	X	X	X	X			X	X	X	X		X	X
Redwood City, CA	X				X	X	X			X		X	
Southern Nevada				X					X			X	X

Reading through the conservation and drought management plans, we determined that there are certain techniques that have been widely implemented across a number of locations. Consumer education programs, plumbing retrofits, and landscape conservation techniques, while important components of any plan, are hardly groundbreaking strategies for the Bay Area. These techniques have been widely accepted in the Bay Area; in fact, the Bay Area has been much more forceful integrating these approaches into their water management strategy. For plumbing conservation techniques alone, the SFPUC has implemented an incentive program to encourage the purchase of high efficiency products and local ordinances have been enacted modifying the local plumbing code to require the implementation of water savings conservation devices.

There are also strategies that are not as widely accepted across locales, such as leak detection programs, the installation of flow meters to limit use among excessive water users, and protocols for monitoring system water levels to prepare for potential drought scenarios. These practices are all clearly covered by the Interim Water Shortage Allocation Plan. Given the advanced nature of the Bay Area's water management protocols in comparison to the industry standard, we will only focus on management techniques that appear to suggest alternative approaches to water management as compared to the Interim Water Shortage Allocation Plan.

Overall, The Interim Water Shortage Allocation Plan appears to incorporate many of the strategies used by locations recognized as performing best management practices. The plan includes, system audits, management by price, the inclusion of drought response by stages, and adjusted rationing levels adjusted with each stage. The plan also has a clear set of defined protocols that identify responsible parties for each element of the plan. Nonetheless, our review did identify some practices – including the seasonal adjustment of water rates, business exemptions and the adjustment of rationing levels to reflect the value of water use – which are not referred to in the Interim Water Shortage Allocation Plan.

Seasonal Drought Management was used by a few locations to adjust for va riation over the course of the year. These plans track water usage patterns and adjust water rates accordingly. Phoenix, Arizona, Albuquerque, NM and Seattle , WA each refer to seasonal pricing method as part of their drought plans; however, it appears that this technique is used as a method of cost recovery as a result of higher operational costs to produce water during these periods, than an attempt to minimize the economic impact on the overall economy.

The San Diego *Guaranteed Water Plan* specifically references the importance of business on the local economy. The *Guaranteed Water Plan* exempts research and development firms and industrial businesses from water rationing during a drought as long as the businesses participate in their water conservation program.

Redwood City, one of the wholesale customers purchasing water from the SFPUC, provides an example of a city using a method to value water. In response to the protocols detailed in the Interim Water Shortage Allocation Plan, the City has recognized their vulnerability in the event of a water shortage. If the SFPUC set the rationing level at 20%, Redwood City would actually be rationed at 28.4% as an additional increase above the 20% level is made by SFPUC to the suburban customers and BAWSCA than applies an additional increase to Redwood City.

In devising a water management plan, city officials decided that they would ration water for each sector by two guiding principals: 1) Outdoor water use has more discretionary uses than indoor use, and 2) water use should be based on need, not historical demand. These concepts form a basic method of valuing water to match need by placing a higher value on indoor water uses and directing supplies from lesser valued uses (outdoor) to higher value activities. Applied on a larger scale, determination of value, by use, might help mitigate the overall impact of a water shortage on the region, by redirecting resources to uses of water that result in economic gains. Obviously, balance is needed in applying this method, and we are not suggesting that all water resources be redirected to business processes. This approach would take both open public discussion to grapple with political challenges and close monitoring to ensure that entities receiving larger volumes of water, as a result of the process of valuing water by activity, are using water in the most efficient manner possible.

Overall, the available water management and drought contingency plans do little to assess and mitigate the potential impact of water reductions on the overall economy. Two reasons are most likely responsible for this pattern: 1) Sharing the burden of water supply reduction is easier from a public policy perspective, reducing arguments of inequity and 2) It is simply easier to manage the process of an across the board cut, than to assess usage patterns by sector and season and adjust prices accordingly. However, the reality, as suggested by previous literature and the current analysis is that future water reductions of the "across the board" variety will have a significant impact on the overall economy.

In comparing the rationing levels set by other locations, we did not find that the rationing levels set by other locations were substantially lower than the level suggested in the Interim Water Shortage Allocation Plan. Some of the drought plans set more specific stages and list rationing levels with each stage; however, the most severe stages suggest that rationing levels would approach or surpass the 20% level referenced in the Interim Plan. The Monterey Peninsula Water District has a rationing level that goes up to as high as 50%. It should also be noted that the Interim Water Shortage Allocation Plan does not specify that water rationing will begin at a 20% level; the plan says that the agreement is binding up to 20%. This suggests that lower rationing rates can be enacted by the SFPUC.

Another potential option did present itself during our review of the Interim Water Shortage Allocation Plan. In the Tier 1 part of the plan, a process for banking credits and voluntary water transfers between wholesale customers is articulated. Water banking allows wholesale customers to transfer unused water allocations during a given period to a future period. Water can then be used at a later date above the specified monthly allotment in accordance with banked credits, or as account credits build, wholesale customers can sign voluntary agreements to transfer water credits to other wholesale customers.

The concept of transferring banked water credits caught our attention and evolved into a concept for further consideration. One could envision a process in which the same process of water credits and banking can occur below the wholesale customer tier, in which an industry or large water user could also bank credits for unused water allotments. However, instead of a voluntary transfer of water credits, the concept applies a market-oriented approach in which the credits are made available for sale to other retail customers. Customers not needing the full allotment of water would benefit from the sale of water credits, and customers desiring access to more water would benefit by increasing their supply of available water. This concept would still allow for an equitable allocation of water to retail customers, but it also creates a mechanism for redistributing water in a way that is mutually beneficial to the parties entering into the agreement.

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EMPIRICAL EVIDENCE FROM THE LITERATURE ON WATER SUPPLY AND RELIABILITY VALUES FOR RESIDENTIAL AND COMMERCIAL CUSTOMERS[4]

Residential customers of water agencies are adversely impacted by drought-related water use restrictions. The loss of value (i.e., economic welfare) borne by residential customers is not often consider as part of an economic impact study, because the focus of these studies tends to be on financial measures such as losses in business revenues and income, employment, and/or tax receipts. However, residential customers do have a real demand for water, and place a relatively high value on their ability to use water in ways in which they are accustomed (e.g., yard irrigation, car washing). A loss of reliable access to water for these valued residential uses would create a loss in the economic well-being for residential customers – what economists refer to as a loss of consumer welfare or "utility", as measured by "consumer surplus."

While drought-related losses in consumer surplus are "real" they are not often taken into consideration in economic impact studies, because such studies tend to focus on the "financial" impacts that can be tracked (or predicted) by changes in cash flows. However, there have been some relevant economic studies of residential demands for water, and on the willingness to pay (WTP) by consumers to avoid drought-related use restrictions. These studies provide a glimpse into the potential types and magnitude of losses faced by consumers in drought conditions. This chapter provides a summary of much of this available literature, offering an overview and discussion of recent literature on the use and value of water in the residential and commercial sectors in the United States. The reviews in this chapter are good examples of the types of water value estimates currently extant in North America. Future trends and conditions will certainly continue to alter the absolute and relative values, and thus require the reassessment of water allocation among competing demands.

While this literature review provides a good representative overview of the available information on the value of water in and across the residential and (in part) commercial sectors, interpretation and applications of these values to other sectors or locations should be done with caution. While there are a significant number of estimates of the cost and value of water provided in this section, it should be noted that there is relatively little information on the actual value of water, as measured by willingness to pay by consumers, for many of the sectors of water use. The value of water will be highly specific to regional, the consumers residing there, and temporal factors. Given that water use and values are highly specific to location, timing, and quality characteristics, the presented values should be seen as representative of the potential relative magnitudes of the values of water in each sector rather than as specific estimates of value applicable for transfer to other situations. All monetary values reported in this chapter and the rest of this report are provided in 2003 U.S. dollars (USD), unless otherwise specified.

Value Of Water In U.S. Residential Use

A relatively extensive body of literature deals with the economic aspects of residential water demand. Unfortunately, there is very little literature on WTP for residential water uses, and most of these studies focus almost exclusively on developing

[4] Most of this literature review is based on and drawn from Raucher et al, 2005, which was funded and managed by the Awwa Research Foundation.

countries. A small, yet growing body of economics literature examines WTP for specific attributes of water for residential use such as reliability. Most of the economics literature on residential water focuses on estimating demand and the factors influencing demand, particularly the price responsiveness (or price elasticity) of demand. A subset of this literature concentrates on measuring the relative effectiveness of price and other nonprice instruments (such as retrofit subsidies, rationing, and landscape irrigation controls) in reducing demand.

Given the preponderance of literature focusing on elasticities of demand, we examine this body of literature first. The discussion here centers on what estimated “elasticities of demand” actually measure and some common misconceptions about elasticities. Looking at the findings from the literature provides guidance on the appropriate role of these studies in water policy and planning decisions. The discussion then turns to existing WTP studies, and the implications of these findings for decision making and future research needs.

Price Elasticity of Residential Demand

The own-price elasticity of demand—frequently referred to as the price elasticity of demand—measures the relative responsiveness of the quantity of a good demanded to a change in its price. Technically, the own-price elasticity of demand equals the percentage change in quantity divided by the percentage change in price. As a result of the negative relationship between prices and quantity demanded, own-price elasticity of demand is always less than or equal to zero. It is nonpositive because as prices increase, the quantity demanded will never increase (all else equal).

Depending on the magnitude of the own-price elasticity, a change in demand is referred to as either “elastic” or “inelastic.” “Elastic” means that for a given percentage change in price (e.g., 1%) the corresponding percentage change in demand is greater (e.g., > 1%). “Inelastic” means that for a given percentage change in price (e.g., 1%), the corresponding percentage change in demand is less (e.g., < 1%). Thus, elasticities are a relative rather than absolute measure. An own-price elasticity estimate provides information only about small (or marginal) changes in prices (i.e., up to a few percentage points). It cannot predict the effect of a large, say 30%, increase in price. Additionally, elasticities are relative to the total quantity of water currently being consumed and the prices paid, so comparisons across households, let alone regions or sectors, should be done with caution.

It is often stated that residential water demand is price inelastic, and most of the empirical estimates support this argument (own-price elasticity of demand is usually between 0 and -1.0). This information is commonly used to argue that consumers do not respond to water prices. This is a false statement; consumers do respond to price but at correspondingly smaller rates. If elasticity is -0.30, for example, a 10% increase in prices results in a 3.1% decrease in demand. In addition, relatively small price responses may be because the prices of water are typically extremely low to begin with, and this is frequently ignored.

Table 1 shows estimated own-price elasticities demand from a number of studies sorted by geographical area, from west to east. Perhaps the most striking feature is the sheer range in estimates. There are many reasons why these estimates diverge, including extent and quality of information on the determinants of demand, specification of variables and functional form, and appropriate application of statistical techniques. For a more thorough discussion of why price elasticities of demand differ, see Espey, Espey, and Shaw (1997), Arbues, Garcia-Valinas, and Martinez-Espineira (2003), and Dalhuisen et al. (2003).

Table 1
Estimated own-price elasticities of demand

Study	Location	Time period of analysis	Own-price elasticity
Nieswiadomy and Cobb (1993)	US	1984	-0.64 to -0.17
Nieswiadomy (1992)	US	1984	-0.60 to 0.02
Williams and Suh (1986)	US	1976	-0.48 to -0.18
Williams (1985)	US	1970	-0.62 to -0.22
Howe (1982)	US	1963-65	-0.57 to -0.03
Howe and Linaweaver (1967)	US	1961-66	-0.23 to -0.21
Foster and Beattie (1979, 1981)	US	1960	-0.76 to -0.12
Conley (1967)	US	1955	-0.35
Moncur (1987)	Honolulu, Hawaii	1977-85	-0.68 to -0.03
Corral, Fisher, and Hatch (1998)	California	1982-92	-0.30 to 0.00
Renwick and Green (2000)	California	1986-96	-0.16 to -0.20
Cassuto and Ryan (1979)	Oakland, Calif.	1970-75	-0.30 to -0.14
Renwick (1996)	Santa Barbara, Calif.	1985-90	-0.33
Renwick and Archibald (1998)	Santa Barbara, Calif.	1985-90	-0.53 to -0.11
Billings (1990)	Tucson, Ariz.	1974-80	-0.72 to -0.57
Agthe et al. (1986)	Tucson, Ariz.	1974-80	-0.62 to -0.27
Agthe and Billings (1980)	Tucson, Ariz.	1974-77	-2.23 to -0.18
Billings and Agthe (1980)	Tucson, Ariz.	1974-77	-0.61 to -0.27
Young (1973)	Tucson, Ariz.	1946-64, 65-71	-0.65 to -0.41
Griffen and Chang (1990)	Texas	1981-86	-0.38 to -0.16
Hewitt and Hanemann (1995)	Denton, Texas	1981-85	-1.59
Hewitt (1993)	Denton, Texas	1981-85	-1.23 to -1.12
Nieswiadomy and Molina (1989)	Denton, Texas	1976-80, 81-85	-0.86
Nieswiadomy and Molina (1991)	Denton, Texas	1976-80, 81-85	-0.94
Hansen and Narayanan (1981)	Salt Lake City, Utah	1961-77	-0.51 to -0.47
Jones and Morris (1984)	Denver, Colo.	1976	-0.34 to -0.07
Schefter and David (1985)	Wisconsin	1979	-0.13 to -0.11
Gottlieb (1963)	Kansas	1952-57	-1.24 to -0.66
Chicoine and Ramamurthy (1986)	Illinois	1983	-0.47
Chicoine, Deller, and Ramamurthy (1986)	Chicago, Ill.	1982	-0.42 to -0.22
Wong (1972)	Chicago, Ill.	1951-61	-0.82 to -0.02
Lyman (1992)	Moscow, Idaho	1983-87	-3.33 to -0.4
Schneider and Whitlatch (1991)	Columbus, Ohio	1955-77	-0.44 to -0.11
Stevens, Miller, and Willis (1992)	Massachusetts	1988	-0.69 to -0.10
Carver and Boland (1980)	Washington, D.C.	1969-73	-0.70 to -0.02
Hogarty and Mackay (1975)	Blacksburg, Va.	1971-72	-1.41
Danielson (1979)	Raleigh, N.C.	1969-70	-0.31 to -0.27
Gibbs (1978)	Miami, Fla.	1973	-0.51 to -0.62

Source: Dalhuisen et al. 2003.

Caveats on Price Elasticity Estimates

Analysts and decision makers who are considering using existing own-price elasticity estimates are advised to use extreme caution. Own-price elasticity estimates are site-, time-, and price-specific; they measure responsiveness of demand to *small* changes in price for a given location, time period, and apply only to a narrow band of prices and quantities demanded (i.e., they apply only to small changes from current prices and quantities consumed). Thus, an own-price elasticity estimate for Northern California is likely to be unsuitable for decision making in Southern California, and an own-price elasticity estimate for Tucson from 1980 is most likely no longer accurate in 2003. In addition, elasticities are valid only for the range of prices used to estimate demand and only over relatively small changes in price. For example, if a demand function were estimated using observed prices of between $1.25 and $1.50 per thousand gallons (kgal), then it would be inappropriate to consider price changes using a price significantly higher than $1.50/kgal, say $2.50/kgal.

The Value Of Water Reliability

The reliability of a water supply refers to the ability to meet water demands on a consistent basis, even in times of drought or other constraints on source water availability. The available empirical evidence suggests that residential and Commercial, Institutional, and Industrial (CII) customers seem to value supply reliability quite highly, as indicated by the literature reviewed in this section.

A core goal of any water supplier, irrigation district, or city utility is to deliver a reliable water supply. Of course there is a cost associated with the development of greater reliability for a given water supply. The question then becomes: "What is the value of water supply reliability and are the associated costs justified?" The managers of water supplies are constantly confronting decisions that require tradeoffs between cost and risk, especially where drought and other hard-to-predict factors affect both the demand and supply of water. The monetary benefits of risk reduction are often not known because they are difficult to quantify; therefore, it becomes difficult to determine the optimal level of drought-related risk reduction. In general, valuing nonmarket goods requires special attention and can be complex, but attempting to ascertain transferable value for water supply reliability is further exacerbated because the value of reliability is dependent on the user of the water supply, its intended use, and abundance of water in the region.

Although interest in water supply reliability is increasing, few studies have directly attempted to quantify its value. The studies that have attempted to quantify the value of reliability used stated preference and revealed preference methods.

Revealed preference infers the value of reliability from data obtained from choices and decisions made in the market place. For example, expenditures made to obtain higher levels of reliability (i.e., to avert potential shortages) sometimes can be used to infer the value of reliability.

Stated preference methods determine estimates for reliability on the analysis of responses to hypothetical choices in surveys. While stated preference approaches have been applied to the valuation of nonmarket goods for many years, the method does have limitations that need to be acknowledged and considered. For example, Griffen and Mjelde (2000) note that one difficulty with stated preference studies for water reliability is the notion of the "birthright" perspective. It is not uncommon for respondents to view water as an inalienable right. Consequently, while they highly value water reliability, the notion that water should be free can lead to a reduction in their stated willingness to pay for reliability. However, if the limitations are acknowledged and efforts are made to perform the studies in an appropriate manner, stated preference studies can yield informative results.

Another method for quantifying the value of reliability attempts to infer values from available cost and price data. While cost does not necessarily equate value, the cost that a city incurs for increased storage to improved reliability can be used under some circumstances as a proxy for the value of a reliable water supply (although, ideally, a utility would apply *value* information to ascertain whether the *benefits* of added storage or other reliability-enhancing measures were worth the *costs*).

Additionally, avoided costs due to higher levels of reliability sometimes can be used to infer the value of reliability.

Stated Preference Studies

In 1987, a contingent valuation study was conducted for the Metropolitan Water District (MWD) of Southern California in an effort to determine the economic value for changes in the reliability of water supply among residents in Southern and Northern California. A reliable water supply is defined in the paper as “one without the threat of periodic shortages and mandatory rationing” (Carson and Mitchell 1987, p. 1). In the study, four scenarios of reductions in reliability are investigated and households’ WTP to alleviate the threat those reductions in reliability is determined. Reductions in reliability are defined in terms of magnitude and frequency. The scenarios with the associated annual median WTP are shown in Table 2, and reveal households are willing to pay considerable amounts per year (e.g., perhaps hundreds of dollars per year) to eliminate the probability that periodic future droughts might reduce their full ability to use water as they wish.

The study uses the 1983 census to determine that there were approximately 5.5 million households in the State Water Project service area. Multiplying the WTP per household by the number of households yields the annual aggregate value of providing greater water reliability. For the MWD residential customers, the results suggest annual values of $ 1 billion or more.

According to Carson and Mitchell, significant attempts were made to ensure that the estimated values are conservative and represent lower bound estimates. First, the study defines the value of water reliability in terms of willingness to pay rather than willingness to accept. Studies have shown that WTA is typically 2 to 6 times larger than WTP for public goods for which there are no substitutes (Carson and Mitchell 1987). Second, the study’s WTP estimates are based on median values rather than mean values. The authors note that, while mean WTP is usually used in economic valuation, mean WTP values are typically 1.5 to 4 times larger than median WTP (Carson and Mitchell 1987). Third, those respondents that refused to participate in the survey or responded “don’t know,” are treated as households who are truly not willing to pay the specified amount. Therefore, they are treated as respondents willing to pay $0 and are not discarded from the study as is typically done in contingent valuation studies (Carson and Mitchell 1987).

Table 2
Annual median willingness to pay for households under four scenarios (2003 USD) (baseline = household’s current consumption of water)

Scenario	Description of scenario	Household annual median WTP	Annual aggregate value of supply reliability ($ millions)
A	A 30-35% reductions from the baseline once every five years	$186	$1,027
B	A 10-15% reduction from baseline once ever five years	$135	$751*
C	A 30-35% reduction from baseline in two out of five years	$421	$2,280
D	A 10-15% reduction from baseline in two out of every five years	$248	$1,370

Source: Based on data from Carson and Mitchell 1987.
*The results for Scenario B were given using a 95% confidence interval ($653 million to $848 million). The mid-point of the confidence interval is reported in the table.

Though the authors attempt to be sound in their methodology, there are some problems associated with the study. The study uses a referendum format in the survey. In the discrete choice referendum format, respondents are asked whether they would vote yes or no on a referendum that would alleviate the threat of a water shortage for a specific magnitude and frequency, given a specified cost to their household if the referendum were to pass. This format of questioning has been shown to be inconsistent and usually overestimates WTP values (Jenkins, Lund, and Howitt 2003). Furthermore, the fact that the survey allows for the prevention of a water shortage (rather than a reduction in likelihood or severity) indicates that the WTP values should be interpreted as upper bounds for consumer valuations (Griffin and Mjelde 2000). The elimination of shortfalls is not a realistic scenario. However, it should be noted Griffin and Mjelde use an improved survey design, not allowing for complete avoidance of shortages, and obtained internally inconsistent WTP values.

In 1993, the California Urban Water Agencies (CUWA 1994) hired Barakat and Chamberlin, Inc. to design, conduct, and analyze the results of a contingent valuation survey to estimate the value to residential users of water supply reliability in 10 California water districts. More specifically, they sought to estimate how much residents are willing to pay to avoid water shortages of varying magnitude and frequency. Shortage magnitudes ranged from 10 to 50% and frequencies ranged from once every 3 years to once every 30 years. Bid amounts ranged from $1 to $50 (1994 dollars) increments to monthly water bills. The survey design was very similar to the Carson and Mitchell (1987) study and faced many of the same problems.

The study found that the household mean WTP for the detailed model over all counties varies from a low $14.49/month ($143/year) to avoid a 20% shortage once every 30 years to a high of $21.10/month ($253/year) to avoid a 50% shortage once every 20 years. The WTP results were not used to calculate annual aggregate value of providing water reliability as in the Carson and Mitchell 1987 study, nor is there any indication of the total number of users served by CUWA members. However, the study does indicate that the given levels of increase that residents are willing to pay per month per household on their monthly water bills demonstrate a significant value of water reliability in the area. Aggregating across all consumers in the state, additional customer payments would total more than $1 billion per year (CUWA 1994). Other findings include:

- As expected, WTP increases with increasing magnitude and frequency of shortages. Respondents were willing to pay to even avoid minor shortage scenarios.
- Users may make a greater distinction between “shortage” and “no shortage” than between magnitudes and frequency.
- Shortage magnitude is a more important determinant of WTP than shortage frequency.
- Individuals who indicated a desire for their community to grow have a higher WTP than those that wish for their communities to stay the same size or get smaller.
- Those respondents who considered water to be long-term problem in the area have higher WTP than those that did not.

The survey was carefully designed and executed well, and the study is cited several times in water reliability literature. However, it is by no means perfect. Like Carson and Mitchell (1987), a shortfall in the design of the survey was their use of WTP to “avoid” a shortage. Barakat and Chamberlin’s findings should be interpreted as upper bounds for consumer valuations pertaining to modified shortfall scenarios because the elimination of shortfalls is not a realistic scenario (Griffin and Mjelde 2000).

Furthermore, again like the Cason and Mitchell (1987) study, the survey asks questions in a referendum format, which may produce unreliable and usually overestimated values (Jenkins, Lund, and Howitt 2003).

Another stated preference study was conducted in seven Texas cities by Griffin and Mjelde (2000). Their first objective was to investigate the value of current water supply shortfalls (existing shortages of known strength and duration). Second, the study attempted to determine the value of future shortfalls, probabilistic shortages of differing strength duration and frequency.

Each questionnaire included two contingent valuation questions.

- The first CV question was a closed-ended WTP question that established a current supply shortfall of X% of the community's water demand expected to have a duration of Y summer days. The respondent was then asked if they would be willing to pay a one time fee of $Z to be exempt from the outdoor water restrictions.

- The second CV question was an opened ended WTP or WTA question concerning a hypothetical increase or decrease in future water reliability. An initial situation was posed to the respondent in which approximately once every U years a shortfall of V% would occur for a duration of W days. Depending on the particular survey, the question then posed a potential improvement of decline in one of the parameters and the other stayed constant. This question design is intended to be an improvement on the "avoided shortage" problem in the Carson and Mitchell (1987) and the CUWA (1994) studies.

The results of the WTP survey for households to be exempt from outdoor water restrictions due to the current shortfall are given in Table 3.

- For the average respondent, $32.04 is the avoidance value for a three week current shortfall of 20%. A one week increase/decrease in shortfall duration increases/decreases this value by $2.59. Every 10% increase or decrease in shortfall strength increases or decreases this value by $2.27.

- As duration increases, respondents are likely to pay more to avoid restrictions; therefore, the value of reliability increases with duration of the shortage.

Table 3
Respondents' WTP to avoid water restrictions from a single current shortfall event (2003 USD)

	Shortfall duration		
Shortfall strength	14 days	21 days	28 days
10%	$27.19	$29.77	$32.35
20%	$29.46	$32.04	$34.62
30%	$31.74	$34.31	$36.90

Source: Griffin and Mjelde 2000.

WTP and WTA measures were obtained as means from the survey responses as well as calculated from the tobit models. Both are presented below:

- Mean WTP and WTA per respondent are $109/year and $163/year, respectively.

- The mean tobit predicted WTP and WTA per respondent are $125/year and $170/year, respectively.

While the authors attempted to leave the future shortfall scenarios open ended for improved methodology purposes, the future shortfall values appear to be inconsistent with the reported current shortfall values. When the current shortfall values are used to calculate the future shortfall values, the calculated values are much lower than the WTP and WTA from the survey results The authors believe that the future shortfall valuation is the source of the discrepancy because the current shortfall valuation is easily understood by the respondents and is a common line of questioning for contingent valuation surveys. On the other hand, respondents did not appear to understand the future shortfall query. Using frequency to convey probability may have been a bad idea because of scaling problems and because respondents became confused by the added dimension of frequencies and probabilities. Therefore, while the Griffen and Mjelde study may have been an improvement in design from previous studies, their WTP/WTA results are inconsistent and somewhat overstated for small changes in future probability shortages (Jenkins, Lund, and Howitt 2003).

A study conducted by Howe and Smith (1994) attempts to formulate a framework for determining the optimal level of water supply reliability. The study uses contingent valuation survey methods to measure customers' willingness to pay for improved reliability and willingness to accept lower water costs for reduced reliability.

This survey was conducted in three Colorado towns: Boulder, Aurora, and Longmont. Respondents were asked to consider several specific changes in their city's level of reliability (increase and decrease) and to assert whether or not these changes would be acceptable if accompanied by appropriate (but unspecified) changes in their water bills. The first decrease (scenario 1) was smaller than the second decrease (scenario 2). The questions were set up in a "yes" or "no" format. For "yes" answers, quantitative WTA and WTP values were elicited from the respondents.

The type of shortage investigated in the study is a "standard annual shortage event" (SASE). The SASE can be defined as "a drought of sufficient severity and duration that residential outdoor water use would be restricted to three hours every third day for the months of July, August, and September" (Howe and Smith 1993). The base probabilities of the SASE occurring for each city were 1/300 for Boulder, 1/10 for Aurora, and 1/7 for Longmont. Their results were as follows:

- In Aurora and Longmont, the two towns with lower levels of reliability, consumers were not willing to pay enough to cover the cost of investment necessary to improve reliability. However, in the town with very reliable water supplies (Boulder), consumers were actually willing to pay less for reduced reliability.

- A household's WTA compensation for the first scenario (decrease in reliability in a range of approximately 0.7% to 11%, depending on the city) ranges from $68/year in Boulder to a high $166/year in Longmont. The WTA compensation for the second scenario (decrease in reliability in a range of approximately 1.7% to 40% depending on city) ranges from $81/year in Boulder to $240/year in Longmont.

- Two sets of WTP averages were developed for each scenario. The first average is based only on "yes" answers to the accompanying WTP. For the second average, "no" responses were counted as $0 and incorporated into the overall average.

  - The WTP for the first scenario (increase in reliability in a range of approximately 0.16% to 9.2% depending on city) ranged from $70/year in Boulder to $90/year in Longmont. The WTP including "no" respondents ranged from $16/year in Boulder to $28/year in Aurora.

  - The WTP for the second scenario (increase in reliability in a range of approximately 0.23% to 12.2% depending on city) ranged from $64/year in Boulder to $119/year in Longmont. The WTP including "no" respondents ranged from $15/year in Boulder to $29/year in Aurora.

- In general, as expected, larger WTAs are required for greater decreases in reliability and larger WTP are offered for greater increases in reliability.

The WTP results, when compared to the results of the other contingent valuation surveys, are clearly lower. The reason that Howe and Smith's results differ from the others is that their methodology is slightly different. Carson and Mitchell (1987) and CUWA (1994) both asked respondents their WTP for <u>complete avoidance of a shortfall</u> with given percentage. Griffen and Mjelde (2000) questioned respondents on their WTP to <u>reduce the probability</u> of, not avoid, the probability of a potential shortfall. All three of these studies are determining what people will pay to *maintain* their current well-being.

Howe and Smith approached the issue from the opposite direction. They determined respondents' WTP for a percentage *increase* in reliability. The lower values of their study may be attributable to the fact that respondents were already content with their current level of reliability. *People may be more willing to pay for maintaining a level of service they currently have than they will pay for a potential improvement in that service*, which is consistent with economic theory.

It should be noted that Howe and Smith study's emphasis on a single type of shortage, the SASE, limits the transferability of the results (Griffin and Mjelde 2000). More severe or moderate events are not considered in the calculation of the WTP/WTA results.

Another noteworthy observation about Howe and Smith's theory is that they set aside the potential role of price in managing excess demand during shortfall events (Griffen and Mjelde 2000). It often is difficult for water managers to use price as a demand management tool because of institutional controls, time lags, and local political considerations. However, districts in California have used price to help manage demand during periodic shortfall events (Fisher et al. 1995) and, as shown later, analysis of demand management using price can aid in estimating the value of reliability through avoided consumer loss due to price increases (Fisher et al. 1995).

Based on data from Michelsen, McGuckin, and Stumpf (1998), McGuckin (2000) estimated the WTP for water by residential customers in three Southwest cities—Albuquerque, N.M.; El Paso, Texas; and Las Cruces, N.M. The study estimated the economic loss if current water deliveries were reduced by 5% because of drought. To do this, the study used inverse demand functions to estimate WTP under current and 95% of current consumption levels, on a monthly basis, and found that the WTP for water at the 5% shortfall margin more than tripled in each city. The economic loss attributed to a potential drought was estimated as the difference in WTP before and after the reduction in use, multiplied by 12 months and the number of households. The findings are shown in Table 4. However, the research team's investigation suggests that there are several empirical limitations to this analysis and, therefore, McGuckin's empirical results should be interpreted with a high degree of caution.

Overall, while the stated preference studies discussed above are valuable in terms of gaining insight into the value of reliability, none of them are perfect in their methodology. Furthermore, the studies are unique to each location and situation. It probably is ill advised to attempt to use any single value for the transfer of benefits to other situations. However, in looking at the entire set of stated preference results, as summarized in Table 5, it is interesting to note the consistency in the range of values across all the studies. It appears the majority of households value water supply reliability in excess of $100 per year.

Table 4
Willingness to pay for water before and after drought: Three southwestern cities (2003 USD)

	Albuquerque		El Paso		Las Cruces	
	Current use	Drought use current less 5%	Current use	Drought use current less 5%	Current use	Drought use current less 5%
Residential use (kgal/mo)	14.7	13.4	13.3	12.0	16.6	15.3
WTP/kgal	$1.38	$4.40	$0.99	$3.95	$1.08	$3.55
WTP/AF	$450	$1,433	$322	$1,287	$352	$1,156
Number of households	107,000	107,000	120,553	120,553	18,840	18,840
Annual economic loss per household		$28.57		$29.38		$22.89
City total		$3,058,000		$3,342,000		$431,000

Source: Based on data from Michelsen, McGuckin, and Stumpf 1998, as interpreted by McGuckin (2000).

Table 5
Summary table of results from stated preference studies (2003 USD)

Source	Shortfall amount	Frequency	Probability	Annual WTP/household
Carson and Mitchell (1987)	10% to 15 %	1 in 5 years	20%	$135
Carson and Mitchell (1987)	10% to 15 %	2 in 5 years	10%	$248
CUWA (1994)	20%	1 in 30 years	3.3%	$143
Carson and Mitchell (1987)	30% to 35%	1 in 5 years	20%	$186
Carson and Mitchell (1987)	30% to 35%	2 in 5 years	10%	$421
CUWA (1994)	50%	1 in 10 years	5%	$253
Griffen and Mjelde (2000)	na	na	na	$109
Griffen and Mjelde (2000)	na	na	na	$125
Howe and Smith (1994)*	0.16% to 9.2%†	na	na	$80‡
Howe and Smith (1994)	0.23% to 12.2%†	na	na	$92§

na = not applicable.
*Howe and Smith (1994) also estimated WTA values for decreases in reliability. Mean annual WTA results per household for approximately a 0.7% to 11% decrease in reliability, depending on the city, ranged from $68 to $166. Mean annual WTA results for approximately a 1.7% to 40% decrease in reliability, depending on the city, ranged from $81 to $241.
† This percentage range does not represent the magnitude of the shortfall, as is the case in the other studies. Rather, this range represents increased probability over the base probabilities of the SASE. The actual percentage increase is dependent on the city. The associated dollar values are the annual WTP per respondent for an increase over their current reliability.
‡Value represents the average of the WTP range given in the study ($70 to $90 per year). If "no" respondents for this increased probability range are included into the data set (respondents' WTP = $0), the WTP range is from $16/year to $28/year per respondent.
§Value represents the average of the WTP range given in the study ($64 to $119 per year). If "no" respondents for this increased probability range are included into the data set, the WTP range is from $15/year to $29/year per respondent.

Revealed Preference Studies

Fisher et al. (1995) explored how price can be used as a tool to reduce demand during a drought. The authors note that the associated consumer surplus loss due to a price induced reduction in water consumption can be regarded as the benefit from mitigating drought through the construction of new storage capacity or operating a conjunctive use program.

Using estimated price elasticities for residential customers, the loss of surplus was computed with a price-induced cutback of 25% in consumption in the East Bay Municipal Utility District (EBMUD, California) service area. A demand reduction of 25% was used in the study because it is one of two EBMUD operation parameters for maximum acceptable demand reductions in drought (the less conservative parameter is 39%).

The authors produced a range of estimates using a selection of studies that most effectively addressed the econometric issues associated with calculation (Fisher et al. 1995). The selected studies, with varying demand elasticities, produce a range of welfare loss of $51 to $230/AF.

Inferring the Value of Reliability From Cost and Price Differentials

In 2002, the California Recycled Water Task Force was established to investigate specific recycled water issues. The economic group of the task force was charged with identifying economic impediments to enhancing water recycling statewide. The report uses a case study of the Ground Water Replenishment System (GWRS) in Orange County as an illustration for the importance of economic feasibility analysis. The GWRS was designed to recycle an estimated 70,000 AF/year of effluent and inject it into the Orange County Aquifer.

According to the Groundwater Replenishment System Financial study (Public Resources Advisory Group 2001), conducted for Orange County Water District and Orange County Sanitation District, the value of drought proofing (the value of reliability) based on drought penalties and rate increases for consumers is estimated at $179-$256 AF/year (and aggregate benefits of $7.8-$13.3 million per year for 40 years, with a total present value of $232 million, 5.5% discount rate) (2002 Recycled Water Task Force 2002).

The task force also looked at several other benefits realized from the Orange County Groundwater Replenishment System. They noted that one benefit of reusing wastewater is its availability year round, thus making it an uninterruptible supply. The lower bound value for the higher degree of reliability can be inferred through the difference between interruptible and noninterruptible supply if purchased from MWD in Southern California. In 2002, the price difference was $141/AF (2002 Recycled Water Task Force 2002). The study asserts that when the $141/AF is eliminated from future water supply cost calculations, the Groundwater Replenishment system will provide well over $10 million annually in terms of cost reductions for reliability (2002 Recycled Water Task Force 2002), but the study goes no further to show how they arrived at this estimate. Clearly, these values are unique to the GWRS; however, they illustrate the potentially high value of reliability, especially in relatively arid regions.

In a similar investigation in 1997, the National Research Council (NRC) estimated that if Orange County were to lose its reliable groundwater supply to salt water intrusion, the cost of securing water by the retail producers to serve their customers would jump from the 1997 cost of $106 million to $210 million. The $104 million increase arises because the water once pumped from the aquifer would now have to be purchased from MWD at the noninterruptible rate (NRC 1997).[5] The sharp increase in cost charged by MWD for noninterruptible water supplies highlights the fact that reliability has a key role in water pricing (Paul 2004). Water users are willing to pay a premium for water that is available to them in drought years. As actual or potential shortages worsen and demand outpaces supply, users are willing to pay more for water. Therefore, it can be assumed that water with a high reliability factor

[5]. In 1995, 300,000 AF were pumped from the basin at a cost of $158.33/AF (pumping assessment of $97.52/AF and an energy cost of $60.81/AF). The retailers in the district purchased 130,000 AF from MWD. Of the water purchased, approximately 100,000 AF was noninterruptible treated water at $488.76/AF. The additional 30,000 AF was purchased as seasonal shift water at $328.13/AF. In 1995, the cost of purchasing all water (groundwater and imported water) by the retail producers to serve their customers was approximate $106.2 million. If the groundwater basin had not been available, the entire 430,000 AF of necessary supplies would had to have been purchased at the noninterruptible rate of $488.76/AF.

will be much more valuable in the future than in the past and should be priced accordingly.

As mentioned earlier, while *cost* of a water project does not necessarily equal the *value* of the project or program, cost sometimes can be used as a lower bound proxy estimate of the value attached to increased reliability. For example, Varga (1991) investigated the role of local projects and programs in the City of San Diego to enhance imported water supply and improve reliability. MWD provides water to San Diego from the Colorado River and Northern California, based on availability. To encourage the use of existing local reservoir capacities and improve the reliability and yield of the imported water system, MWD and California introduced water rate credits for serviced cities.

- The first of two programs instituted was the Interruptible Credit Program. An interruptible credit applies to either treated or untreated water that either could be reduced or have its delivery interrupted by the MWD or another external agency. This program encourages water retailers like the City of San Diego to store water in reservoirs to overcome possible interruptions of imported water. In 1991, the interruptible credit rate was approximately $60/AF.

- The second program is the Seasonal Storage Credit program. A seasonal storage credit applies to water stored during seasons when imported water is available in excess of demand. This program encourages water agencies to use available local storage to increase the capacity and yield of the imported water system. The 1991 seasonal storage rate was approximately $111/AF.

MWD is paying for direct increases in reliability, and therefore, the credit rates can be used as the value for an AF increase in water supply reliability.

A 1996 study by Thomas and Rodrigo attached higher levels of value to storage than the MWD credit rates that Varga (1991) cites in his paper. Thomas and Rodrigo (1996) measured the benefits of nontraditional water resource investments. The focus of the study was on MWD and its member agencies. They investigated the benefits (expected yields and cost savings) of developing additional resources in the region through several alternatives: increased imported supplies (base case), the addition of significant conjunctive storage of local groundwater basins (groundwater case), and the implementation of recycled water and groundwater recovery projects (preferred case).

To determine the value of recycled water and conjunctive use storage, the savings attributable to each of these resources were compared to the yield associated with the resource. Thomas and Rodrigo note that “dividing the total present value of benefits by the expected groundwater replenishment deliveries (e.g., the difference between the base case and the preferred case and the groundwater case for conjunctive use storage), yields a dollar/AF index” (Thomas and Rodrigo 1996). In the case of conjunctive use storage, the modeling revealed that carryover or drought storage, which helps ensure greater reliability during dry periods, provides a benefit of approximately $353/AF to the region. Implementing the recycled water program would increase that figure by an additional $294 per AF.

An overview of the value of reliability inferred from results of revealed preference and cost-based approaches is provided in Table 6.

Table 6
Water supply reliability values inferred from revealed preference or cost and price differential results (2003 USD/AF)

Source	Value ($/AF)	Basis
Revealed preference studies:		
Fisher et al. (1995)	$51 to $230	Welfare loss per AF due to a price induced reduction in water consumption of 25%
2002 Recycled Water Task Force (2002)	$179 to $256	The value (AF/year) of drought proofing based on drought penalties and rate increases for customer
NRC (1997)	$331	The difference in cost of local groundwater supplies versus the MWD noninterruptible rate
Cost based studies:		
Varga (1991)	$60	The rate per AF that MWD credits local water retailers to store imported water in local reservoir to increase reliability of imported supplies
Varga (1991)	$111	The rate per AF that MWD credits local water retailers to seasonally store imported water to increase capacity and yield of imported water system
Thomas and Rodrigo (1996)	$353	The benefit per AF of conjunctive use storage to ensure greater reliability

Drawing Inferences About the WTP for Residential Water

Despite the considerable body of empirical research reviewed in the preceding sections regarding elasticity of demand and reliability values, there is a general lack of direct empirical evidence about how much residential customers of water utilities value the water they receive. This leaves open the key question of "how much are households willing to pay for the water provided by their community water system?" In this section, the research team applies a series of simple assumptions to interpret the available empirical evidence on reliability values, in a manner that provides some insight on the more basic issue of the WTP for residential water. In addition, the few studies that directly estimate WTP for residential water are reviewed.

Several of the reliability valuation studies summarized above provide WTP estimates for specific frequencies and severities of water shortfalls. These scenarios imply an approximate volume of water foregone over a given time period. The WTP estimates derived from these studies can be compared to the associated water quantities, to infer a monetary WTP per AF.

For example, Griffin and Mjelde (2000) evaluated a "current shortfall" scenario of 20%, lasting for 3 weeks. To estimate how much water is at stake in this scenario, consider that the average U.S. household uses approximately 0.5 AF per year (172 gallons per capita per day [based on Mayer et al. 1999], times 2.6 persons per household, times 365 days per year, which equals over 163,000 gallons per household per year, or about 50% of the 325,850 gallons in an AF). The shortfall scenario used by Griffin and Mjelde thus may amount to about 0.0058 AF of water (3 weeks out of 52 weeks being 5.77% of the year, times a 20% shortfall, times 0.5 AF per year, which equals 0.0058 AF). Given the estimated WTP to avoid such a shortfall was $32.04 per household per year, the implied value per at risk AF is $5,553 ($32.04 divided by 0.00577 AF).

Several caveats are required in evaluating a value estimate derived from this process. First, the assumptions applied to estimate the volume of water at stake might be in error. For example, if the water shortfall occurred in summer (which is likely), and the water use in summer is 2.4 times higher than in winter (the ratio of typical total use to indoor use only, as per Mayer et al. 1999, as discussed in chapter 3), then the implied quantity of water shortfall is understated. If the outdoor water use season in California (the study location) is assumed to be roughly one-half the year, then the 0.5 AF used per home per year comprises roughly 0.15 AF used in the winter months and 0.35 AF per household used in the six months in which outdoor irrigation occurs. The 3-week shortfall of 20% is thus equivalent to 0.008 AF (3 of 26 weeks of the outdoor watering season, times 20%, times 0.35 AF). Then, the implied residential customer WTP is $4,005 per AF ($32.04 divided by 0.008 AF).

Second, the reliability-based WTP values obtained by the original researchers reflect not just the value of the water per se, but also some degree of the residential customers' aversion to risk and uncertainty. In other words, the WTP values from the reliability studies undoubtedly embody some risk avoidance premium as well as the value held for the quantity of water at risk. This implies that the inferred WTP estimate would overstate the value of the water alone. This may be particularly true for the studies that value eliminating the risk of shortfalls, rather than reducing their likelihood or severity.

Third, the WTP estimates reflect values at the margin for the households' lowest valued current uses of the water (e.g., a portion of their outdoor irrigation). As more and more water is withheld from the households, the water uses that would be affected would be of increasing importance and value to the residential customers. Therefore, the WTP estimates inferred above might be understated compared to the WTP for water used for more highly valued purposes in the home (e.g., drinking, cleaning).

Finally, the reliability estimates we are interpreting are based on stated preference surveys of households. Given the hypothetical nature of some of the survey questions and the difficulty some respondents may have had with probability-based scenarios of water shortfalls and reliability, it may be the case that the results from the original research are skewed in one direction or the other.

Based on the above caveats, the values derived here need to be interpreted with considerable caution. There are reasons why the estimates may be under- or overstated relative to the true WTP of households for utility-supplied water. With these caveats in mind, by applying the general assumptions and procedures described above to the applicable reliability value estimates, the following illustrative WTP estimates for residential water are inferred:

- Griffin and Mjelde's (2000) current shortfall scenario implies a WTP for residential water on the order of $4,005 per AF.
- Carson and Mitchell's (1987) scenarios for MWD imply a possible WTP for residential water of between $4,675 and $7,714 per AF.
- The Barakat and Chamberlin study for CUWA (1994) implies a possible WTP of over $14,500 per AF.

As noted, these value estimates may be overstated for water use at the margin (i.e., for modest cutbacks in current outdoor uses), for reasons described above. In particular, the results based on Carson and Mitchell (1987) and CUWA (1994) may be overstated because they are based on certainty equivalents of eliminating future shortfalls. However, these estimates may be on-target, or possibly understated, for more essential water uses.
To provide some additional context for these results, some existing empirical research that examines water values more directly is described below. Colby (1989b) presents a simple, utility-theoretic model of water demand and consumer surplus to present a synthesis of water value studies for different water uses. Of particular

relevance is the work of Young and Gray (1972), who found that the national value of residential outdoor water use is $810 per AF, and the value for indoor use is $1,435 per AF. This study is more than 30 years old, and so the values, even as updated by the Consumer Price Index (CPI) here, may not be entirely applicable today.

Gaudin, Griffin, and Sickles (2001) used data from 221 Texas communities to estimate a utility-theoretic Stone-Geary demand function for municipal water. Based on estimated demand curves, loose lower-bound assumptions, and simple geometry, total WTP (i.e., at a zero price) for *discretionary* municipal water use (as opposed to basic necessity water use) is $267 per person per year. Assuming a typical household size (roughly 2.6 persons per household), this amounts to about $700 per household per year. Assuming typical water use patterns of outdoor use being roughly 60% of total household use (Mayer et al. 1999), and assuming outdoor uses are largely discretionary and indoor uses are largely nondiscretionary, then about 0.3 AF may be assumed to be discretionary use by a typical household (60% of 0.5 AF per household per year). This suggests a value of $2,333 per AF for discretionary uses ($700 divided by 0.3 AF). Higher values would be expected for essential water uses.

In conclusion, based on the body of empirical evidence provided above, it is clear that households hold a high value (WTP) for their residential uses of water. While each of the above value estimates has some limitations, it seems likely that values of at least $800 to $1,400 per AF apply for non-essential water uses by residential customers of water utilities. The evidence also suggests that WTP values as high as $4,000 per AF, or perhaps considerably higher, may apply for current residential water uses.

Water Use And Value In The Commercial, Industrial And Institutional Sectors

This section presents an overview of water use in the commercial, industrial, and institutional sectors in the United States and provides a brief literature review on the value of water to these sectors.

Nonresidential water use accounts for 53% of total water use in U.S. community water systems (CWSs), and of that, over 70% is delivered to commercial, industrial, and institutional water users (RMI 2003). Moreover, self-supplied commercial, industrial, and institutional facilities use about as much water as all public and private community water systems put together (RMI 2003). Commercial, industrial, and institutional (CII) sectors alone have a significant impact on water consumption, particularly in urban areas. Nearly one-fourth of the potable water demand in an urban area is made by a wide variety of CII customers who in turn devote the water to a wide variety of end uses (Aquacraft 2003). To reveal the relative shares of the CII sectors, Table 7 displays the categories of water users and their water use and corresponding percentages during 1995.

Industrial Water Use

Industrial water use (27,184 mgd in 1995) includes water for such purposes as processing, washing, and cooling in facilities that manufacture products (Solley, Pierce, and Perlman 1998). Major water-using industries include, but are not limited to, steel, chemical and allied products, paper and allied products, and petroleum refining.

Table 7
Water use by sector in 1995 (all values in million gallons per day)

	Millions of gallons per day	Percent of total water use*	Percent of public supplied water†
Thermoelectric	189,900	47%	<1%
Irrigation	134,000	33%	
Industrial	27,184	7%	12%
Domestic	25,902	6%	56%
Commercial/institutional	9,724	2%	17%
Livestock	5,490	1%	
Mining	3,770	1%	
Total	401,800	100%	85%†

Source: Solley, Pierce, and Perlman 1998.
*Figures may not add to totals because of independent rounding.
†Fifteen percent of public water is unaccounted for water or public use and losses. This unaccounted for water represents 2% of freshwater use.

Commercial and Institutional Water Use

Commercial and institutional water use includes water for motels, hotels, restaurants, office buildings, other commercial facilities, and civilian and military institutions. The USGS Survey estimates of CII water use (9,724 mgd) also include public-supply deliveries to golf courses (Solley, Pierce, and Perlman 1998).

Similar to industrial water use, 14% of CII water use is consumptive use and 86% is return flow (Solley, Pierce, and Perlman 1998). The public supplies 70% of the CII water needs, while the rest of the CII sector meets its water needs by self supplied withdrawals (Solley, Pierce, and Perlman 1998).

In 1998 the AWWA Research Foundation (AwwaRF) funded a study on the Commercial and Institutional End Uses of Water (Dziegielewski et al. 2000). This study spent two years working with five municipalities to create a database of a representative sample of CII customers from existing information, which was verified by field studies. The study team evaluated several characteristics of 11 categories of CII customers, shown in Table 8. Table 8 includes both the average annual use by customer category and the scaled average use, which combines the intensity of use for each category with the prevalence of the category in the municipal system.

Five of the 11 categories were selected for further study. These five categories were chosen because they ranked high on the list of scaled average daily use, which means they are significant both in terms of average use per customer and as a percentage of the total CII use in the municipal system. The final five categories selected for the study were schools, hotels/motels, office buildings, restaurants, and food stores.

Schools/Colleges

Schools and colleges comprise approximately 9% of the total CII water use. They may range from very small facilities where water use is limited to hand washing and toilet facilities to large campuses requiring water use for swimming pools, showers, and food preparation and service. Water may be used for seasonal and nonseasonal purposes; however, separate metering data for these purposes are not always available. Some campuses may serve students on a year-round schedule while others may follow a more conventional schedule with minimal use during the summer months.

Hotels/Motels

Water use in hotels and motels is 6% of the CII water use. Water use is affected by the number of rooms, the number of occupants, and services provided, ranging from icemakers and water cooling to swimming pools, spas, laundry, and restaurants. In-room use for toilets, faucets, and showers places the most significant demand on water use; irrigation, cooling, and swimming pools contribute a seasonal component of water use for many facilities.

Office Buildings

The CII water demand for office buildings is approximately 10%, the highest water user of the five categories evaluated in the AwwaRF study. Occupancy rates and worker numbers affect the water use in office buildings, as does water for seasonal purposes such as irrigation and cooling. Further, the number and types of business found on the first floor of large office buildings vary and may include restaurants, salons and florists, all requiring diverse uses of water. While disaggregation of water uses in office buildings often presents a challenge, much of the water is used for typical domestic purposes such as faucets, toilets, cleaning, cooling, and irrigation.

Table 8
Characteristics of significant CII categories in five participating agencies

Customer category description	Average annual daily use (gpcd)	Coefficient of variation in daily use (gpcd)*	Percent of total CII use (%)	Percent of CII customers (%)†	Percent seasonal use (%)‡	Scaled average daily use (gpcd)§
Urban irrigation	2,596	8.73	28.48	30.22	86.90	739.0
Schools and colleges	2,117	12.13	8.84	4.79	57.99	187.0
Hotels and motels	7,113	5.41	5.82	1.92	23.07	414.0
Laundries and laundromats	3,290	8.85	3.95	1.38	13.35	130.0
Office buildings	1,204	6.29	10.19	11.67	29.04	123.0
Hospitals and medical offices	1,236	78.50	3.90	4.19	23.16	48.0
Restaurants	906	7.69	8.83	11.18	16.13	80.0
Food stores	729	16.29	2.86	5.20	19.37	21.0
Auto shops	687	7.96	1.97	6.74	27.16	14.0
Membership organizations	629	6.42	1.95	5.60	46.18	12.0
Car washes	3,031	3.12	0.82	0.36	14.22	25.0

Source: Dziegielewski et al. 2000.
*Coefficient of variation in daily use: The ratio of standard deviation of daily use to average of daily use.
†Percent of CII customers pertains to CII customers in agencies that have respective category only.
‡Percent seasonal use = [(total annual use—12 H minimum month use] / total annual use.
§Scaled average daily use = average annual daily use in category x percent of total CII use attributed to the category.

Restaurants

Overall, restaurants account for approximately 9% of CII water use. A 2001 study of water use for Westminster, Colorado, revealed considerable variation in water use per meal prepared based on the type of restaurant. The results of this study revealed that Chinese restaurants used significantly more water than average while fast food restaurants used significantly less (Aquacraft, Inc. and Stratus Consulting 2001). Typical water uses for restaurants include faucets for bathrooms, food preparation, and janitor closets; dishwashers; toilets; ice makers; irrigation; and cooling.

Food Stores

Food stores account for approximately 3% of CII water demand, and the water use per customer is dependent on factors such as hours of operation, amount of refrigeration, type of cooling system, the number of aisles, types of services, presence of restroom facilities, and the use of mist sprayers on vegetables. Typically, however, water used in the cooling system for refrigeration represents more than half of the water used for all other purposes combined.

Value of Water to the Commercial, Industrial, and Institutional Sectors

The value of water to the commercial, industrial, and institutional sectors has not been studied as extensively as the value of water used in other sectors such as the agriculture and residential sectors (Renzetti and Dupont 2002). Thus, while it is commonly believed that commercial, industrial, and institutional water use is a relatively high value application of water (Frederick, Vandenberg, and Hanson 1997), there is actually relatively little empirical evidence to support this (Renzetti and Dupont 2002).

Values of Industrial Water Use

It is difficult to develop empirical estimates of estimate value for industrial water use largely because most industries self-supply their water, and pay little or nothing for their raw water input (Dinar and Subramanian 1997). Where industries have had to make purchases on water markets, those prices may be examined.

Frederick, VandenBerg, and Hanson (1997) examined seven industrial water valuation studies (the most recent of which was 1982) and found the median value of industrial water intake to be $132/AF (1994 USD), with a range of values from $28 to $802/AF. Renzetti and Dupont (2002) created a model, applied it to the manufacturing sector in Canada at the margin, and found a much lower median value (less than $1/AF). The authors attribute the low estimate to the fact that manufacturing in Canada self-supplies 90% of their water needs at almost zero internal cost, and that marginal costs for the remaining water needs are very low.

Water used in the production process can also be estimated by examining its value as an input to production. The ratio of the value of the output and the quantity of water intake may offer some insight; however, this method cannot be used as a shortcut to obtaining water values because it is the value of the marginal products that is needed, which is extremely difficult to extract from typical production data. In addition, Renzetti and Dupont (2002) point out that this approach does not account for the contributions to production of non-water inputs and for differences in revenue across firms that are related to the structure of output markets. Renzetti and Dupont (2002) also mention that two studies have used this approach: Giuliano and Spaziani (1985) and Mody (1997). Table 9 lists the water needs of various products for illustrative purposes, but provides no values for these quantities of water because of the inherent difficulties described above.

Table 9
Water needs of selected products

Product	Water use (gallons)
1 day's supply of U.S. newsprint	300,000,000
1 ton of steel	62,600
1 new car	39,090
1 ton of beet sugar (water used to process)	33,100
1 ton of cane sugar (water used to process)	28,100
1 kilowatt-hour of hydroelectric power	4,000
1 barrel of crude oil (water used to refine)	1,851
1 barrel of beer (water used to process)	1,500
1 ton of cement	1,360
1 car or truck tire or inner tube	518
1 pound of wool or cotton	101
1 pound of synthetic rubber	55
1 pound of plastic	24
1 gallon of paint	13
1 chicken (water used to process)	11.6
1 computer chip	10
1 can of fruit or vegetables (water used to process)	9.3
1 board foot of lumber	5.4
1 pound of meat (water used to process)	3.6
1 quarter pound of hamburger (water used to process)	1

Source: U.S. EPA 1995.

Values of Water to the Commercial and Institutional Sector

Values of the water used in the CII sector are also difficult to estimate. Information on CII withdrawals is limited but may be available through state agencies that permit withdrawals or require permits to operate potable water supplies (Solley, Pierce, and Perlman 1998). In many cases, withdrawal estimates are based on the population of the commercial facilities, that is, the number of students attending a university, inmates in a penal institution, workers in an office building, or the average occupancy rate of a hotel, rather than actual reported use (Solley, Pierce, and Perlman 1998).

Aquacraft (2003) analyzed the value of CII water and found that it is intimately connected with the purpose for which the water is being used. The study examined water use in three CII sectors (office buildings, hotels, and dialysis centers,) and concluded that low priority end uses have low values to the customer and high priority end uses have high values. In other words, faced with an increase in the price of water, the customer would first reduce or eliminate the low value uses before considering changes to those of high value. Water can be a convenience in some uses, but in others it can be an irreplaceable commodity.

For example, the study examined the relative value of water by observing water use patterns in two comparable office buildings. Building 1 is a relatively efficient user and Building 2 is a very heavy user. They deduced that the marginal value of water in Building 1 is greater than the marginal value in Building 2, since reducing water use in Building 2 (by upgrading fixtures and repairing leaks) would be relatively more simple (quicker and less costly) than reducing water use in Building 1. The net effect would be that because it would be less costly for the owners of Building 2 to reduce their water consumption, it would take a smaller increase in the cost of water to motivate them to do so. In Building 1, on the other hand, the inexpensive conservation steps have already been taken, so additional reductions would be more costly, and the owners would require a larger increase in the price for them to be justified from an economic perspective in making these upgrades.

In a second example, Aquacraft (2003) compared the average daily water use per room in five hotels. Water use in four of the hotels was very similar (about 78 gallons per room per day), while one of the hotels used 204 gallons per room per day. This hotel is a luxury hotel with high water using fixtures in the rooms, including extra deep soaking tubs and multihead showers. The rooms also include wet bars. The study deduced that the four hotels had probably eliminated most of the low value water use in the rooms, while the high water use hotel provides a great deal of luxury water use to its guests, and would be presumably more subject to reduction in response to price changes.

These two examples clearly support the long-held notion that the efficiency with which water resources are produced and consumed can be improved considerably if the general principles of marginal cost pricing are used as a guide in evaluating water pricing policies (Hanke and Davis 1973).

A similar conclusion was reached when water use was investigated at one of the largest dialysis clinics in the Midwest. Each year this center treats 300 patients, who each require 150 dialysis treatments per year. Water is essential for this process, and one would imagine that it would have such a high value that a very high price would be paid. However, because the costs of maintaining a patient on dialysis are paid by Medicare, Medicaid, and private companies, cost increases cannot be passed along and every effort must be made to contain all costs rigorously.

The total water used at the dialysis center in a typical year averages 12.5 million gallons. Of this, the major uses are 2.25 million gallons for dialysis, another 2.25 million gallons rejected in the purifying process (explained in further detail below), 2.0 million gallons used by the laundry, and 1.0 million gallons used by the staff for sanitation and cleaning (see Table 10). It was estimated that 2.75 million gallons of water use per year is unknown (this is a very large volume for this type of facility, and warrants further investigation).

The reject water is produced in the purifying process as the center produces its ultra-pure water on site using city water as raw material. During this process, for every gallon of final product water, about another one-half gallon is rejected. This reject water is currently wasted to the sewer.

Table 10
End uses of water at dialysis center

End use	Amount (kgal)
Dialysis water	4,220
Reject water	2,260
Toilet, urinals, hand sinks	1,000
Cleaning	50
Irrigation	20
Cooling and cooling system bleed	200
Laundry	2,000
Unknown (leaks, other uses, etc.)	2,750
Total	12,500

Source: Aquacraft 2003.

Next, water costs were examined, and unit water and wastewater costs amounted to $2.31 and $4.02/kgal, respectively (see Table 11). The average budgeted cost for water and wastewater at this facility, excluding the laundry, is approximately $76,000 per year. When non-personnel costs for this facility were examined, water and wastewater charges were found to rank sixth in a list of 18 categories of non-personnel costs.

Table 11
Water and sewer charges for dialysis center*

Parameter	Volume (kgal)	Water charge ($)	Sewer charge ($)	Total charge ($)
Water consumption	12,536	28,876	50,212	79,880
Unit price ($/kgal)		2.31	4.02	6.33

Source: Aquacraft 2003.
*Estimated from 1st quarter 2003 water and wastewater bills.

The study concluded that the value of water ranged from a value of practically zero for the reject water (and a low value for the leakage and unaccounted water) to almost infinite for the water used for the actual treatment (the value for this water relates to the value placed on maintaining the lives of the 300 patients using the center each year), with the small amount of water used for domestic and irrigation uses falling in between.

The Aquacraft study then pointed out that another way to gauge the value of water to a particular group of customers is to observe how their use patterns change as a function of price. This provides a measure of the elasticity of demand. The inverse of this value, sometimes referred to as the elasticity of value, provides a fairly direct estimate of the relative value the customer would place on the next unit of consumption in the face of a unit increase in the price.

Aquacraft reviewed a study (Lynne, Luppold, and Kiker 1978) on the responsiveness of a group of commercial water users in south Florida that used a multiple regression modeling approach. The use of water was modeled as one of several inputs required for the production of a specific good or service. Since this water had an easily determined cost, it was possible to create what the authors referred to as a "derived demand" model using regional data from south Florida of the response of water use to changes in its price for a range of commercial customers.

The study included 4,356 customers in the Miami/Florida Keys area. Five categories were examined: department stores, grocery stores, drinking and eating establishments, motels and hotels, and "other commercial." Price elasticities for each customer category were determined by regression techniques. All had the expected negative slope (reflecting the decrease in demand in response to increases in price), but their magnitude varied considerably (see Table 12). Department stores had the largest absolute value of price elasticity and therefore are expected to have the largest response of the sectors to price changes, while eating and drinking establishments had the smallest absolute value of price elasticity, and therefore would not be expected to change their water consumption much (compared to the other sectors) in response to water price changes.

Table 12
Price elasticities for commercial customers in Miami/Florida Keys

Category	Price elasticity
Department stores	-1.074
Grocery stores	-0.719
Other commercial	-0.480
Motels and hotels	-0.175
Eating and drinking	-0.174

Source: Based on Lynne, Luppold, and Kiker 1978.

Summary of Water Use and Value in Commercial, Industrial, and Institutional Sectors

Even though the allocation of water is not often optimized in an economic sense, available commercial, institutional, and industrial water values can be compared within their sectors and among other water uses (such as domestic and agricultural, or even instream flow values for recreation and ecosystem support) to reveal the wide range of values that exist for various water uses. Drought, natural disasters, and structural failures in water supply systems sometimes lead to temporary water shortages, and minimizing economic losses would require knowing where the least valued water is provided (Renshaw 1982).

Values among the sectors tend to vary significantly by region, yet some relative values may be consistent across regions. Another factor affecting value is time. Future market values depend on a particular industry's sustainability with regard to its inputs (water, in particular) and the fate of each industry (i.e., their economic growth or decline).

Water Values And Community Economic Development

Changes in water use may affect specific sectors of the economy (e.g., tourism, agriculture), which will have secondary effects on the regional economy. Initial impacts are directly experienced through changes in expenditures. Subsequent, indirect impacts are experienced as the other industries that serve as inputs to production experience changes in demand for goods and services. This creates a multiplier effect, because there are multiple rounds of industries purchasing from other industries. Also, there are changes in money put into the local economy in the form of wages and spending by households. All of these economy-wide impacts can be estimated from the industry-specific economic changes by use of a number called an economic multiplier.

The multiplier is a factor that when multiplied by new or increased expenditures (or reductions in expenditures) yields the benefits (or reductions in benefits) to the region. In this context, the term "benefits" usually refers to levels of economic activity, such as total wages or income or employment in the region. Different industries have different multipliers—some industries tend to produce greater regional, or even national, impacts than others.

Michigan State University's "Multiplier" webpage states that the size of a multiplier depends on four basic factors: (1) the overall size and economic diversity of a region's economy, (2) the geographic extent of the region and its role within the broader region, (3) the nature of the economic sectors under consideration, and (4) the year (MSU 2003).

Regions with large, diversified economies producing many higher order goods and services will have high multipliers, whereas regions that are not able to buy and hire locally will have low multipliers. Large geographic regions will have higher multipliers, all other things equal, than small areas because transportation costs will tend to inhibit imports. Multipliers vary across different sectors of the economy based on the mix of labor and other inputs and the propensity of each sector to buy goods and services from within the region. Tourism-related businesses tend to be labor intensive and thus tend to have larger induced effects rather than indirect effects. A multiplier also depends on the characteristics of the economy at a single point in time. Multipliers for a given region may change over time in response to changes in the economic structure as well as price changes.

The Minnesota IMPLAN Group (2003) has estimated multipliers for over 500 industrial sectors at the county, state, and national levels for estimating regional, statewide, and nationwide economic projections. Their "Multiplier Report Package" is available for $500 and contains multipliers for 528 industrial sectors, either for the nation, state, or county.

The industrial sectors identified here as potentially affected by water use changes are recreation, tourism, hydropower, agriculture, and municipal water for home use. The literature was examined to determine if general multiplier estimates were available for these sectors, and the results are summarized below.

Different multipliers have been estimated for different types of recreational activities (e.g., fishing, kayaking). Cordell et al. (1990) estimated regional economic multipliers of 2.00 and 2.03 for the total economic effects of water-based recreation expenditures on local economies. That is, for every $1 spent on water-based recreation, the total regional economic impact would be $2.00 to $2.03. Norton, Smith, and Strand (1981) estimated a range of multipliers from 2.03 to 2.88 in an analysis of the total economic value of recreational fishing. Therefore, a range of literature-based multipliers from 2.00 (the low end of the range of Cordell et al.) to 2.88 (the high end from Norton, Smith, and Strand) might reflect expected regional impacts from changes to water-based recreation expenditures.

Changes to recreation use of resources often affect recreation-based tourism. Small communities or communities with simple, narrow-based economies may have tourism multipliers of 1.0, and large communities with broad economic bases may have multipliers approaching 3.0 or 4.0 (TAMU 2003). However, most tourism-related multipliers appear to be under 2.0. Michigan State University operates a "Michigan Tourism Economic Impact Calculator" webpage, which can translate visitor spending in Michigan into economic impacts (MSU 2003). The calculator uses a set of multipliers from 1996 Michigan IMPLAN data; a sales multiplier for a typical tourist spending pattern is 1.6 for statewide impacts, 1.45 for metro regions, and 1.3 for rural regions. A similar multiplier of 1.5 was used for ski-tourism impacts in Colorado (Goldsmith, Seidl, and Weiler 2001), and 1.68 was used in a study that examined the impact of fall tourism on the Vermont economy (UVM 2001). One study that examined the economic impacts of reduced recreational opportunities in northern Tampa Bay lakes used IMPLAN multipliers for the general merchandise retail business. The specific multipliers used were not given in the analysis, but the authors do mention that a more precise multiplier would be derived by modifying the IMPLAN model to reflect the specific types of business being evaluated.

Reductions in water flows available for hydropower could primarily affect the economy through power prices because an alternative might increase the cost of power, which in turn could affect the viability of local industries. This case was illustrated in the Federal Energy Regulatory Commission's (FERC's) analysis of the Ripogenus and Penobscot Mills projects in Maine (FERC 1996). In relicensing proceedings, the applicant (Great Northern Paper) claimed that changes in streamflows would add incremental costs to its production of pulp and paper products that might threaten the viability of some of its mills. FERC largely agreed with the applicant's analysis, concluding that increased power costs could have significant repercussions for the Maine economy. This study used a multiplier of 2.61 to estimate total employment impacts in Maine.

Changes in the amount of water available for agriculture may have economic impacts to the agricultural sector and related industries. The Oklahoma Cooperative Extension Service (Song and Doeksen 2003) estimated two multipliers for the agriculture industry: one for income effects (change in personal income resulting throughout the economy from a $1.00 change in income in a sector) and another for employment effects (change in employment due to a one unit change in the labor force in a specific sector). The income multipliers estimated for the livestock and crop sectors were 2.72 and 2.51, respectively. The employment multipliers estimated for the livestock and crop sectors were 2.02 and 1.69, respectively.

Reductions in water flows available for municipal use may increase the prices businesses and homes pay for water use. These fee increases are often considered "burdens" on small businesses and individuals with low or fixed incomes such as the elderly. No specific municipal government multiplier has been located, but such a multiplier would be similar to tax multipliers: the ratio of the change in aggregate output (or gross domestic product) to an autonomous change in a taxes. A tax cut increases disposable income, which is likely to lead to added consumption spending; therefore, income will increase by a multiple of the decrease in taxes. The reverse is true for tax increases, or in this case, an increase in fees. The formula for calculating the tax multiplier relies on the level of the marginal propensity to consume. No general tax multipliers were stated in the literature examined, but are likely to lie between -1 and -4 (tax multipliers are negative since an increase in taxes causes a decrease in expenditures).

In addition, there may be secondary effects stemming from water flows enhancing local property values and improving or renewing community quality of life and ability to attract tourists and businesses, but multiplier impacts for these aspects were not found in the literature.

Literature Review Summary

This section summarizes the literature available on the value of water in specific sectors of the United States. As demonstrated in the various sections and summarized in Table 15, the value of water can vary dramatically, even within a specific sector. These ranges of values are not necessarily due to imprecise measurement of the value of water, but often in fact represent the true situation that the value of water is site, time, and use specific, such that one value does not fit all. While this table helps develop an appreciation for the relative values of water by sector, it is important to understand the methods used to develop these values for each sector. The specific value of water may vary widely, but there is still much to be gleaned from an overarching view of the literature.

Agriculture is a major user of water in the United States, accounting for 80% of the nation's consumptive water use and over 90% in many western states (Solley, Pierce, and Perlman 1998). Most of the major water markets in the United States are based on transfers either within the agricultural sector or between the agricultural and municipal sectors. Because agriculture plays such a significant role in total water use of the United States, understanding the value of water to this sector of the economy is especially important.

Estimating the value for water in the agriculture sector is based on the concept of farm production functions and the incremental increase in yields resulting from the application of additional quantities of water. Table 13 shows the range of estimated values for water when applied to various crops across the nation. In the agricultural sector, one major factor that controls the overall value is the relative amount of purchased irrigation water versus rainfall or natural irrigation. Hops are mainly grown in the Pacific Northwest region, where rainfall is often plentiful, whereas potatoes are typically grown in more arid climates. While these are not the only factors influencing the value of water in the respective crop production, they do shed light on possible reasons for the wide difference in the value of water when applied to each crop.

The total quantity of water used for domestic purposes is minor when compared to agriculture, but clearly residential water use is one of the driving forces in water policy and allocation issues in the United States today. Total U.S. residential water use is approximately 10% of all national consumptive uses of water.

Table 13
Relative value of water by sector (2003 USD)

Sector	Low $/kgal ($/AF)	High $/kgal ($/AF)
Agriculture	0.065 (hops) ($21/AF)	4.44 (potatoes) ($1,447/AF)
Residential	4.30 ($1,400/AF)	12.28+ ($4,000+/AF)
CII	0.086 ($28/AF)	2.47 ($805/AF)
Instream	0.03 (recreation) ($10/AF)	2.36 + (recreation) ($770+/AF)
Cultural	Unknown	Unknown

Estimating a single “value” of water in the residential sector is difficult, as in agriculture. Most of the residential water valuation studies do not look at water as in input to household production, though clearly one could. The studies focus on the value of changing current or future water use levels, or changes in the quality of water used for specific purposes. A main approach to estimating the value of water is through the relative elasticity of water demand for given price changes. Another approach is to estimate what individuals would be willing to pay to forego a potential reduction in water consumption. Studies of the WTP of residential customers are limited, but suggest values may be on the order of $1,400 per AF. Interpreting results of surveys that estimate WTP to avoid potential shortages (increase reliability) suggests values may be $4,000/AF or higher.

These illustrative numbers support the intuition that residential water users are willing to pay a relatively high price for water, but there are limitations to the application of these estimates to other geographical areas. First, these estimates are for avoiding water shortages in areas that have rather limited supplies to begin with (e.g., California). It is likely that the residential users’ willingness to pay to increase the quantity or reliability of water available to them may be lower than their WTP to avoid a loss of water. Thus utility managers trying to identify the benefits of increasing the supply of water to their consumers would be cautioned against applying these full values.

Nonresidential water use accounts for 53% of total water use in U.S. CWSs, and of that, over 70% is delivered to commercial, industrial, and institutional water users. The value of water to the commercial, industrial, and institutional sectors has not been studied as extensively as the value of water used in the agriculture and residential sectors. Thus, while it is commonly believed that commercial, industrial, and institutional use is a relatively high value application of water, relatively little empirical evidence supports this belief.

A review of seven industrial water valuation studies (the most recent of which is 1982) found the median value of industrial water intake to be $165/AF ($0.51/kgal), with a range of values from $35/AF ($0.11/kgal) to $1,002/AF ($3.07/kgal). Many industrial facilities self-supply their water, and pay little or nothing for their raw water input.

Values of the water used in the CII sector are difficult to estimate. Information on CII withdrawals is limited, and many industries supply a larger portion of their water independent of municipal systems. Values among the sectors vary significantly by region, yet some relative values may be consistent across regions. Another factor affecting value is time. Future market values depend on a particular industry's sustainability with regard to its inputs (water, in particular) and the fate of each industry

Measuring Total Economic Impacts on a Regional Economy

The first step in evaluating the fiscal and economic impact of a program, project, event, or industry expansion is to estimate its regional economic impact. This appendix focuses on how to estimate regional total economic impacts. The manner in which total economic impacts are created in an economy is often compared to the way ripples are made in a pond. The total economic impact has three segments, which are delineated in Figure 1.

- *Direct impacts* (the initial drops causing the ripple effects) are the changes in spending due to a new or existing economic activity.
- *Indirect impacts* are economic changes required to produce the supplies and services required by the direct effects.
- *Induced impacts* are the changes in consumer spending generated by changes in regional labor income that results from the direct and indirect effects.

Figure 1: Components of the Multiplier for the Construction of a Hotel

DIRECT IMPACT	INDIRECT IMPACT	INDUCED IMPACT
Excavation/Construction Labor Concrete Wood Bricks Equipment Finance and Insurance	Production Labor Steel Fabrication Concrete Mixing Factory and Office Expenses Equipment Components	Expenditures by wage earners on-site and in the supplying industries for food, clothing, durable goods, entertainment

Types of Direct Economic Effects

It is important to understand that the direct effects can be classified into two types of expenditure streams—those generated by projects (typically composed of construction and/or equipment purchases) or special events and those resulting from programs or new commercial establishments (on-going operations and maintenance). The two types of direct effects are delineated by the duration of their economic impacts and the manner in which the annual level of spending that generates the economic impacts is estimated. Often a proposed project has both types of direct effects (e.g., a new hotel has a construction phase as well as an operations phase). In such cases, the economic activity that makes up the two types of direct impacts must be separated.

Impacts of Projects and Special Events

Typically only the total spending or person-years of effort for the full duration of projects and special events is well known. Therefore, in order to provide a sense of the phase-in process of any project, annual spending estimates over the life of the project are made as proportions of the total. Examples are the construction of a new hotel or spending generated by having an existing local facility serve as the venue for a soccer tournament. In both cases, the economic activities involved are likely to be measured in total dollars spent or in terms of the total number of jobs that will be "created." Further, the term of the economic activity associated with projects and events typically is a period shorter than five years. (Equipment purchases also fall into this category of "one-time economic impacts" through the spending for equipment. Generally, equipment purchases are not made in the region, so the economic impacts generated directly from such spending tend to be small.)

Recurring Impacts

Unlike spending on special events or construction and equipment purchases, the annual operation and maintenance expenditures of new and/or expanded facilities generate an on-going stream of economic impacts. Such economic impacts are typically referred to as *recurring impacts*. The regional economic impacts of operations and maintenance expenditures are based on spending or employment levels for a typical year. Generally, however, the establishment or program for which the impacts are measured, tends to endure for a much longer period. Hence, the recurring economic impacts are often measured as a stream of annual income with no well-defined end date. Examples of recurring expenditures are the operation and maintenance of a hotel or set of roads. Events, such as festivals, can also be classified into this category, provided they occur every year.

Defining and Estimating the Direct Economic Effects

Direct effects of a program, project, event, or industry expansion can be defined for either a single industry or multiple industries. The decision regarding which of the two options is appropriate should be based on the how closely the direct effect matches one of the 500 or so industries available in the input-output model. If one of the 500-plus industries (such as Electronic Component Manufacturing) alone is sufficient to identify the source of the direct effects, then a single-industry direct effect can be used. For example, if an industry is identical to that of the entire direct effect or if it is an aggregate of the industry that is disturbed plus one or more other industries, then the choice of a single-industry direct effect is the correct one. Otherwise, the direct effect should be defined by two or more industries. Examples of both are provided as follows:

Example 1. Single-industry direct effect.

It is probably best to start learning how to estimate economic impacts by first measuring the effects of change in a single industry. As mentioned above, this type of analysis should only be performed when the industry directly affected by the event, project, or program is defined well by the economic model that is used. This is because, for each industry, the economic model is based upon something akin to a recipe of production for each industry specified in it. Thus, if the "recipe" for the model's industry does not portray the direct effects well, then the multiplier effects will be inaccurately estimated. It cannot be emphasized enough that the direct effects must be estimated accurately. One way to assure that the direct effects are as precise as possible is to use as much project-specific data as possible or to perform a survey of the suppliers.

If the direct effects appear to be defined well by the model (e.g., if the direct effects are hotel operations and the model has an industry labeled Hotel and Motels) then simply using the annual projected industry revenues (or employment) that define the direct effect may be sufficient. If the duration of the project is less than a year (such as the Republican national convention) and the direct effects is specified in terms of jobs, then the number of jobs should be multiplied by the fraction of the year the direct effect endures. Regardless, it is best if the industry's wages and salaries are calibrated to that known for the direct effect. This assures that the bulk of the direct effects, which tend to be in the form of labor income (on average nearly 70 percent of industry revenues are used for payroll) are specified precisely.

Even if the direct effects are portrayed extremely well by the model's industry, the economic impacts can be estimated improperly by the model in a regional setting. This is because, in some cases, not all of the estimated direct effects are produced in the impact region. The situations where this is the case are those where the direct effects are due to a change in local demand for a good or service. An example of such a direct effect would be the set of goods and services required in order to build a new hotel in Uvalde. In this case, the architects, engineers, and construction contractors involved need not be from Uvalde. They could come from Uvalde or places beyond. The same could be said for the equipment and other manufactured goods that they use in the construction process. Furthermore, if the contractor is not from Uvalde then the labor income is probably mostly spent by employees outside of the Uvalde metropolitan area. In such cases, the direct effects must be discounted (shared down/bifurcated) so that they reflect only the purchases that are likely to be made *in the region*. This process is called "regionalizing the direct effects."

Regionalizing the direct effects can be done in either of two ways. The first requires a survey of the direct effects. The survey would ask the organization causing the direct effects to provide the proportion of each of their industry expenditures that will be fulfilled by local producers. The second way is to use a set of proportions that, for each industry, represents the average propensity at which local goods and services are used to fulfill local demands. This set of proportions is technically called the vector of regional purchase coefficients (RPCs). Although less accurate than those obtained via survey work, they are readily available from some regional input-output model vendors. Further, they are better than doing nothing at all about the regionalization issue. Indeed, since many economic impact-modeling situations afford neither the time nor the money for the requisite survey work and since often times even when such work possible the actual proportions are unknown, the vector of RPCs must be used (see Appendix B for more information).

Example 2. Direct effects defined by two or more industries.

Multiple-industry direct effects must be estimated when no single industry in the economic model is sufficient to define the direct effects. The term "economic translator" derives from their purpose, which is—no matter what they are called—to translate a single figure representing an economic disturbance into its industry components for modeling. (The term impact vector is derived from the fact that they form the vector of industry effects from which the economic impacts are estimated.) Regardless, like the industries of the models typically used to estimate economic impacts, they can be viewed as industry-level recipes of direct effects.

Not surprisingly, multiple-industry direct effects are peculiar to each application. Further, in practice, multiple-industry direct effects are the norm rather than the exception. Economic consultants pride themselves on the expertise that they have developed with regard to specific types of multiple-industry direct effects. Some have developed a niche in developing port impact vectors that divide cargo into different commodities, handling types, and surface transportation transshipments. Others have worked exclusively on the various types of tourism. And still others have expertise in airport activity, convention center construction and operations, or highway construction. In large measure, experience in a particular industry can substitute for survey work that might otherwise be required. But in most cases there are regional peculiarities that require at least some basic spending information in order to calibrate information in the economic model.

A prime example of an activity that must be defined as a multiple-industry direct effect is tourism. Tourism is not a pre-defined industry in economic models. In fact, there are many types of tourism, so that even if there were a pre-defined industry that could sometimes be used as an impact vector, it probably would not be appropriate for most applications. Tourists have direct contact with several industries, the most important of which are shown in Table 1. But even the set of industries displayed in Table 1 is not sufficient for modeling tourism. This is because input-output models only measure the margins of retail trade industry. That means that the goods retailers sell are not measured in the retail industry of the input-output model. The goods sold by retailers must be assigned separately by the analyst to the industries that made them. Otherwise the economic effect of both wholesaling and manufacturing functions will not measured. Hence, only a portion of the retail sales dollars (about 20 percent) are assigned to the retail trade industries. The rest of the dollars should be allocated to wholesale trade and appropriate manufacturing, mining, and agricultural industries, the selection of which depends on the types of retail purchases made.

Table 1. Primary Tourism Sectors with Example Spending Levels

#	Sector Name	
463	Hotels & Lodging Places	$ 85.00
437	Air Transportation	$ 67.00
454		$ 50.00
	Eating and Drinking	
449	General Merchandise Stores	$ 15.50
451	Automobile Service Stations	$ 10.30
477	Automobile Rental and Leasing	$ 7.75
486	Commercial Sports (except racing)	$ 6.00
488	Amusement & Recreation Services	$ 5.70
455	Miscellaneous Retail	$ 3.40
483	Motion Pictures	$ 3.00
478	Automobile Parking and Services	$ 1.20

The precise pattern of tourism spending that should be used for an application depends upon the tourism base (e.g., heritage, nature, and conventions), the tourism destination, and the distribution of tourists by type of overnight lodging (e.g., day-tripper, hotel/motel, campground, stayed with friends and family). The formation of the tourism impact vector needed for a particular application, then, depends on many things. Hence, in order to produce an accurate tourism impact vector, a survey should be conducted.

Regardless of the type of direct effect the following procedures apply:

(1) Determine whether the direct effects can be identified by a single industry in the economic model.

(2) To calibrate the model, obtain local data on the average earnings per worker for each major industry that comprises the direct effects.

(3) If retail and wholesale trade are involved be sure to find out details on the types of goods and services that are provided. If possible identify the operating margins of the retail and wholesale establishments involved. If this is difficult or impossible, assume that the establishments operate with a margin of about 20 percent of sales revenues. Distribute the remaining 80 percent to manufacturers and local wholesalers. This distribution should be made on the basis of the types of goods that the wholesalers/retailers sell.

(4) Use all of the primary data sources that you can.
  a) Use all available local survey data on the direct effects (e.g., often some data on visitor spending are available)

b) Use architecture and engineering cost estimates for construction projects to get an idea of the types of materials, equipment, and labor that are required. The materials and equipment can be translated into industry purchases.
c) Obtain the new organization's estimates of its operation and maintenance costs in as detailed a fashion as possible.
d) Bifurcate by industry the direct effects into the value of goods and services that will be supplied by local organizations and that supplied by organizations outside of the impact area. That is, determine how much of each expenditure item in the direct effects will be spent in the impact area.
e) Get information on all of the major taxes that will be affected by the direct effects (e.g., sales tax, property tax, income tax, hotel occupancy tax, cement production tax, other gross receipts taxes, and corporation franchise tax).
f) Get information on the prospective increase in public services (by level of government and by department) that will be needed, if any.

Estimating Indirect and Induced (Multiplier) Economic Effects

The process for estimating a given project's indirect and induced economic impacts is more roundabout. By definition, a project's first round of *indirect impacts* includes the purchases of any supplies and/or services that are required to produce the direct effects. Subsequent purchases of supplies and services generate other rounds of indirect impacts. The *induced impacts* are the purchases that arise, in turn, from the increase in aggregate labor income of households. Both the indirect and induced economic impacts demonstrate how the demand for direct requirements reverberates through an economy.

One means of estimating these indirect and induced impacts would be to conduct a survey of the organization producing the direct effect. In the case of a construction project, like a new hotel, the questionnaire would ask for the names and addresses of the contractor's suppliers, what and how much they supply, the names and addresses of their employees, and their annual payroll. It would also ask for the organization to identify which of the suppliers were in the impact region. Another questionnaire might cover the household spending of the employees of the surveyed firms. It could request a characterization of the employee's household budget by detailed line items, including name and address of the firm or organization from which each line item is purchased. The business questionnaire could also be sent to the regional business addresses identified in these other questionnaires, and the household questionnaires, in turn, could be sent to the homes of the employees of the businesses contacted in the first round of surveying. This snowball-type sampling could continue until time or money was exhausted. The spending of each organization or household surveyed would then be weighted by its contribution to either the project or to household consumption. The weighted sum of these survey responses would yield the total regional economic impact.

This survey-based approach to estimating indirect and induced impacts, however, consumes a great deal of money and time. Economic models that cost far less are typically used instead. The model that has proven to estimate the indirect and induced economic effects of events most accurately is the input-output model. Its advantage stems from its level of industry detail and its depiction of interindustry relations.

Estimates of the total economic impacts of a project, program, or event are derived from regional input-output models by applying them to the regionalized direct effects, discussed earlier. The total economic impacts produced by input-output models typically come in many forms. First, they present the economic activity in terms of output or revenues (except for the retail and wholesale trade industries), employment, and income. Also, they often present it in terms of the regional equivalent of gross domestic product (GDP), which represents the wealth accumulated in the region due to the project, program, or event. Second, they decompose each of these total economic effect measures into their direct and indirect portions.

The best way to compare the relative return of projects, programs, or events competing for dollars from the same funds is to calculate the economic impacts per million dollars of investment. To derive such a measure for a government entity, this means the total economic impacts of the project, program, or event should be divided by the amount of public spending/incentives given that is required to make it come about. The two components of public spending required typically are in the form of tax incentives and the marginal cost to the government of the additional public services and goods that must be provided.

RIMS 2 System of Regional Multipliers (from the Bureau of Economic Analysis)

Overview

Effective planning for public- and private-sector projects and programs at the State and local levels requires a systematic analysis of the economic impacts of these projects and programs on affected regions. In turn, systematic analysis of economic impacts must account for the interindustry relationships within regions because these relationships largely determine how regional economies are likely to respond to project and program changes. Thus, regional input-output (I-O) multipliers, which account for interindustry relationships within regions, are useful tools for conducting regional economic impact analysis.

In the 1970's, the Bureau of Economic Analysis (BEA) developed a method for estimating regional I-O multipliers known as RIMS (Regional Industrial Multiplier System), which was based on the work of Garnick and Drake. [/1/] In the 1980's, BEA completed an enhancement of RIMS, known as RIMS II (Regional Input-Output Modeling System), and published a handbook for RIMS II users. [/2/] In 1992, BEA published a second edition of the handbook in which the multipliers were based on more recent data and improved methodology. In 1997, BEA published a third edition of the handbook that provides more detail on the use of the multipliers and the data sources and methods for estimating them.

RIMS II is based on an accounting framework called an I-O table. For each industry, an I-O table shows the industrial distribution of inputs purchased and outputs sold. A typical I-O table in RIMS II is derived mainly from two data sources: BEA's national I-O table, which shows the input and output structure of nearly 500 U.S. industries, and BEA's regional economic accounts, which are used to adjust the national I-O table to show a region's industrial structure and trading patterns.

Using RIMS II for impact analysis has several advantages. RIMS II multipliers can be estimated for any region composed of one or more counties and for any industry, or group of industries, in the national I-O table. The accessibility of the main data sources for RIMS II keeps the cost of estimating regional multipliers relatively low. Empirical tests show that estimates based on relatively expensive surveys and RIMS II-based estimates are similar in magnitude.

BEA's RIMS multipliers can be a cost-effective way for analysts to estimate the economic impacts of changes in a regional economy. However, it is important to keep in mind that, like all economic impact models, RIMS provides approximate order-of-magnitude estimates of impacts. RIMS multipliers are best suited for estimating the impacts of small changes on a regional economy. For some applications, users may want to supplement RIMS estimates with information they gather from the region undergoing the potential change. Examples of case studies where it is appropriate to use RIMS multipliers appear in the RIMS II User Handbook.

To effectively use the multipliers for impact analysis, users must provide geographically and industrially detailed information on the initial changes in output, earnings, or employment that are associated with the project or program under study. The multipliers can then be used to estimate the total impact of the project or program on regional output, earnings, and employment.

RIMS II is widely used in both the public and private sector. In the public sector, for example, the Department of Defense uses RIMS II to estimate the regional impacts of military base closings. State transportation departments use RIMS II to estimate the regional impacts of airport construction and expansion. In the private-sector, analysts and consultants use RIMS II to estimate the regional impacts of a variety of projects, such as the development of shopping malls and sports stadiums.

RIMS II Methodology

RIMS II uses BEA's benchmark and annual I-O tables for the nation. Since a particular region may not contain all the industries found at the national level, some direct input requirements cannot be supplied by that region's industries. Input requirements that are not produced in a study region are identified using BEA's regional economic accounts.

The RIMS II method for estimating regional I-O multipliers can be viewed as a three-step process. In the first step, the producer portion of the national I-O table is made region-specific by using six-digit NAICS location quotients (LQ's). The LQ's estimate the extent to which input requirements are supplied by firms within the region. RIMS II uses LQ's based on two types of data: BEA's personal income data (by place of residence) are used to calculate LQ's in the service industries; and BEA's wage-and-salary data (by place of work) are used to calculate LQ's in the nonservice industries.

In the second step, the household row and the household column from the national I-O table are made region-specific. The household row coefficients, which are derived from the value-added row of the national I-O table, are adjusted to reflect regional earnings leakages resulting from individuals working in the region but residing outside the region. The household column coefficients, which are based on the personal consumption expenditure column of the national I-O table, are adjusted to account for regional consumption leakages stemming from personal taxes and savings.

In the last step, the Leontief inversion approach is used to estimate multipliers. This inversion approach produces output, earnings, and employment multipliers, which can be used to trace the impacts of changes in final demand on directly and indirectly affected industries.

Accuracy of RIMS II

Empirical tests indicate that RIMS II yields multipliers that are not substantially different in magnitude from those generated by regional I-O models based on relatively expensive surveys. For example, a comparison of 224 industry-specific multipliers from survey-based tables for Texas, Washington, and West Virginia indicates that the RIMS II average multipliers overestimate the average multipliers from the survey-based tables by approximately 5 percent. For the majority of individual industry-specific multipliers, the difference between RIMS II and survey-based multipliers is less than 10 percent. In addition, RIMS II and survey multipliers show statistically similar distributions of affected industries.

Advantages of RIMS II

There are numerous advantages to using RIMS II. First, the accessibility of the main data sources makes it possible to estimate regional multipliers without conducting relatively expensive surveys. Second, the level of industrial detail used in RIMS II helps avoid aggregation errors, which often occur when industries are combined.

Third, RIMS II multipliers can be compared across areas because they are based on a consistent set of estimating procedures nationwide. Fourth, RIMS II multipliers are updated to reflect the most recent local-area wage-and-salary and personal income data.

Applications of RIMS II

RIMS II multipliers can be used in a wide variety of impact studies. For example, the U.S. Nuclear Regulatory Commission has used RIMS II multipliers in environmental impact statements required for licensing nuclear electricity- generating facilities. The U.S. Department of Housing and Urban Development has used RIMS II multipliers to estimate the impacts of various types of urban redevelopment expenditures. In addition, BEA has provided RIMS II multipliers to numerous individuals and groups outside the Federal Government. RIMS II multipliers have been used to estimate the regional economic and industrial impacts of the following: opening or closing military bases, hypothetical nuclear reactor accidents, tourist expenditures, new energy facilities, energy conservation, offshore drilling, opening or closing manufacturing plants, shopping malls, new sports stadiums, and new airport or port facilities.

BAWSCA's Top 100 Non-Residential Water Users in 2002-03 By Size ** Data provided by BAWSCA*				
	Agency	**Description/Function**	**Zip Code**	**In CCF**
1	City of Santa Clara	Electronic Manufacturing	95054	567,995
2	City of Sunnyvale	Municipal: All other accounts	94088	420,374
3	ACWD	Automobile manufacturing	94538	410,705
4	Cal Water - SSF District	Biotech	94080	330,296
5	City of Santa Clara	Paper Manufacturing	95050	306,444
6	Stanford University	Student Housing & Dining	94305	300,449
7	City of Santa Clara	Electronic Manufacturing	95050	289,853
8	ACWD	Municipal Government	94537	287,963
9	City of Santa Clara	Paper Manufacturing	95050	280,582
10	Stanford University	Central Energy Facility	94305	257,649
11	ACWD	Public School District	94538	247,730
12	City of Sunnyvale	Semiconductors & Related Devices	94087	233,797
13	City of Palo Alto	Parks & Rec/Government	94301	229,486
14	City of Sunnyvale	Aircraft Manufacturing	94088	195,687
15	City of Palo Alto	Gen. Medical/Surgical Hosp.	94304	192,939
16	City of Santa Clara	Electronic Manufacturing	95054	188,356
17	City of Hayward	Public School District	9454X	187,514
18	City of Hayward	Food: Beverage Production	94545	182,848
19	ACWD	Electronic Manufacturing	94538	179,436
20	City of Hayward	Park District: all accounts	9454X	165,162
21	City of Menlo Park	Electronic Manufacturing	94025	161,041
22	City of Menlo Park	Electronic Manufacturing	94025	160,853
23	Stanford University	Academic	94305	154,094
24	City Mountain View	Golf Course	94043	153,120
25	City of Redwood City	Municipal - All Accounts	94063	146,873
26	City of Milpitas	General Government	95035	144,353
27	ACWD	Various Office	9453X	143,049
28	City of Sunnyvale	Semiconductors & Related Devices	94086	140,864
29	ACWD	Public School District	94560	129,113

BAWSCA's Top 100 Non-Residential Water Users in 2002-03 By Size ** Data provided by BAWSCA*				
30	City of Sunnyvale	Public Golf Courses	94088	127,624
31	Coastside	Agriculture: Nursery	94019	121,036
32	ACWD	Research	95035	119,848
33	City of Hayward	Food: Beverage Production	94545	115,606
34	City of San Jose	Electronic Manufacturing	95134	115,470
35	ACWD	Municipal Government	94587	115,379
36	City of San Jose	Electronic Manufacturing	95134	113,802
37	City of San Jose	Electronics: Administration / R&D	95134	105,644
38	Cal Water - Mid-Peninsula	Municipal: all other accounts	94401	104,100
39	City of Palo Alto	Golf Courses/Country Clubs	94304	100,191
40	City of Hayward	Electronic Manufacturing	94544	97,630
41	Stanford University	School of Medicine and Hospital	94305	97,361
42	City of Redwood City	Computer Software	94065	96,369
43	City of San Jose	Electronic Manufacturing	95134	94,378
44	City of Hayward	Municipal: all accounts	9454X	94,375
45	City of Hayward	University	94542	93,585
46	City of Sunnyvale	Transportation Equipment Manufacturing	94088	93,083
47	Cal Water - SSF District	Municipal: all other accounts	94080	92,324
48	City of Menlo Park	Medical: Hospital	94025	90,089
49	Cal Water - Mid-Peninsula	Municipal: Golf Course	94403	84,323
50	City of San Jose	Medical: Hospital (Mental)	95134	83,855
51	City of San Jose	Power Plant	95134	83,591
52	City of Palo Alto	R&D, engineering, and life sciences	94306	82,650
53	City of San Jose	Electronic Manufacturing	95134	78,623
54	City of Santa Clara	Chemical Manufacturing	95054	78,075
55	City of Palo Alto	Elem/Secondary Schools	94306	78,022
56	City of Santa Clara	Food processing	95050	71,243
57	Cal Water - Mid-Peninsula	Race Track	94401	68,306
58	City of Hayward	Food: Beverage Production	94545	67,922
59	City of Redwood City	Office Building (Gov't)	94063	65,339

BAWSCA's Top 100 Non-Residential Water Users in 2002-03 By Size ** Data provided by BAWSCA*				
60	City of Santa Clara	Electronic Manufacturing	95050	64,900
61	City of Milpitas	Admin, educ programs	95035	63,350
62	Coastside	Municipal: Cemetery	94402	60,668
63	Cal Water - SSF District	Public School District	94080	58,368
64	City of Sunnyvale	Semiconductors & Related Devices	94089	55,889
65	City of Mountain View	Gold Course	94043	53,795
66	City of San Jose	Electronic Manufacturing	95134	53,473
67	City of Menlo Park	Electronic Manufacturing	94025	52,506
68	City of Santa Clara	Electronic Manufacturing	95054	51,725
69	Coastside	Agriculture: Nursery	94019	51,026
70	City of Sunnyvale	Computers, Sales & Services	94085	50,100
71	City of Mountain View	Hospital	94043	49,983
72	Cal Water - SSF District	Food Processing	94080	49,843
73	City of Hayward	Chemical Manufacturing	94545	49,689
74	City of Palo Alto	R&D/, engineering, and life sciences	94304	48,727
75	City of Millbrae	Golf Course	94030	48,039
76	City of Sunnyvale	Public School	94088	47,753
77	Mid-Peninsula (Belmont)	Electronic Manufacturing	94070	47,598
78	City of Palo Alto	Space satellites, comm, manufacturing	94303	45,940
79	City of Santa Clara	Electronic Manufacturing	95050	45,869
80	Cal Water - Mid-Peninsula	College	94401	44,303
81	City of Palo Alto	R&D/Engineering, Life Sciences	94306	43,420
82	City of Menlo Park	Municipal: all other accounts	94025	40,327
83	City of Santa Clara	Electronic Manufacturing	95054	40,013
84	City of Palo Alto	R&D/Engineering, Life Sciences	94304	39,724
85	Cal Water - SSF District	Medical Laundry Processing	94080	38,300
86	Cal Water - Mid-Peninsula	Municipal: all other accounts	94401	38,075
87	Cal Water - Mid-Peninsula	Public School District	94070	37,909
88	City of Redwood City	Real Estate Office	94065	37,220
89	Cal Water - SSF District	Food Processing	94080	36,772

BAWSCA's Top 100 Non-Residential Water Users in 2002-03 By Size ** Data provided by BAWSCA*				
90	City of San Jose	Electronic Manufacturing	95134	36,215
91	City of Redwood City	Hospital	94063	35,441
92	Stanford University	Athletics	94305	35,408
93	City of Santa Clara	Electronic Manufacturing	95054	35,134
94	City of San Jose	Water Pollution Treatment Plant	95134	34,396
95	City of Redwood City	Hospital	94063	33,292
96	Cal Water - Mid-Peninsula	Public School District	94402	32,247
97	City of Hayward	Cemetery	94544	31,261
98	City of Burlingame	Hotel	94010	30,500
99	City of Milpitas	Computer Manufacturing	95035	29,919
100	City of Santa Clara	Electronic Manufacturing	95054	29,766
		Top 100		11,427,351

Exhibit No. CSF-20

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Turlock Irrigation District and Modesto Irrigation District	Project Nos. 2299-065 2299-053

ANSWERING TESTIMONY OF DAVID L. SUNDING ON BEHALF OF SAN FRANCISCO PUBLIC UTILITIES COMMISSION

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is David L. Sunding, Berkeley Economic Consulting, Inc., 2531 Ninth Street, Berkeley, CA 94710.

Q. WHAT IS YOUR OCCUPATION?

A. I am a director of Berkeley Economic Consulting, Inc. (BEC), an independent economic research firm. I am an economist specializing in natural resource and environmental economics, including water resource economics.

Q. ON WHOSE BEHALF DO YOU APPEAR IN THIS PROCEEDING?

A. I am appearing on behalf of the San Francisco Public Utilities Commission (SFPUC).

Q. PLEASE SUMMARIZE YOUR BACKGROUND AND EXPERIENCE.

A. I completed a Ph.D. in natural resource economics from the University of California, Berkeley (UC Berkeley). I earned a bachelor's degree in economics from Claremont McKenna College. My CV is attached hereto as Exhibit CSF-21. I have over 20 years of experience as a water resource economist and have held several prominent academic appointments. I currently hold the Thomas J. Graff Chair in Natural Resource Economics and Policy at UC Berkeley and am co-director of the Berkeley Water Center. I have served on panels of the National Academy of Sciences and the U.S. EPA Science Advisory Board. Prior to joining the Berkeley faculty, I taught at Boston College in the Department of Economics and the School of Law. During the Clinton Administration, I was a senior economist at the President's Council of Economic Advisors.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. I have been asked to present my estimates of the economic impacts that would result from water rationing in the SFPUC service area if the SFPUC Regional Water System is required to provide flows from its water system to the Turlock and Modesto Irrigation Districts (Districts) for release to the lower Tuolumne River below LaGrange Dam, as recommended by National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) in their direct testimony submitted on September 14, 2009 (Exh. NMF-1), which USFWS witness Michelle Workman supports in her direct testimony (Exh. No. FWS-2).[1]

Q. PLEASE DESCRIBE BRIEFLY HOW ECONOMISTS EVALUATE THE ECONOMIC IMPACTS OF WATER RATIONING ON THE RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL SECTORS OF THE BAY AREA ECONOMY.

A. Economists measure economic impacts in terms of changes to consumer and producer surplus. Consumer surplus refers to the difference between what a

[1] Exhibit No. NMF-1 is the interim protection measures newly recommended by NMFS and USFWS in their September 14, 2009 direct testimony, and it does not appear to be sponsored by any single NMFS or USFWS witness. As stated by NMFS witness Strange in Exhibit No. NMF-2, page 16 of 25, lines 7-8, different experts support the different elements of Exhibit No. NMF-1. I understand that six witnesses from NMFS (Steven Lindley (Exh. NMF-6), Erin Strange (Exh. NMF-2), Craig Anderson (Exh. NMF-4)), USFWS (Michelle Workman (Exh. FWS-2) (referring to identical Exhibit No. FWS-1), and the California Department of Fish and Game (CDFG) (Timothy Heyne (Exh. DFG-2), Andrew Gordus (Exh. DFG-4) (referring to identical Exhibit No. DFG-1)), all filed direct testimony stating that they support the Exhibit No. NMF-1 Interim Measure Elements.

consumer is willing to pay for a good or service and what a consumer actually pays. Producer surplus is a similar measure; it is defined by the difference between revenues and variable costs, and is a measure of economic profit. Producer surplus reflects the benefit of an activity to business owners by measuring revenues in excess of levels adequate to keep producing goods or services.

While consumer and producer surplus measures are preferred by economists since they are grounded in modern concepts of welfare economics and public finance, we are often asked to calculate changes in other measures such as employment and sales. Economists typically estimate these impacts by using an empirical relationship between variables of interest, referred to as elasticity.

Q. PLEASE DESCRIBE BRIEFLY THE PRIOR STUDIES THAT HAVE BEEN CONDUCTED ON THE IMPORTANCE OF THE BAY AREA REGIONAL WATER SYSTEM TO THE ECONOMY OF THE SFPUC SERVICE AREA, INCLUDING ANY PRIOR STUDIES IN WHICH YOU PARTICIPATED.

A. Several studies have been conducted to measure the impacts of water supply shortages in the San Francisco Bay area over the past 15 years. Exhibit CSF-22 lists four of them, including one that I collaborated on in 2007 on behalf of SFPUC and one that I directed in 2002 for the Bay Area Economic Forum. Dr. William Wade conducted a drought impact study on behalf of the Bay Area Water Supply and Conservation Agency (BAWSCA) in 2005. Just over 10 years earlier, Dr. Philip McCleod conducted a study on behalf of SFPUC. All three studies found that even a 10% water shortage results in substantial losses in industrial output (sales or shipments). The most recent study found that a 10% shortage would reduce industrial output by over $0.5 billion and create job losses of over 1,300. The previous study estimated that industrial output would fall by $2.5 billion. (Employment impacts were not addressed). Larger losses may be explained in part by changes in industrial composition over time. Many water “intensive” industries have left the region since the late 1990s thereby reducing the impact of water shortages.

According to all three studies, economic losses increase relative to increased water shortages. Doubling the water shortage from 10% to 20% roughly doubles the industrial losses ($0.5 billion to $1.1 billion) according to the most recent study and more than triples the industrial losses ($2.5 billion to $7.66 billion) according to the 2005 study. The earlier study showed an even more dramatic increase. Doubling the water shortage from 15% to 30% resulted in a five-fold increase in industrial losses ($0.4 billion to $2.1 billion). The most recent study found that a 30% water shortage would result in industrial losses totaling $3.6 billion with job losses exceeding 8,000.

I also conducted a study in 2002 with funding from the Bay Area Economic Forum to calculate the economic impacts of a Hetch Hetchy system failure caused by an earthquake or other catastrophic event. In such events, water supplies would be unavailable or severely rationed for 10 to 30 days and possibly as long as 60 days. This study, which was published in *Water Resources Research*, concluded that this type of supply interruption occurring along the San Andreas Fault would result in economic losses in excess of $28.7 billion in the Bay Area. Commercial and industrial losses alone would be at least $14.2 billion.

Q. WHAT IS THE IMPORTANCE TO THE BAY AREA ECONOMY OF THE SFPUC REGIONAL WATER SYSTEM?

The SFPUC Regional Water System is comprised of the SFPUC retail agency and the member agencies of BAWSCA. The retail agencies serve residential, commercial, industrial, and government customers across four counties – San Francisco, Alameda, San Mateo, and Santa Clara counties.

Across the agencies receiving water from the Regional Water System, residential demand represents 60% of FY 04-05 demand, industrial demand represents 7%, commercial demand accounts for 19%, and government and other sectors account for the remaining 14% of demand.

Six agencies—SFPUC retail, Alameda County Water District (Alameda CWD), California Water Service Company (CWS),[2] Santa Clara, Sunnyvale, and Hayward—account for about two-thirds of total water demand. Six agencies, including SFPUC retail, Alameda CWD, Sunnyvale, Hayward, CWS - Mid Peninsula, and CWS - Bear Gulch account for roughly two-thirds of residential demand. Santa Clara, Alameda CWD, and Hayward account for nearly two-thirds of industrial water demand.

The SFPUC provides retail water delivery service within the City and County of San Francisco to over 147,800 residential accounts and 21,600 non-residential

[2] CWS is broken down into its three jurisdictions in the area: CWS - Bear Gulch, CWS – Mid-Peninsula, and CWS – South San Francisco.

accounts and to 27 wholesale agencies. BAWSCA is composed of the 24 cities and water districts and two private utilities, Stanford University and California Water Service Company, that are wholesale customers of SFPUC. Member agencies of BAWSCA service a population of nearly 1.7 million, with over 370,000 residential accounts, 5,500 industrial accounts, and 25,800 commercial accounts. In FY 04-05, SFPUC water accounted for roughly 68% of total water supply for BAWSCA members; the remaining 32% of water supply is from other sources.

The area served by the SFPUC Regional Water System is one of the largest centers of employment and economic activity in the United States. There are over 1.6 million jobs located in the service area. Firms located in the service area produce over $280 billion in goods and services each year. Because of the Bay Area's arid climate, this economic activity is dependent on the importation of water from other areas.

Q. HAVE YOU REVIEWED THE TESTIMONY OF DAN STEINER REGARDING POTENTIAL LEVELS OF RATIONING FOR THE REGIONAL WATER SYSTEM AND ELLEN LEVIN'S TESTIMONY ON STRATEGIES FOR REDUCING THE IMPACTS OF RATIONING?

A. Yes, I have.

Q WHAT STEPS DID YOU UNDERTAKE TO ANALYZE THE IMPACTS OF THESE LEVELS OF RATIONING IN THE SAN FRANCISCO BAY AREA?

A I developed an economic model of agency-level water allocation that reflects the demand for water for various customer classes. The model incorporates all retail agencies receiving water from the SFPUC Regional Water Supply System. The technical report attached to this testimony as Exhibit CSF-24 describes the specification of the model.

In developing the impact model, I estimated a detailed statistical demand relationship for residential water use in the Regional Water System. The data used in the estimation capture a number of important factors that influence demand, including income, climate variables, residential density, water rates, and adoption of the Best Management Practices described in Ms. Levin's direct testimony. As she notes, retail agencies receiving water from SFPUC have made good progress in encouraging efficient water use practices. Residential water use accounts for over 60% of total water consumption in the SFPUC Regional Water System. The econometric model I developed for this customer class greatly enhances my ability to make accurate predictions about the economic ramifications of water supply disruptions.

For each customer class in each agency, the economic impact model calculates the rationing levels that minimize economic surplus losses while still achieving necessary levels of conservation. Actual surplus losses may be larger than those calculated here to the extent that agencies use other factors to determine mandated levels of conservation for different groups of consumers. Even with this conservative assumption in place, the economic losses resulting from the levels of rationing described by Mr. Steiner and Ms. Levin are extraordinarily large and would have a devastating effect on the economy of the Bay Area.

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS ON THE ECONOMIC IMPACTS OF THE POTENTIAL LEVELS OF RATIONING IDENTIFIED BY MR. STEINER AND HOW SUCH RATIONING MIGHT BE IMPLEMENTED BETWEEN THE WHOLESALE AND RETAIL CUSTOMERS AS DESCRIBED BY MS. LEVIN.

A. I calculated economic impacts for several levels of rationing: 10%, 20%, 41%, and 51%. While the first two scenarios do not represent the maximum potential impacts of the proposed instream flow requirements, these lower rationing levels will occur with much greater frequency than at present, and with much greater frequency than the maximum rationing scenarios. The results of my analysis of these four scenarios are presented in Exhibit CSF-23.

With respect to lost consumer and producer surplus, the potential rationing losses will result in significant impacts, which I calculate at $471 million annually in the 51% rationing scenario. Losses in the other scenarios are $324 million (41% Rationing), $119 million (20% Rationing), and $53 million (10% Rationing).

Rationing in the range of 40% - 50% is extreme, and it is more reminiscent of the effects of a major earthquake than the effects of typical environmental regulation. To understand some of the practical difficulties associated with conservation of this magnitude, consider that residential consumption accounts for around 60% of all water use in the Regional Water System. The United Nations recommends that a minimum level of water to maintain human survival with basic levels of sanitation is 13.7 gallons of water per person per day (gcd). Multiplying this basic human water requirement across the population served by the Regional Water System (and accounting for the proportion of supply from non-SFPUC sources), it follows that roughly 34 mgd is needed to meet this basic level. Thirty-four mgd is close to 13% of the total water delivered by the SFPUC, meaning that this quantity is absolutely off-limits to conservation, and conservation must come from remaining uses.

More realistic levels of residential indoor uses can be determined by looking across retail agencies in the Bay Area. A level of 50 gcd is below that of any retail agency in the Regional Water System, is below the level currently attained in East Palo Alto, a severely depressed city, and 13% below the current level of residential consumption in the City of San Francisco, which has one of the lowest levels of per capita water use of any major city in California. At a level of 50 gcd, residential consumption across the Regional Water System would account for nearly 125 mgd in total. In this instance, all required conservation would need to be met by reductions in other demands such as outdoor use, commercial and industrial uses. In addition, some agencies can turn to alternative supplies to replace some portion of lost SFPUC deliveries as described in Exhibit CSF-24

Q. PLEASE DESCRIBE THE IMPACT OF THE POTENTIAL WATER RATIONING LEVELS ON EMPLOYMENT AND SALES IN THE SAN FRANCISCO BAY AREA.

A. The impact of the potential rationing levels on employment is severe. In the 51% rationing scenario, I estimate that the Bay Area would lose more than 188,000 jobs as industrial and commercial output is reduced to meet conservation requirements. Such losses account for over one-tenth of all payroll in the SFPUC Regional Water System service area. Job losses in the other scenarios are 139,146 (41% Rationing), 6,562 (20% Rationing), and 3,922 (10% Rationing). Note that job losses increase dramatically in the event of larger rationing as firms run out of ways to reduce water consumption that do not require shutting down.

Lost sales of firms in the SFPUC Regional Water System area are in excess of $49 billion annually in the event of 51% rationing. This figure corresponds to roughly 20% of all economic activity in the region. Sales losses in the other scenarios are $37 billion (41% Rationing), $3.1 billion (20% Rationing), and $1.8 billion (10% Rationing).

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.