San Francisco Public Utilities Commission

Measures to Reduce the Economic Impacts of a Drought-Induced Water Shortage in the SF Bay Area

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In late 2005, Public Financial Management (PFM), at the request of the San Francisco Utilities Commission (SFPUC), undertook a study of the economic impacts of water rationing on the commercial and industrial sectors in the SFPUC's service area. This analysis was based on elasticities of output that were derived from data and studies undertaken in the early 1990's. A summary of the analysis and conclusions are attached. While the reductions in output calculated were within expected ranges, there was concern that the economic relationships reflected in the elasticities were not adequately representative of changes that have occurred in the economy since that time. In particular, there was concern that "hardening of demand" had occurred; that is, that the drought of the late 80's and early 90's had encouraged the use of technological and behavioral changes that became ingrained in the relationship between water availability and usage. The implication of demand hardening is that additional reductions in water usage in response to reduced availability would be marginally more difficult and expensive.

Another limitation of the 2005 study was that it analyzed the impact of reduced water availability absent any policy efforts to mitigate those impacts. While this provides one perspective on the impacts, it is inherently unrealistic; there clearly will be various types of policy interventions aimed at reducing the impacts. Therefore, one of the important tasks of Phase 2 was to consider a range of policy measures and to attempt to understand their effectiveness.

The 2005 study was undertaken without substantial involvement from retail customers, or from actual commercial and industrial customers. The Phase 2 study, by involving the Bay Area Water Supply and Conservation Agency (BAWSCA) from the outset, has included extensive interaction with the retail agencies and BAWSCA. Also, as part of the study's methodology, there has been a systematic effort to communicate with water sensitive commercial and industrial customers in the service area.

Another important aspect of the context of this study is that the SFPUC is now undertaking a massive renovation of its infrastructure. This Water System Improvement Plan (WSIP) comprises a wide variety of projects throughout the system intended to modernize and improve the system. This set of improvements is being undertaken in part based on planning assumptions regarding demand and supply. This study is built on those planning assumptions, and is intended to enhance the SFPUC's understanding of how best to cope with periods of reduced water availability given those assumptions and the design capacity of the upgraded system.

This report presents the results of the Phase 2 study. The report was prepared by PFM, the Bay Area Economic Forum, TXP, and CRA International (hereafter the study team). The analysis proceeded in four major steps. The first step was to assess the potential response of key economic sectors to various forms of drought mitigation. This included a survey, focus groups, and a literature review. The second step was to identify specific mitigation policies for further analysis reflecting potential response. The third step was to develop a model to project the water demand and supply responses to mitigation policies and their economic impacts. The fourth step was to employ this model to evaluate selected mitigation policies with respect to economic impact.

These efforts have indicated that the following policies are likely to be the most effective at avoiding and minimizing the economic consequences of a drought:

- Drought-contingent pricing to reduce consumption
- Public education and advertisement
- Increased regional cooperation among water agencies
- Expanded program to purchase and bank water
- Improved coordination among BAWSCA agencies and the SFPUC with respect to drought planning

We have reached these conclusions in part through the development and use of an economic impact model that accounts for differences in the availability and value of water among agencies and sectors in the SFPUC service area. The model measures the impact of increased reliance on supplemental supplies to meet drought shortfalls and, if these prove insufficient to meet demands, the impact of reduced water availability to retail customers. The model is flexible in that it can be tailored to various allocation and shortage sharing schemes.

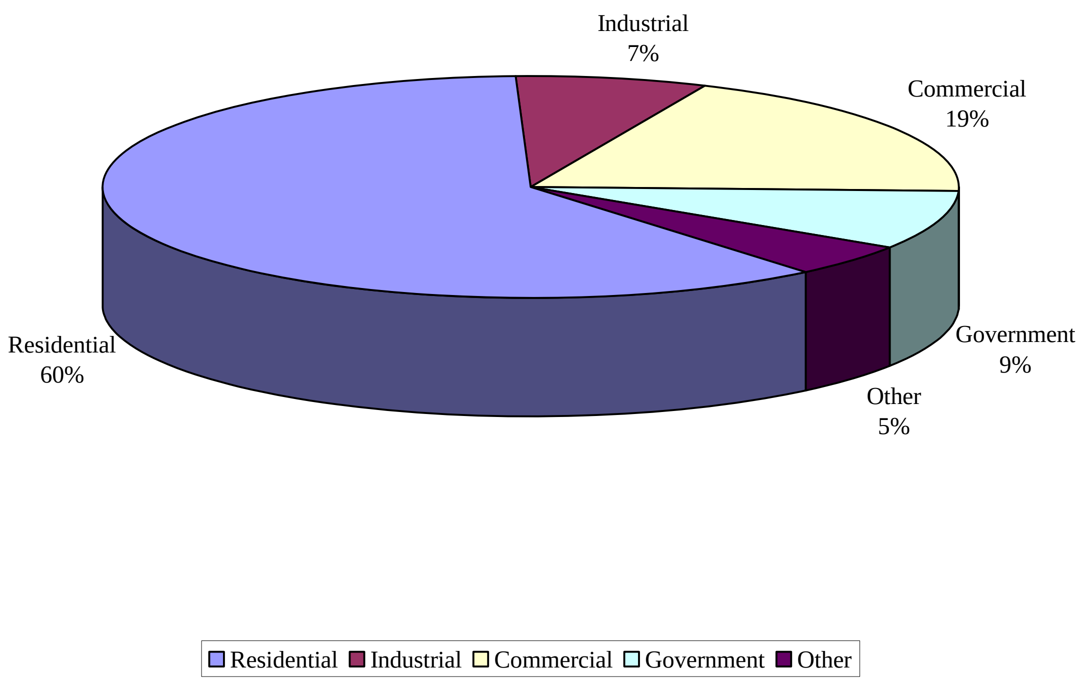
This report is organized as follows. Section 2 reviews the SFPUC regional water system, SFPUC's wholesale customers, operating rules for shortage sharing among agencies, and socioeconomic characteristics of the study region. Section 3 presents an analysis of sectoral demands for water in the SFPUC service area. This analysis lays the foundation for the regional modeling by characterizing the willingness to pay for water by various customer classes in different retail agencies. This section also describes the results of a survey of commercial and industrial customers conducted by PFM. Section 4 describes and assesses various strategies to reduce the regional economic impact of drought. Finally, Section 5 contains conclusions about economic impacts and the relative effectiveness of policies, and our recommendations for further study and action by the SFPUC and BAWSCA.

1. Residential consumption is by far the largest component of consumption (page 7).
2. There is diversity in demand across the agencies operating in service area driven by different sector mixes (residential, commercial, and industrial), lot size, household income, and weather (page 12).
3. There is diversity of sources within the service area. There is also diversity of effort with respect to the implementation of conservation practices within various jurisdictions (page 16).
4. Residential demand is not very responsive to prices. Relatively large price increases are needed to influence residential demand (page 21).
5. Residential demand becomes more difficult to reduce as additional conservation measures are implemented; demand hardening is real (page 22).
6. Water is a relatively small cost factor for most commercial and industrial customers (page 28).
7. Drought-contingent (tiered) pricing would be an effective and appropriate method to influence demand for business customers during droughts (page 29).
8. Welfare losses created by rationing can be lessened by utilizing drought contingent pricing and regional shortage sharing (page 41).
9. Because residential demand is more inelastic than the industrial and commercial demands for water, the drought-contingent pricing and regional cooperation strategies allocate more water towards the residential sector, resulting in higher sales and payroll losses in the commercial and industrial sectors (page 44).
10. A 10% drought causes payroll losses of between 0.8% and 1.1% in the industrial sector depending on mitigation strategy. A 20% drought causes payroll losses of between 1.6% and 2% in the industrial sector depending on the mitigation strategy; a 30% drought increases those impacts to between 4.9 and 6.8%. Payroll losses in the commercial sector are 0.1% regardless of a strategy in a 10% drought, 0.2% regardless of mitigation strategy under a 20% drought. A 30% drought increases this loss to between 3% and 6% depending on the mitigation strategy (page 44).
11. Policy makers can protect commercial and industrial water availability in droughts by allowing or mandating higher losses in the residential sector. This would reduce negative impacts on the industrial and commercial sectors (page 45).

2.a. Configuration

The SFPUC Regional Water System is comprised of the SFPUC retail agency and the 27 member agencies of BAWSCA. The twenty-seven agencies serve residential, commercial, industrial, and government customers across four counties – San Francisco, Alameda, San Mateo, and Santa Clara counties. As shown in Figure 1, residential demand represents 60% of current 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 CWD, California Water Service Company (CWS), Santa Clara, Sunnyvale, and Hayward, account for 68% of total water demand (see Table 1). The six agencies or jurisdictions of SFPUC retail, Alameda CWD, Hayward, Sunnyvale, CWS - Mid Peninsula, and CWS - Bear Gulch account for 63% of residential demand. Three agencies, Santa Clara, Alameda CWD, and Hayward account for 60% of industrial water demand.

Figure 1: Water Consumption by Sector in the SFPUC Service Area



Key Finding #1: Residential consumption is by far the largest component of consumption.

Table 1: Percent of Total Water Consumption by Agency for BAWSCA Members and SFPUC for FY 2004-2005

Agency	Residential	Industrial	Commercial	Government	Other	Overall
SFPUC Retail	24.1%	11.2%	35.2%	3.8%	0.0%	22.4%
Alameda CWD	15.6%	18.5%	10.4%	11.0%	18.4%	14.5%
Brisbane	0.1%	*	0.1%	0.3%	0.1%	0.1%
Burlingame	1.0%	2.7%	0.7%	5.0%	2.2%	1.4%
CWS - Bear Gulch	5.3%	0.0%	2.0%	0.9%	1.7%	3.7%
CWS - Mid Peninsula	5.8%	0.5%	5.0%	3.0%	6.2%	5.0%
CWS - South San Francisco	1.8%	2.9%	5.1%	1.5%	7.0%	2.7%
Coastside CWD	0.7%	1.4%	0.8%	0.0%	1.8%	0.8%
Daly City	3.0%	0.0%	1.4%	1.7%	3.5%	2.4%
East Palo Alto WD	0.7%	0.0%	0.1%	0.9%	0.0%	0.5%
Estero MID	1.6%	0.3%	0.7%	5.1%	1.6%	1.6%
Guadalupe Valley	0.0%	*	0.1%	0.5%	0.3%	0.1%
Hayward	5.4%	15.1%	2.9%	4.5%	12.3%	5.9%
Hillsborough	1.6%	0.0%	0.1%	0.0%	1.0%	1.1%
Menlo Park	0.8%	4.2%	0.7%	2.0%	1.0%	1.1%
Mid-Peninsula	1.2%	0.8%	0.8%	0.7%	0.8%	1.0%
Millbrae	0.9%	*	0.6%	0.9%	0.8%	0.8%
Milpitas	2.5%	6.8%	2.6%	8.3%	5.9%	3.4%
Mountain View	3.1%	2.2%	2.6%	8.6%	9.0%	3.7%
North Coast CWD	1.3%	0.0%	0.4%	0.9%	2.3%	1.1%
Palo Alto	3.7%	4.1%	3.5%	5.6%	7.6%	4.0%
Purissima Hills WD	0.9%	0.0%	0.0%	0.5%	0.7%	0.6%
Redwood City	4.1%	*	4.7%	0.5%	2.3%	3.5%
San Bruno	1.4%	*	1.0%	0.8%	1.1%	1.2%
San Jose (North)	0.5%	7.3%	0.3%	7.4%	0.0%	1.5%
Santa Clara	5.2%	19.6%	10.4%	6.3%	5.3%	7.3%
Skyline WD	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%
Stanford	0.6%	2.4%	0.3%	5.0%	0.0%	1.0%
Sunnyvale	6.7%	*	7.2%	13.6%	5.5%	6.9%
Westborough WD	0.3%	0.0%	0.3%	0.3%	1.5%	0.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Notes:

Some agencies did not report industrial and commercial water consumption separately. These agencies have an asterisk in the Industrial column, and the Commercial column represents combined industrial and commercial water consumption.

A record-keeping error for East Palo Alto makes it appear that the agency sold more water than it received in FY 2004-05.

Sources:

BAWSCA Annual Survey FY 2004-2005

SFPUC Data <CP Accounts.xls>

2.b. Agencies

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 accounts and to 27 wholesale agencies.The Bay Area Water Supply and Conservation Agency (BAWSCA) is composed of the 25 cities and water districts and two private utilities, Stanford University and California Water Service Company,[1] that are wholesale customers of SFPUC. Member agencies of BAWSCA service a population of 1.6 million, with over 370,000 residential accounts, 5,500 industrial accounts, and 25,800 commercial accounts. SFPUC water accounts for roughly 68% of total water supply for BAWSCA members, and 32% of water supply is from other sources.

2.c. Economic and Weather Characteristics by Agency

There is notable variation among residential customers across the agencies. As shown in Table 2, average single family home consumption varies considerably. Water consumption varies between an average of 176 gallons per day (gpd) to 882 gpd.The range in average lot size is 2,800 sq. ft. to 26,200 sq. ft, the range in household income is $51,000 to $186,400, the range in maximum temperature is 65.6 degrees F to 82.7 degrees F, and the range in yearly precipitation is 17.3 inches to 37 inches. Differences in the level of per capita consumption are largely explained by variation in average lot size, household income, and climate (measured by maximum temperature and precipitation).

1 The California Water Service Company is broken down into its three jurisdictions in the area: CWS – Bear Gulch, CWS – Mid-Peninsula, and CWS – South San Francisco.

Table 2: Economic and Weather Characteristics by Agency

Agency Name	Mean Single-Family Home Consumption (ccf)	Mean Single-Family Home Consumption (gpd)	Average Lot Size (1000s sq ft)	Average Household Income ($1000s)	Average Maximum Summer Temperature (F)	Average Yearly Precipitation (inches)
SFPUC Retail	7.05	176	2.80	58.80	72.4	21.5
Alameda CWD	13.09	326	7.12	85.57	77.9	17.3
Brisbane	7.31	182	4.22	63.67	72.2	24.4
Burlingame	12.09	301	14.37	76.32	72.2	24.4
Coastside CWD	9.70	242	7.00	86.36	65.6	31.3
CWS - Bear Gulch	25.48	635	19.97	169.33	80.8	22.6
CWS - Mid Peninsula	12.37	308	6.86	77.08	80.8	22.6
CWS - South San Francisco	9.61	240	4.80	59.14	72.2	24.4
Daly City	9.02	225	3.71	65.02	70.5	37.0
East Palo Alto WD	13.77	343	7.03	51.00	79.6	18.5
Estero MID	12.89	322	4.78	92.95	80.8	22.6
Hayward	10.61	264	6.67	59.36	77.9	17.3
Hillsborough	31.46	784	14.62	186.42	72.2	24.4
Menlo Park	15.09	376	8.61	94.38	79.6	18.5
Mid-Peninsula	10.75	268	7.84	83.95	80.8	22.6
Millbrae	9.87	246	7.61	69.02	72.2	24.4
Milpitas	12.76	318	5.99	86.29	82.7	17.7
Mountain View	11.05	275	6.33	70.03	79.6	18.5
North Coast CWD	9.62	240	6.22	72.87	70.5	37.0
Palo Alto	14.96	373	9.84	127.72	79.6	18.5
Purissima Hills WD	35.37	882	26.22	150.78	79.6	18.5
Redwood City	11.71	292	6.96	71.78	80.8	22.6
San Bruno	11.01	275	5.73	64.26	72.2	24.4
San Jose	9.00	225	7.69	99.98	82.7	17.7
Santa Clara	14.11	352	6.02	71.51	82.7	17.7
Skyline WD	11.88	296	14.93	89.83	80.8	22.6
Sunnyvale	13.34	333	6.48	76.57	82.7	17.7
Westborough WD	8.32	207	5.01	75.88	70.5	37.0
Overall	**13.41**	**334**	**8.48**	**87.33**	**76.9**	**23.0**

2.d. Allocation and Utilization

2.d.i. Uses by Agency and Customer Type

Each retail agency in the SFPUC service area provides water to a unique mix of customers. For example, as shown in Figure 2 and Table 3, 65% of Alameda CWD demand is residential, 9% is industrial, and 13% is commercial. In contrast, 42% of Menlo Park is residential, 27% is industrial and 11% is commercial. Some agencies serve residential customers almost exclusively. Several serve a substantial share of government/institutional customers. Less than one-third have a substantial industrial customer base (10% or more).

Figure 2: Water Consumption by Sector for All Agencies

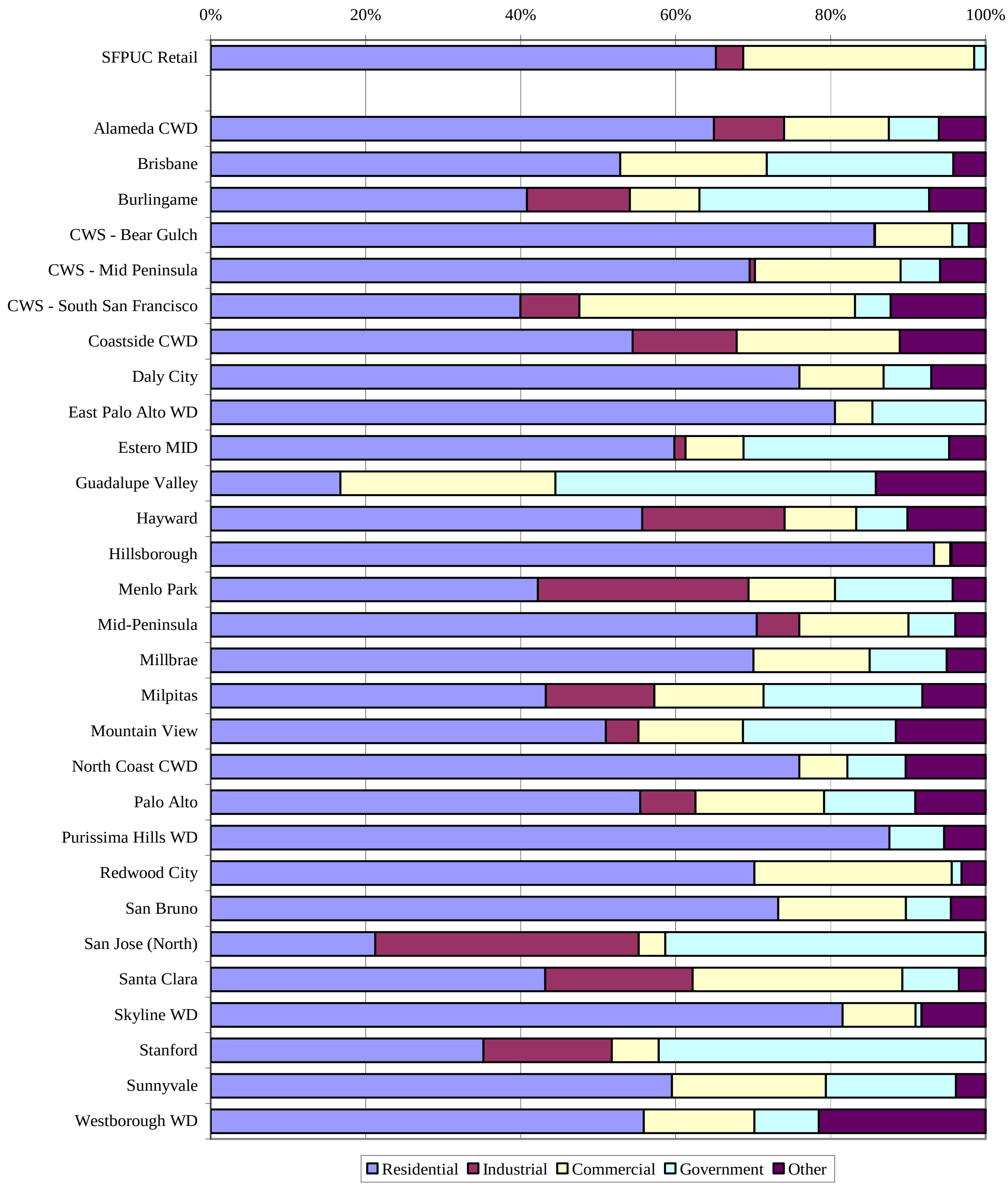


Table 3: Percent of Total Water Consumption by Sector for BAWSCA Members and SFPUC for FY 2004-2005

Agency	Residential	Industrial	Commercial	Government	Other	Total
SFPUC Retail	65.2%	3.5%	29.8%	1.5%	0.0%	100.0%
Alameda CWD	64.9%	9.1%	13.5%	6.4%	6.1%	100.0%
Brisbane	52.8%	*	18.9%	24.1%	4.2%	100.0%
Burlingame	40.8%	13.2%	9.0%	29.6%	7.3%	100.0%
CWS - Bear Gulch	85.7%	0.1%	10.0%	2.1%	2.2%	100.0%
CWS - Mid Peninsula	69.6%	0.7%	18.8%	5.1%	5.9%	100.0%
CWS - South San Francisco	40.0%	7.6%	35.6%	4.6%	12.2%	100.0%
Coastside CWD	54.4%	13.4%	21.0%	0.0%	11.1%	100.0%
Daly City	76.0%	0.0%	10.9%	6.1%	7.0%	100.0%
East Palo Alto WD	80.5%	0.0%	4.8%	14.6%	0.0%	100.0%
Estero MID	59.8%	1.4%	7.5%	26.5%	4.7%	100.0%
Guadalupe Valley	16.7%	*	27.8%	41.3%	14.2%	100.0%
Hayward	55.7%	18.3%	9.3%	6.6%	10.1%	100.0%
Hillsborough	93.3%	0.0%	2.1%	0.2%	4.4%	100.0%
Menlo Park	42.2%	27.2%	11.1%	15.2%	4.2%	100.0%
Mid-Peninsula	70.5%	5.5%	14.1%	6.0%	3.9%	100.0%
Millbrae	70.0%	*	15.0%	9.9%	5.0%	100.0%
Milpitas	43.2%	14.0%	14.1%	20.5%	8.2%	100.0%
Mountain View	51.0%	4.2%	13.5%	19.7%	11.6%	100.0%
North Coast CWD	75.9%	0.0%	6.2%	7.5%	10.3%	100.0%
Palo Alto	55.4%	7.1%	16.6%	11.8%	9.1%	100.0%
Purissima Hills WD	87.6%	0.0%	0.0%	7.1%	5.4%	100.0%
Redwood City	70.2%	*	25.5%	1.3%	3.1%	100.0%
San Bruno	73.2%	*	16.5%	5.8%	4.5%	100.0%
San Jose (North)	21.3%	34.0%	3.4%	41.3%	0.0%	100.0%
Santa Clara	43.2%	19.0%	27.0%	7.3%	3.4%	100.0%
Skyline WD	81.5%	0.0%	9.4%	0.8%	8.3%	100.0%
Stanford	35.2%	16.6%	6.0%	42.2%	0.0%	100.0%
Sunnyvale	59.5%	*	19.9%	16.8%	3.8%	100.0%
Westborough WD	55.9%	0.0%	14.3%	8.3%	21.5%	100.0%

Notes:

Some agencies did not report industrial and commercial water consumption separately. These agencies have an asterisk in the Industrial column, and the Commercial column represents combined industrial and commercial water consumption.

A record-keeping error for East Palo Alto makes it appear that the agency sold more water than it received in FY 2004-05.

Sources:

BAWSCA Annual Survey FY 2004-2005

SFPUC Data <CP Accounts.xls>

Key Finding #2: There is diversity in demand across the agencies operating in service area driven by different sector mixes (residential, commercial, and industrial), lot size, household income, and weather.

There is also great variation with respect to pricing and conservation efforts. Table 4 presents the average marginal residential rates by agency and the percentage of the 14 Best Management Practices

(BMPs) for conservation implemented by agency. [2] The mean marginal rate for residential water ranges from a low of $1.05/ccf in Milpitas to a high of $6.65/ccf in the Skyline WD. BMP implementation varies from a low of 33% in Brisbane, Hillsborough, and San Bruno to a high of 100% in SFPUC retail. There are also important differences regarding which BMPs have been implemented as shown in Table 5. For example all agencies have implemented BMPs 4, 6, and 11 and most have implemented BMPs 2 and 3, but far fewer have implemented BMPs 5a, 5b, 9a, and 9b.

Table 4: Mean Marginal Rate and BMP Implementation

Agency Name	Mean Marginal Rate ($/ccf)	BMP Implementation
SFPUC Retail	$1.49	100%
Alameda CWD	$1.88	87%
Brisbane	$2.42	33%
Burlingame	$2.23	80%
Coastside CWD	$2.62	87%
CWS - Bear Gulch	$2.35	67%
CWS - Mid Peninsula	$2.20	67%
CWS - South San Francisco	$1.74	73%
Daly City	$2.80	80%
East Palo Alto WD	$1.86	53%
Estero MID	$1.36	53%
Hayward	$1.92	60%
Hillsborough	$2.75	33%
Menlo Park	$1.77	47%
Mid-Peninsula	$2.87	53%
Millbrae	$2.23	87%
Milpitas	$1.05	87%
Mountain View	$2.39	93%
North Coast CWD	$3.52	73%
Palo Alto	$3.03	93%
Purissima Hills WD	$2.87	60%
Redwood City	$2.11	87%
San Bruno	$2.60	33%
San Jose	$1.56	93%
Santa Clara	$1.52	87%
Skyline WD	$6.65	40%
Sunnyvale	$1.74	80%
Westborough WD	$2.04	53%
Overall	**$2.35**	**69%**

Notes:
As of the San Francisco 2005 UWMP, SFPUC retail implemented 80% of the BMPs.
As of the FY 2004-05 BAWSCA Annual Survey, Sunnyvale implemented 73% of the BMPs.

2 The SFPUC and some BAWSCA agencies entered into a memorandum of understanding with the California Urban Water Conservation Council to implement 14 best management practices. These BMPs are: 1) residential surveys; 2) residential retrofits; 3) system water audits; 4) metering; 5a) landscape audits; 5b) water budgets; 6) clothes washers; 7) public info; 8) school education; 9a) commercial water audits; 9b) commercial ultra low flow toilets; 10) Wholesaler incentives; 11) Rates; 12) conservation coordinator; 13) waste prohibitions; and 14) residential ultra low flow toilets. See www.CUWCC.com

Table 5: BMP Implementation by Water Agency

Member	BMP1	BMP2	BMP3	BMP4	BMP5a	BMP5b	BMP6	BMP7	BMP8	BMP9a	BMP9b	BMP11	BMP12	BMP13	BMP14
Alameda CWD	nce	x	x	x	x	x	x	x	x	x	x	x	x	x	nce
Brisbane				x			x	x				x		x	
Burlingame	x	x	x	x		x	x	x	x	x	x	x			x
CWS - Bear Gulch	nce	x	x	x			x	x	x			x	x	x	x
CWS - Mid Peninsula	nce	x	x	x			x	x	x			x	x	x	x
CWS - South San Francisco	nce	x	x	x	x		x	x	x			x	x	x	x
Coastside CWD		x	x	x	x	x	x	x	x		x	x	x	x	x
Daly City	nce	x	x	x	x	x	x	x	x	x	nce	x	x	x	nce
East Palo Alto WD		x	x	x			x	x	x			x	x		
Estero MID			x	x			x	x				x	x	x	x
Guadalupe Valley				x			x	x				x	x	x	
Hayward		x	x	x			x	x				x	x	x	x
Hillsborough				x			x	x				x	x		
Menlo Park			x	x			x	x				x	x	x	
Mid-Peninsula	x	x	x	x			x	x	x			x			
Millbrae	x	x	x	x	x		x	x	x		x	x	x	x	x
Milpitas	x	x	x	x	x		x	x	x	x		x	x	x	x
Mountain View	x	x	x	x	x		x	x	x	x	x	x	x	x	x
North Coast CWD	x	x	x	x			x	x	x			x	x	x	x
Palo Alto	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Purissima Hills WD	x	x	x	x			x	x				x		x	x
Redwood City	x	x	x	x	x	x	x	x	x		x	x	x		x
San Bruno				x			x	x	x			x			
San Jose	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Santa Clara	x	x	x	x	x		x	x	x	x		x	x	x	x
Skyline WD		x	x	x			x		e			x			x
Stanford	x	x	x	x	x		x	x			x	x	x	x	x
Sunnyvale	x	x	x	x	x		x	x	x	x		x		x	x
Westborough WD	x		x	x			x					x	x	x	x
SFPUC Retail	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Notes:

The SFPUC and some BAWSCA agencies entered into a memorandum of understanding with the California Urban Water Conservation Council to implement 14 best management practices. These BMPs are: 1) residential surveys; 2) residential retrofits; 3) system water audits; 4) metering; 5a) landscape audits; 5b) water budgets; 6) clothes washers; 7) public info; 8) school education; 9a) commercial water audits; 9b) commercial ultra low flow toilets; 10) Wholesaler incentives; 11) Rates; 12) conservation coordinator; 13) waste prohibitions; and 14) residential ultra low flow toilets.

BMP 10 is excluded because it is only relevant for wholesale water sellers.

As of the San Francisco 2005 UWMP, SFPUC retail implemented 80% of the BMPs.

As of the FY 2004-05 BAWSCA Annual Survey, Sunnyvale implemented 73% of the BMPs.

nce = not cost effective

e = exempt

Sources:

Bay Area Water Supply and Conservation Agency Annual Survey, FY 2004-05

2005 San Francisco Urban Water Management Plan

2.d.ii. Supply Sources by Agency

While the SFPUC provides a critically important supply of water to the Bay Area, it is by no means the only water source in the region. Retail agencies in BAWSCA have, to varying degrees, built a portfolio of water supplies that supplement and, in some cases, eclipse the SFPUC supply. For example, one of SFPUC's largest wholesale customers, the Alameda County Water District, has invested in numerous supply sources, including State Water Project supplies, local surface water, local ground water, recycling, desalination and externally banked groundwater.[3]

Some water supplies are positively correlated with deliveries from Hetch Hetchy. Local surface supplies, State Water Project deliveries and Central Valley Project supplies fall into this category. Other supplies may be used more heavily during a drought. For example, agencies may choose to temporarily overdraft groundwater basins and call on water banked outside the region.

Further, the SFPUC and BAWSCA member agencies have crafted an agreement, as yet untested, that would allow retail agencies to reallocate available supplies through voluntary trading during a drought. An analysis of drought mitigation must include all of these short-run supply strategies, including trading

3 Alameda County Water District's supply options include the Newark desalination plant. http://www.acwd.org/sources_of_supply.php5#desal.

between SPFUC and BAWSCA members, access to external sources, and further conservation investments. Modeling these strategies requires descriptions of available capacity, opportunities for trade, and conservation investment cost and projected water savings. In this section, we describe existing capacities by source and existing interties. In the next section, we review the current rules for within region trading. These rules demonstrate that the agencies anticipate trading in the face of shortages may be an attractive drought mitigation strategy.

Table 6 lists supply sources by retail agency. While 17 agencies, excluding SFPUC retail, rely solely on SFPUC water, the remaining 12 agencies have alternative water supply sources according to the BAWSCA Annual Report for fiscal year 2004-2005. Table 6 lists each BAWSCA member, whether it receives water from SFPUC only, its alternative water sources, and its emergency interties with other local agencies. The alternative sources of water have the potential to offer additional relief in the event of a region-wide drought.

Table 6: Water Supplies for BAWSCA Agencies

		Alternative Sources					
Member	SFPUC Only	Water Treatment (Surface)	Wells and Groundwater	State Water Project	Santa Clara Valley WD	Recycled Water	Emergency Interties
Alameda CWD		x	x	x			Milpitas, Hayward
Brisbane	x						CWS - South SF, Daly City
Burlingame	x						CWS, San Mateo, Hillsborough, Millbrae
Coastside CWD		x	x				
CWS - Bear Gulch		x					Redwood City, Menlo Park
CWS - Mid Peninsula	x						Mid-Peninsula, Redwood City, Burlingame, Hillsborough, Estero
CWS - South San Francisco			x				Brisbane, San Bruno, Daly City
Daly City			x			x (NP)	North Coast, Westborough, CWS, Brisbane
East Palo Alto WD	x		x (EM)				Palo Alto, Menlo Park, O'Connor Tract Water Coop
Estero MID	x						CWS - San Mateo, Mid-Peninsula
Guadalupe Valley	x						Brisbane
Hayward	x		x (EM)				Alameda, EBMUD
Hillsborough	x						Burlingame, CWS - San Mateo
Menlo Park	x						CWS - Bear Gulch, Redwood City, East Palo Alto, O'Connor Tract Water Coop, Palo Alto Park Mutual Water Co.
Mid-Peninsula	x						Estero, Redwood City, CWS - San Mateo, CWS - San Carlos
Millbrae	x						Burlingame
Milpitas			x (EM)		x	x (NP)	Alameda, San Jose WC, Santa Clara Valley WD
Mountain View			x		x		Palo Alto, Sunnyvale, Santa Clara Valley WD, CWS
North Coast CWD	x	x					San Bruno, Daly City, Westborough
Palo Alto	x		x (EM)			x (NP)	East Palo Alto, Mountain View, Stanford
Purissima Hills WD	x						CWS - Los Altos
Redwood City	x					x (NP)	CWS - Bear Gulch, CWS - Mid-Peninsula, Mid-Peninsula, Menlo Park
San Bruno			x				North Coast, CWS - South SF
San Jose (North)			x			x (NP)	Santa Clara
Santa Clara			x		x	x (NP)	Santa Clara Valley WD
Skyline WD	x		x (EM)				
Stanford		x (NP)	x (NP/EM)				Palo Alto
Sunnyvale			x		x	x (NP)	CWS, Santa Clara Valley WD, Mountain View, Cupertino
Westborough WD	x						North Coast, Daly City

NP = non-potable water source
EM = emergency water source

Notes:
SFPUC Retail receives all its water from SFPUC.
An agency marked as SFPUC Only receives its entire non-emergency supply of water from SFPUC.
For Wells and Groundwater, a mark of "x(EM)" denotes that groundwater is activated only for emergencies.
Menlo Park receives a small percentage if its water from East Palo Alto. The ultimate source of this water is from SFPUC.
Mountain View receives a small portion of its water from CWS.
San Bruno receives a small portion of its water from North Coast CWD. The ultimate source of this water is from SFPUC.

Source: Agency Profiles, BAWSCA Annual Survey FY 2004-05.

The majority of the BAWSCA member agencies in San Mateo County use SFPUC as their only supply. However, Coastside CWD receives over a quarter of its water from local groundwater and surface water. CWS – Bear Gulch uses surface water for over 12% of its supply, Daly City uses groundwater for 8% of its supply, and San Bruno uses groundwater for 16% of its supply.

In Santa Clara County, all agencies but Purissima Hills WD and Palo Alto[4] rely on water sources other than SFPUC. Milpitas, Mountain View, Santa Clara, and Sunnyvale all purchase significant shares of their water supply from the Santa Clara Valley WD. Milpitas receives over 30% and Sunnyvale receives 46% of its water supply from SCVWD. Milpitas, Palo Alto, San Jose (North), Santa Clara, and Sunnyvale all use recycled water for five to ten percent of their supply. Stanford draws over 20% of its water needs from local surface water and over 7% from groundwater. Santa Clara uses groundwater for over 56% of its water supply, relying on SFPUC for only 18% of its supply.

In Alameda County, Hayward relies exclusively on SFPUC water, but Alameda CWD derives only 23% of its water supply from SFPUC. Alameda CWD is the only BAWSCA agency that utilizes State Water Project water, which accounts for over 25% of its water supply. Additionally, groundwater accounts for 32% of Alameda CWD's supply, its desalination plant accounts for roughly 8% of supply, and local surface water accounts for the remaining 12% of supply.

Overall, five of the BAWSCA agencies have water treatment plants or surface water sources. Ten of the BAWSCA agencies extract groundwater as a normal supply source, and five additional agencies have wells in case of emergency water shortages. The larger of the BAWSCA agencies also tend to draw supplies from other non-local sources such as the State Water Project or the Santa Clara Valley Water District.

In the event of emergencies, all BAWSCA agencies except for Coastside CWD and Skyline WD have emergency interties with local agencies, both inside and outside of BAWSCA members. These interties allow agencies to mitigate localized water emergencies. In a sustained drought condition, however, interties may not be an effective source of water because all the water agencies in the Bay Area will likely be facing similar pressures.

Across all BAWSCA agencies, SFPUC water accounts for 68% of water supply, groundwater accounts for over 12%, surface and recycled water account for nearly 6% combined, and Santa Clara Valley WD and State Water Project water combined account for 14% of water supply. While a large number of the BAWSCA agencies are either entirely or nearly entirely dependent upon SFPUC for their water supply, a few of the larger agencies have significant alternative water sources. In the event of a reduction in SFPUC water, these agencies may be able to mitigate regional short-term economic losses from a drought by tapping more extensively into these other sources. The presence of these alternative sources along with banked water adds an interesting dynamic to the Bay Area water supply in the event of a drought.

Key Finding #3: There is diversity of sources within the service area. There is also diversity of effort with respect to implementation of conservation practices.

4 Palo Alto receives 100% of its potable water supply from SFPUC, but uses recycled water for non-potable purposes.

2.d.iii. Shortage Sharing Agreements

The "Interim Water Shortage Allocation Plan" and the "Interim Water Shortage Allocation Plan among Suburban Purchasers" discuss the method for allocating water procured by the San Francisco Public Utilities Commission (SFPUC) and outlines the process by which Suburban Purchasers can transfer banked water and shortage allocations among themselves and the SFPUC to meet their demand.[5]

Each year the SFPUC determines whether a shortage condition exists based upon projected available water supply and the projected system-wide SFPUC purchases. If projected demand exceeds projected supply a water shortage is declared and the SFPUC decides on whether voluntary or mandatory actions are required to reduce purchases. If a voluntary response is deemed sufficient, the SFPUC and the Suburban Purchasers make good faith efforts to reduce water purchases to remain within their annual shortage allocations and associated monthly budgets. If a mandatory response is required however, the SFPUC will implement the following strategy:

- Calculate the proportion of reduction for each Suburban Purchaser according to a multi-variable equation which essentially applies the fraction of each entity's averaged historical purchases over the aggregate historical average

- Apply the proportion to the total reduction deemed necessary by the SFPUC to determine the necessary reduction for each Suburban Purchaser[6]

The SFPUC permits voluntary transfers of banked water and shortage allocations between the SFPUC and Suburban Purchasers, as well as among Suburban purchasers themselves. The process for such transactions is outlined below:

- Volume of transferred water will be credited to the transferee's water bank or shortage allocation account and debited from the transferor's.

- Transferring parties must notify SFPUC and the Bay Area Water Users Association (BAWUA) so that adjustments to accounts can be made.

- The transfer of banked water or shortage allocations will be deemed an "emergency transfer" according to the Master Contract signed with the SFPUC.

- If the SFPUC incurs "extraordinary costs"[7] associated with the implementation of the transfers: i) in the case of transfers between Purchasers, the cost will be borne equally between the two, ii) in the case of transfers between the SFPUC and the Purchaser the SFPUC's share of the costs will not be added to the Suburban revenue requirement.

Because of wholesale excess use charges which escalate substantially as shortage allocations are surpassed, the ability to transfer banked water or shortage allocations enables Suburban Purchasers to avoid some of the additional costs associated with exceeding their shortage allocations. Currently, Suburban Purchasers annual excess use charges are calculated by comparing annual purchases against shortage allocations (adjusted for transfers) which makes transfers among Suburban Purchasers or the SFPUC an important mechanism for ameliorating costs. There has been discussion recently among the SFPUC and Suburban Purchasers about diverting the excess charge payments towards the purchase of

5 San Francisco Public Utilities Commission 2004, "Interim Water Shortage Allocation Plan"

San Francisco Public Utilities Commission 2004, "Interim Water Shortage Allocation Plan Among Suburban Purchasers"

San Francisco Public Utilities Commission 2004, "Wholesale Customer Water Conservation Potential"

6 The calculation and final adjustments contain other complexities which are not mentioned here and can be found in the SFPUC report, "Interim Water Shortage Allocation Plan Among Suburban Purchasers"

7 "Extraordinary costs means additional costs directly attributable to accommodating transfers and are not incurred in non-drought years nor simply as a result of the shortage condition itself. (Interim Water Shortage Allocation Plan, p. 5)"

water from the State Drought Water Bank or other willing sellers to procure more water, but the terms of such an agreement have yet to be negotiated in the master contract. This system of allocation will not necessarily result in an equal reduction across retail customers.

The following example shows how the shortage sharing rule is applied to a particular agency:

Step 1: Calculate Purchaser's Allocation Basis using an arithmetic average of three components:

- The greater of a Suburban Purchaser's Supply Assurance for the Master Contract or its average purchases in million gallons per day from SFPUC over three years[8]; 1996-97, 97-98, 98-99 (17.07 mgd).
- Average of purchases from SFPUC during 96-97, 97-98, 98-99 (12.96 mgd).
- Average of purchases from SFPUC during the three fiscal years immediately preceding the declaration of water shortage emergency (12.96 mgd).
- (Palo Alto Average = 14.33 mgd)

Step 2: Calculate Purchaser's Allocation Factor using the above average divided by the sum for all Suburban Purchasers.

- (Palo Alto Average/Sum of Suburban Purchasers' Averages) = (14.33 mgd/ 268.35 mgd) = (Palo Alto's Allocation Factor of 5.34%)

Step 3: Calculate Purchaser's Initial Shortage Allocation by multiplying the Allocation Factor against the amount of water available to Suburban Purchasers collectively; assumed as the sum of the previous year's purchases minus the percentage reduction deemed necessary.

- (Palo Alto's Allocation Factor * Available Water) = (5.34% * 186.66 mgd) (Palo Alto's Initial Shortage Allocation = 9.97 mgd)

Step 4: Determine Purchaser's Final Shortage Allocation by adjusting initial allocations to ensure that San Jose and Santa Clara's have the highest percentage reductions among Suburban Purchaser's:

- If San Jose or Santa Clara's percent reductions are smaller than the highest among purchasers then their initial allocations will be reduced to a point where they are not.
- The amount of shortage allocation removed will be distributed among the other suburban purchaser's proportionally and the Final Shortage Allocation will be determined
- (Palo Alto's Final Shortage Allocation = Initial Allocation + Allocation Factor * San Jose & Santa Clara's Total Allocation Reduction) (9.97 mgd + 5.34% * 0.26 mgd) = (Palo Alto's Final Allocation of 9.99 mgd)

8 With specifications for Hayward, Estero, San Jose and Santa Clara.

3.a. Residential Use

Determining residential consumer response to potential mitigation strategies is critical to assessing effectiveness and economic impacts. We have estimated residential water demand models for SFPUC and BAWSA member agencies. We have also reviewed the literature regarding these values as well as willingness to pay to avoid water shortages. In brief, we have found that all customers demonstrate sufficient price sensitivity to support price and investment related drought mitigation policies.

3.a.i. Econometric Study

A price elasticity of demand for water was calculated using single-family residential price and consumption data from SFPUC and BAWSCA member agencies. Water consumption, marginal price, and customer data were taken from BAWSCA Annual Surveys (FY 1995-96 through FY 2004-05). Price and consumption data for FY 2002-03 were unavailable for BAWSCA member agencies. Additionally, the following BAWSCA agencies were not included in the regression analysis: Cordilleras, Guadalupe Valley Municipal Improvement District, Los Trancos, and Stanford University.[9] SFPUC data, received from the SFPUC,[10] only spanned FY 1999-00 through FY 2004-05.[11] In total, there are 249 observations spanning 28 water agencies (27 BAWSCA members and SFPUC). Each of the BAWSCA members with price data has nine years of data, and SFPUC has six.

Average yearly single-family household consumption for each water agency was calculated by dividing the total single-family residential consumption for the fiscal year by the number of single-family residential accounts for that fiscal year. A monthly average consumption was created by dividing the yearly average by twelve. The marginal price of water is equal to the marginal price charged by each agency to residential customers for a ccf of water at the calculated average monthly consumption for that fiscal year. While we would ideally like to have an actual marginal price of water, the lack of customer-level data forces us to use the above marginal price as a proxy.

Table 7 lists by water agencies the number of observations, average price and consumption, income, lot size, BMP percent, annual precipitation, summer temperature, and the nearest weather station.

9 No price data are available for Cordilleras, Stanford, and Guadalupe Valley. Los Trancos was merged into CWS – Bear Gulch in FY 2004-05. Cordilleras dropped out of BAWSCA after FY 2001-02.

10 Excel file <CP Accounts.xls> received from SFPUC.

11 The fiscal years of BAWSCA and SFPUC start on July 1st.

Table 7: Summary of Residential Demand Model Data by Water Agency

Agency Name	Number of Observations	Mean Marginal Rate ($/ccf)	Mean Single-Family Home Consumption (ccf)	BMP Implementation	Average Lot Size (1000s sq ft)	Average Household Income ($1000s)	Average Maximum Summer Temperature (F)	Average Yearly Precipitation (inches)	Nearest Weather Station
SFPUC Retail	6	$1.49	7.05	100%	2.80	58.80	72.4	21.5	San Francisco WSO
Alameda CWD	9	$1.88	13.09	87%	7.12	85.57	77.9	17.3	Newark
Brisbane	9	$2.42	7.31	33%	4.22	63.67	72.2	24.4	San Francisco WSO
Burlingame	9	$2.23	12.09	80%	14.37	76.32	72.2	24.4	San Francisco WSO
Coastside CWD	9	$2.62	9.70	87%	7.00	86.36	65.6	31.3	Half Moon Bay
CWS - Bear Gulch	9	$2.35	25.48	67%	19.97	169.33	80.8	22.6	Redwood City
CWS - Mid Peninsula	9	$2.20	12.37	67%	6.86	77.08	80.8	22.6	Redwood City
CWS - South San Francisco	9	$1.74	9.61	73%	4.80	59.14	72.2	24.4	San Francisco WSO
Daly City	9	$2.80	9.02	80%	3.71	65.02	70.5	37.0	Pacifica 4 SSE
East Palo Alto WD	9	$1.86	13.77	53%	7.03	51.00	79.6	18.5	Palo Alto
Estero MID	9	$1.36	12.89	53%	4.78	92.95	80.8	22.6	Redwood City
Hayward	9	$1.92	10.61	60%	6.67	59.36	77.9	17.3	Newark
Hillsborough	9	$2.75	31.46	33%	14.62	186.42	72.2	24.4	San Francisco WSO
Menlo Park	9	$1.77	15.09	47%	8.61	94.38	79.6	18.5	Palo Alto
Mid-Peninsula	9	$2.87	10.75	53%	7.84	83.95	80.8	22.6	Redwood City
Millbrae	9	$2.23	9.87	87%	7.61	69.02	72.2	24.4	San Francisco WSO
Milpitas	9	$1.05	12.76	87%	5.99	86.29	82.7	17.7	San Jose
Mountain View	9	$2.39	11.05	93%	6.33	70.03	79.6	18.5	Palo Alto
North Coast CWD	9	$3.52	9.62	73%	6.22	72.87	70.5	37.0	Pacifica 4 SSE
Palo Alto	9	$3.03	14.96	93%	9.84	127.72	79.6	18.5	Palo Alto
Purissima Hills WD	9	$2.87	35.37	60%	26.22	150.78	79.6	18.5	Palo Alto
Redwood City	9	$2.11	11.71	87%	6.96	71.78	80.8	22.6	Redwood City
San Bruno	9	$2.60	11.01	33%	5.73	64.26	72.2	24.4	San Francisco WSO
San Jose	9	$1.56	9.00	93%	7.69	99.98	82.7	17.7	San Jose
Santa Clara	9	$1.52	14.11	87%	6.02	71.51	82.7	17.7	San Jose
Skyline WD	9	$6.65	11.88	40%	14.93	89.83	80.8	22.6	Redwood City
Sunnyvale	9	$1.74	13.34	80%	6.48	76.57	82.7	17.7	San Jose
Westborough WD	9	$2.04	8.32	53%	5.01	75.88	70.5	37.0	Pacifica 4 SSE
Overall	**249**	**$2.35**	**13.41**	**69%**	**8.48**	**87.33**	**76.9**	**23.0**	

Climatic and other exogenous agency-specific factors were used as controls. The weather variables used in the regression are average maximum daily temperature during the summer months of July, August, and September; and total annual precipitation. (In general, there is little to no precipitation in the Bay Area during the summer.) Each water agency was matched to the geographically closest weather station reporting to the Western Regional Climate Center.[12] Some water agencies share the same weather data because there are only seven weather stations to the 28 water agencies in the regression data.

Additional variables to control for differences in water consumption behavior include average single-family home lot size from DataQuick and average household income from Census data. Both these variables control for socioeconomic factors. We would expect water agencies with larger housing lots to consume more water because larger lots correlate with more outdoor water use (for lawns and landscapes, etc.). Wealthier households are also expected to use more water than poorer households.

Lot size data from DataQuick were for single family homes by ZIP code. An average agency lot size was calculated by intersecting ZIP code boundaries with BAWSCA and SFPUC agency boundaries using ArcView and taking an area- and population-density-weighted average of the ZIP codes that comprise each agency. Similarly, median household income data by census tract were intersected with water agency boundaries, and an area- and population-density-weighted average of the census tracts median household incomes is used as the average household income for each water agency.

The percent of best management practices (BMPs) implemented in FY 2004-05, as reported in the BAWSCA Annual Survey report, is also included to control for variations in consumption behavior among the different agencies. SFPUC BMP implementation was derived from the 2005 San Francisco Urban Water Management Plan.[13] Note that this variable does not vary with time. Table 4 shows the BMPs implemented by each water agency in FY 2004-05.

12 Available at http://www.wrcc.dri.edu/summary/Climsmcca.html. The seven weather stations reporting to the WRCC are Half Moon Bay, Newark, Pacifica 4 SSE, Palo Alto, Redwood City, San Francisco WSO (SFO), and San Jose.

13 BMP implementation for prior years is not available, although the California Urban Water Conservation Council has additional data for some of the water agencies.

Table 8 summarizes the results of the regression analysis. A detailed description of the model and results are presented in Appendix C. Controlling for weather and other agency-specific factors detailed below, we estimate a price elasticity of -0.176, which means that a 10% increase in the incremental price of water will cause single-family residential customers in the SFPUC service area to reduce water consumption by 1.76 percent. This elasticity indicates that the price elasticity for water is relatively inelastic: customers do not respond to increases in water prices by proportionately decreasing water consumption. However, the coefficient on the term is statistically significant, indicating that there is some water consumption change due to changes in price.

Table 8: Estimation Results for Residential Water Demand Model

Dependent Variable: ln(water consumption)

	[I]		[II]		[III]		[IV]	
	Base Specification		With Rate-BMP Interaction		With Rate-BMP and Rate-Income Interactions		With Rate-BMP, Rate-Income, and Rate-Lotsize Interactions	
Variable	coeff.	|t-statistic|	coeff.	|t-statistic|	coeff.	|t-statistic|	coeff.	|t-statistic|
ln(rate per ccf at average use)	-0.1759	4.89	-0.5477	4.94	-1.1263	5.37	-0.9381	3.59
percent of BMPs implemented	-0.1845	2.45	-0.6988	4.08	-0.7524	4.55	-0.6018	3.11
average lot size (thousand sq. ft.)	0.0351	10.23	0.0361	10.11	0.0347	11.50	0.0548	5.97
"average median" household income (thousand dollars)	0.0053	8.82	0.0050	7.43	-0.0003	0.20	-0.0019	1.16
average daily maximum summer temperature (July, August, September)	0.0093	3.72	0.0120	4.88	0.0132	5.43	0.0146	5.70
annual precipitation (inches)	-0.0013	0.81	-0.0016	0.96	-0.0007	0.43	-0.0005	0.28
year	0.0041	0.90	0.0040	0.91	0.0036	0.84	0.0041	0.96
Rate-BMP Interaction			0.6067	3.76	0.6770	4.50	0.4627	2.26
Rate-Income Interaction					0.0062	3.66	0.0078	5.19
Rate-Lotsize Interaction							-0.0218	2.27
R-squared	0.78		0.80		0.81		0.81	

Notes:
Robust t-statistics shown.

Sources:
BAWSCA Annual Survey
SFPUC data (<CP Accounts.xls>)
DataQuick lot size data
Census data for household income
Weather data from WRCC

Key Finding #4: Residential demand is not very responsive to prices. Relatively large price increases are needed to reduce residential demand.

As expected, the percentage of BMPs implemented significantly affects the amount of water consumption. However, the coefficient on this term is not very high, indicating that BMPs as a whole do not significantly influence residential water consumption. An increase of two BMPs (out of 15 total) in an agency can be expected to yield a 2.5% reduction in water consumption, a modest amount.

The average lot size coefficient is also as we would expect: agencies with larger lot sizes will tend to have consumers who consume more water. The coefficient, which is highly significant, indicates that an increase in lot size of 1,000 square feet results in approximately a 3.5% increase in water consumption. Similarly, the hypothesis that water consumption increases as income increases is also borne out by the analysis: an increase in household income of $10,000 corresponds with a 5.3% increase in water consumption. Also as predicted, higher summer temperature is correlated with water consumption. An average increase of one degree Fahrenheit in the maximum temperature in summer months causes a 0.9% increase in water consumption.

The model also indicates that annual precipitation is negatively correlated with consumption. There is, however, correlation between temperature and precipitation so that precipitation does not appear statistically significant when both temperature and precipitation are included in the model.

An additional specification of the regression model was run to test for the effects, if any, of demand hardening. Demand hardening refers to the phenomenon where the demand for water becomes relatively more inelastic as more of the easier or more attractive forms of water conservation have been implemented, rendering any current or future initiatives for water reduction much more expensive. Because of the Bay Area's drought history, it is widely believed that demand hardening has indeed occurred to mitigate the effects of each of the succeeding droughts.

To estimate the effects of demand hardening in our regression model, we interact the price term with the percent of BMPs implemented, allowing us to estimate a price elasticity that depends on the BMP term. Assuming the most economical BMPs are implemented first, as more BMPs are employed, demand is expected to harden because each additional BMP is more expensive to implement.

At the average BMP implementation and at the average price, the calculated elasticity is -0.236, which means that a 10% increase in the incremental price of water will cause single-family residential customers to reduce water consumption by 2.36 percent.[14]

Key Finding #5: Residential demand becomes more difficult to reduce as additional conservation measures are implemented; demand hardening is real.

A third specification was tested to study the relationship between income and water rate in addition to the BMP rate interaction. The results show that this interaction term renders the income term insignificant, while making the price-income interaction term significant. This relationship was positively associated with consumption. Other coefficients do not change dramatically. The results are shown in specification III in Table 8 and Appendix C. Importantly, the interaction term did not result in an adjustment to the price elasticity found in the previous specification.

A fourth specification tested the relationship between lot size and rate in addition to the other interactions above.This is shown in specification III in Table 8 and Appendix C. This relationship was negatively associated with consumption. Again however, it did not materially affect the price elasticity established by the initial equation, and the other coefficients did not change dramatically. The consistency across the four different regression models indicates that the models are robust.

The price elasticity of demand for residential water calculated from our model fits very well with the price elasticities from previous studies, especially those that examined price elasticities in California. While estimates of the price elasticity for water vary significantly, our estimate is near the inelastic side of the results.

Our calculated elasticity of -0.176 is within the range of calculated price elasticities of demand in the academic literature. For example, Schneider and Whitlatch estimated short-run residential price elasticity to be -0.119 and long-run elasticity to be -0.262.[15] Espey, Espey, and Shaw, in their meta-analysis, found an average price elasticity of -0.51, with a short-run median elasticity of -0.38.[16] Renwick and Green

14 Calculated as the mean BMP-price interaction value (.514) multiplied by the rate-bmp coefficient (.6067) plus the rate term (-.5477).

15 Schneider, M.L. and Whitlatch, E.E. "User Specific Water Demand Elasticities." Journal of Water Resources Planning and Management Vol 117 no 1, pp. 52-73, 1991.

16 Espey, M., J. Espey, and W.D. Shaw, Price Elasticity of Residential Demand for Water: A Meta-Analysis. Water Resources Research, vol 33 no 6, pp. 1369-74, June 1997.

estimated a price elasticity of -0.16 for the eight California water agencies they studied (only SFPUC overlaps with our water agencies), a result very close to our own.[17]

3.a.ii. Literature Review

An alternative to calculating price elasticities directly is the measure of willingness to pay. A number of studies have been conducted specifically to measure how much customers would be willing to pay to avoid water shortages of various amounts and durations. At a minimum this measurement can be used as a check against the elasticity estimates. Alternatively, this measure can be used to approximate the demand estimates necessary for our model.

Summarized below are some of the contingent valuation studies regarding customers' willingness to pay to avoid drought restrictions or water supply interruptions. The Howe and Smith and the Griffen and Mjelde reports were previously summarized in the PFM 2005 report, while the other two are new.

"The Value of Water Supply Reliability in Urban Water Systems"
Charles W. Howe and Mark Griffin Smith
Howe and Smith used a survey to deduce the willingness to pay of consumers in the Colorado cities of Boulder, Longmont, and Aurora. They have defined a "standard annual shortage event" (SASE) 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." Because outdoor residential uses are typically the most elastic, the SASE as defined is expected to occur much more frequently relative to other shortage events.

The survey issued had five parts. The first part asked respondents to express their opinions about the quality of service and their perceptions of reliability of their city's water supply system. The second part gave the relationship between water supply reliability and costs, as well as giving the city's actual system reliability and the average monthly water bill. The third part consisted of yes/no questions, asking respondents whether they would accept or reject changes in reliability. The fourth part asked about the respondent's water-related habits and conservation practices. The last part surveyed socioeconomic background.

The results of the study were that residential customers were willing to accept lower levels of reliability than current levels, and willing to pay only a little ($1 to $2 a month) for increased levels of reliability. Roughly 75% of customers were not willing to pay more for increased reliability, even in the cities with relatively low reliability. In contrast, nearly 50% of customers were willing to accept lower levels of reliability, even in the cities with relatively low reliability.

"The Value of Water Supply Reliability in California: A Contingent Valuation Study"
Patricia Koss and M. Sami Khawaja
This study asks a respondent whether he or she would be willing to pay $X for a particular good or service. If yes, then a follow-up question with a higher amount $Y is asked; if no, then a follow-up question with a lower amount $Z is asked.

The study was conducted through mail/telephone surveys. A total of 3769 surveys were completed across ten water districts in California. Shortage amounts from 10%, 20%, 30%, 40%, and 50% of full service were polled, with frequencies of shortages from 1/30, 1/20, 1/10, 1/5, and 1/3.

Using a model controlling for various socioeconomic factors, Koss and Khawaja found that respondents were willing to pay substantial amounts (over $11 a month) to avoid a 10% reduction with 1/10 frequency. Respondents would pay up to nearly $17 a month to avoid a 50% reduction with 1/20 frequency. Their results indicate that consumers respond to the magnitude of water shortage more than to the frequency of

17 Renwick, Mary E. and Richard D. Green, "Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies," Journal of Environmental Economics and Management, vol 40, pp.37-55, 2000.

a shortage. Thus, respondents feel that large shortages impose higher costs than more frequent smaller shortages.

"Water Supply Security and Willingness to Pay to Avoid Drought Restrictions"
David Hensher, Nina Shore, and Kenneth Train
The analysis is based on experiments where respondents are given options for service levels associated prices, and asked to state which option he or she prefers. Residential and commercial customers in Canberra, Australia, were surveyed. Each respondent was presented with a series of six experiments, each experiment being a pair of attributes (described below) that were randomly selected. The attributes included:

- the frequency with which drought restrictions could be expected to occur (once a year, once per 3 years, once per 10 years, virtually never)
- the duration that water restrictions could be expected to last (all year, all summer, one month in the summer, no restrictions)
- the types of days the water restrictions would apply (every day, every other day, no restrictions)
- the level of water restrictions, with six levels incorporating the mandatory restrictions of the Canberra water supplier and local government, which for residential customers are: no restrictions; (stage 1) sprinkler use allowed in morning and evening; (stage 2) sprinkler use allowed for up to three hours in the morning and evening; (stage 3) sprinkler use is not allowed, but handheld hoses and buckets can be used in the morning and evening; (stage 4) watering of lawns is not allowed, but handheld hoses and buckets can be used in the morning and evening; (stage 5) and all outdoor water use is banned. Commercial restrictions are of a similar nature, but more complicated due to the greater variety of water use.
- Price, equal to total water and sewage bill for the year, calculated as a randomly chosen percentage of the customer's estimate of their actual annual bill.

The study found that restrictions that lasted a month or all summer, that apply every other day, that are stage 1 or stage 2, or that result in brown lawns in public areas, had willingness to pay (WTP) not statistically different from zero for residential customers. The model employed by the study suggests that residential respondents are willing to pay 31.26% of their water bill, or roughly $239 AUD year, to go from a frequency of continuous water restriction at stage 3 or above to no water restrictions all year. Similarly, a respondent is willing to pay only $11.95 AUD on average to reduce the frequency of restrictions from once per 10 years to once per 20 years.

Commercial customers were willing to pay 23% of their water bill to go from a frequency of continuous water restriction at stage 3 or above to no water restrictions all year.

In summary, Hensher, Shore, and Train noticed that customers were unwilling to pay any amount of money for low-level restrictions, or for restrictions that are enforced every other day or only during part of the year. Their results are at odds with contingent valuation studies, but square with choice-modeling and out-of-pocket expense studies.

"Valuing Water Supply Reliability"
Ronald C. Griffin and James W. Mjelde
Griffin and Mjelde used the contingent valuation method to evaluate both a current water supply shortfall of known duration and a future water supply shortfall of unknown duration. Surveys were mailed to residential customers in seven Texas cities. The current shortfall question had thirty-six different combinations of an X percent shortfall over duration of Y days in the summer that could be exempted for a one-time fee of Z dollars.
The second question was an open-ended willingness to pay (WTP) or willingness to accept (WTA) question concerning a hypothetical increase or decrease in future water supply reliability. Respondents were asked to gauge their willingness to pay (for a permanent increase in their water bills) or their

willingness to accept (for a permanent decrease in their water bills) a shortfall of V% that occurs approximately once every U years for a duration of W days.

The study controlled for rain, summer rain, respondent's average water price per unit, income, the respondent's preferences toward water use activities, the number of people in the residence, whether respondents rent or own the residence, whether respondents live at the residence, and whether respondents have experienced water use restrictions in the past five years.

According to their model, the current shortfall data suggests that, on average, respondents are willing to pay $29.86 to avoid a 20% shortfall for 21 days. A one-week increase in the shortfall duration increases this value by $2.41, and a 10% increase in shortfall strength increases the value by $2.12.

Two other models were run with the future shortfall WTP and WTA data. Mean data WTP is $8.47, while the predicted WTP is $9.76, which equal 22.2% and 25.6% of the respondents' mean monthly water bills. Mean data WTA is $12.66, while the predicted WTA is $13.20, which equal 32.4% and 33.8% of mean monthly water bills.

Comparison to the 2005 PFM Report

As noted above, two of the reports (Howe and Smith, and Griffin and Mjelde) were summarized in Appendix 5 of the 2005 PFM report. This section describes how the two other reports above fit in with the studies in the prior PFM report.

The Koss and Khawaja study presents results similar to those of Carson and Mitchell, although with a bit lower WTP in general. For example, Carson and Mitchell estimated a monthly WTP of $8.75 (in 1993 dollars) for a 10-15% shortage once every five years and a monthly WTP of $12.02 for a 30-35% shortage once every five years. Koss and Khawaja estimated a monthly WTP of $12.00 for a 10% shortage once every five years and a WTP of $14.56 for a 30% shortage once every 10 years. Koss and Khawaja, as well as Carson and Mitchell, have higher WTP estimates than the Griffin and Mjelde study, which estimated a one-time WTP of $31.98 to avoid a 30% shortfall that lasts 21 days.

Hensher, Shore, and Train estimated that residential WTP is much lower than those of previous studies. The study estimated that consumers are only willing to pay $19.92 AUD a month to go from continuous water restriction to no water usage restrictions. Their model estimates that consumers would only be willing to pay $3.98 AUD, or 6.25% of their bill, a month to go from a water restriction once every five years to no water usage restrictions. ($1 USD = $1.26 AUD) Since the average monthly residential water bill in BAWSCA for FY 2004-2005 was $43.94, a 6.25% reduction amounts to a monthly WTP of $2.75 for a reduction of water restrictions from once every five years to no water restrictions.

In summary, it appears that the newer willingness to pay studies to avoid drought have found consumers are willing to pay less to avoid water shortfalls than previous studies. Since the majority of any residential water reduction can be done through restricting outdoor water use, this may indicate that people are now more willing to forego outdoor water consumption than before.

3.b. Commercial and Industrial Users: Survey and Focus Group Results

Given the reliance of the Phase 1 study on the use of published reports from the early 1990's to establish relationships between economic output and water availability, part of the focus of the Phase 2 study was to re-examine and validate these past interactions. Several methods were used, including a survey and focus groups that served to inform more recent analyses of output elasticities done elsewhere, "reality-check" the willingness and ability of local business to reduce water usage, and provide some indication of the likely success of mitigation policies.

3.b.i Survey

The study team developed and implemented an online survey that was sent to approximately 1,000 businesses drawn from SFPUC and BAWSCA agency lists of commercial and industrial customers. Approximately 50 companies provided some response, although only about 20 gave complete responses. The results of the survey are summarized on the attached tables.

A few salient results emerged. First, virtually none of the surveyed companies indicated that they had made specific plans for dealing with a reduction in the availability of water. Second, most customers showed a strong willingness to pay more to avoid larger shortages of greater duration. Interestingly, the hotel industry suggested that the degree and duration of the potential shortage would make little difference in their willingness to pay. In subsequent discussions, they indicated that substantial efforts to conserve water have already been made, and did not believe that they could achieve significant additional reductions. Computer and electronics manufacturers indicated a greater willingness to pay to avoid larger shortages but were indifferent to duration.

In general, these results suggest that the commercial and industrial sectors place a substantial value on avoiding water shortages and would respond to higher prices. Tables 9 through 11 summarize the results by water reduction level.

Table 9: Has your firm developed a plan to deal with a potential 10% water shortages?

311 Food Manufacturing - 600 Employees	No
322 Paper Manufacturing - 250 Employees	No
325 Chemical Manufacturing - 75 Employees	No
327 Nonmetallic Mineral Product Manufacturing - 64 Employees	No
333 Machinery Manufacturing - 1,200 Employees	Yes
334 Computer and Electronic Product Manufacturing - 170 Employees	No
334 Computer & Electronic Product Manufacturing- 12,000 Employees	No
336 Transportation Equipment Manufacturing - 5,500 Employees	No
339 Miscellaneous Manufacturing - 15 Employees	No
422 Wholesale Trade, Nondurable Goods - 60 Employees	No
481 Air Transportation - 5,000 Employees	No
623 Nursing & Residential Care Facilities - 650 Employees	Not sure
721 Accommodation - 400 Employees	Not sure
721 Accommodation - 900 Employees	No
811 Car Washes - 80 Employees	No

Table 10: Percentage Increase Willing to Pay to Avoid a 10% Water Reduction

Drought Length	One Year	Two Years	Five Years
311 Food Manufacturing - 600 Employees	1-5%	1-5%	1-5%
322 Paper Manufacturing - 250 Employees	11-15%	16-20%	21-25%
325 Chemical Manufacturing – 75 Employees	1-5%	6-10%	11-15%
327 Nonmetallic Mineral Product Manufacturing - 64 Employees	1-5%	1-5%	1-5%
333 Machinery Manufacturing - 1,200 Employees	0	0	0
334 Computer and Electronic Product Manufacturing - 170 Employees	1-5%	1-5%	1-5%
334 Computer & Electronic Product Manufacturing- 12,000 Employees	Not Sure	Not Sure	Not Sure
336 Transportation Equipment Manufacturing - 5,500 Employees	0	0	6-10%
339 Miscellaneous Manufacturing - 15 Employees	No Change	1-5%	1-5%
422 Wholesale Trade, Nondurable Goods - 60 Employees	1-5%	1-5%	1-5%
481 Air Transportation - 5,000 Employees	No Change	Not Sure	Not Sure
623 Nursing & Residential Care Facilities - 650 Employees	Not Sure	Not Sure	Not Sure
721 Accommodation - 400 Employees	1-5%	1-5%	1-5%
721 Accommodation - 900 Employees	0	0	0
811 Car Washes - 80 Employees	Not Sure	Not Sure	Not Sure

Table 11: Percentage Increase Willing to Pay to Avoid a 20% Water Reduction

Drought Length	One Year	Two Years	Five Years
311 Food Manufacturing - 600 Employees	6-10%	6-10%	6-10%
322 Paper Manufacturing - 250 Employees	11-15%	16-20%	21-25%
325 Chemical Manufacturing – 75 Employees	6-10%	11-15%	16-20%
327 Nonmetallic Mineral Product Manufacturing - 64 Employees	1-5%	1-5%	1-5%
333 Machinery Manufacturing - 1,200 Employees	0	0	0
334 Computer and Electronic Product Manufacturing - 170 Employees	6-10%	6-10%	6-10%
334 Computer & Electronic Product Manufacturing- 12,000 Employees	Not Sure	Not Sure	Not Sure
336 Transportation Equipment Manufacturing - 5,500 Employees	0	0	0
339 Miscellaneous Manufacturing - 15 Employees	1-5%	1-5%	1-5%
422 Wholesale Trade, Nondurable Goods - 60 Employees	1-5%	1-5%	1-5%
481 Air Transportation - 5,000 Employees	No Change	Not Sure	Not Sure
623 Nursing & Residential Care Facilities - 650 Employees	Not Sure	Not Sure	Not Sure
721 Accommodation - 400 Employees	1-5%	1-5%	1-5%
721 Accommodation - 900 Employees	0	0	0
811 Car Washes - 80 Employees	Not Sure	Not Sure	Not Sure

3.b.ii Focus Groups

In order to bolster and cross-reference the survey data, the study team conducted a series of focus groups and one-on-one interviews with water customers during November and December of 2006. The groups included a wide range of business, from small businesses such as laundries and restaurants to large hotels, large bio-tech companies, as well as more traditional industrial consumers. Public sector and large non-profit users also participated. The discussions focused on the nature of their uses, their past efforts to conserve, their expected future ability to make further reductions in water use, their willingness to pay more for water during periods of reduced availability, and the impacts on their activities of reduced water availability. We also sought their reactions to a range of potential policy approaches to reductions in water availability, as well as their suggestions on policy approaches. We discussed the relative importance of water as a cost and factor of production for the users. The appendices to this report contain both the set of questions used for the focus groups as well as paraphrased transcripts of the discussions. A series of clear themes emerged from these discussions that are relevant to the SFPUC's and BAWSCA member agencies' policy considerations. These findings are consistent with the other empirical evidence relating to the economic impact of reduced water availability.

Water Costs Are Relatively Small Components of Production Costs

The importance of water as a factor of production clearly varies from company to company and industry to industry. For some (bio-tech industries, for example), uninterrupted availability of water is critical and a loss or reduction of availability would create immediate financial consequences. For others, it is less important, but still necessary, even at a reduced level of availability. Despite the importance of water, it is typically a small cost factor in production. This is especially true because water tends to be grouped and compared with electrical power, which is far more expensive, and which has increased in cost more dramatically in recent years. This has led many companies to focus more clearly on the reduction of power costs while tending to ignore water conservation. There are important exceptions to this, most notably the hotel industry, which has clearly made serious efforts to reduce water usage. However, more commonly, companies are not concerned about the cost of water because it is so cheap compared to other production inputs.

Key Finding #6: Water is a relatively small cost factor for most commercial and industrial customers.

The Capacity to Reduce Water Consumption Varies Widely

Some users have taken very extensive steps to control demand and can therefore sustain relatively small marginal reductions without reducing their output. For example, the hotel industry has made successful efforts to reduce demand over the last fifteen years as a result of investments in technology as well as behavioral changes. Other organizations conceded that they can sustain substantial reductions without major impacts on their activities. For instance, some of the largest-consuming public sector organizations agreed that they can reduce consumption by a large amount without negatively affecting their activities. As a broad public policy matter, it may be very important to capture these savings, which may be large enough to have system-wide impacts, prior to imposing other demand control policies on the private sector.

As a general matter, many companies stated that they could sustain ten percent reductions in availability for limited periods. Others expressed concern about sustained reductions beyond five percent. At the opposite end of the spectrum, some organizations could create permanent reductions in excess of twenty percent. The majority of users expressed a preference to pay more for water during periods of reduced availability rather than to invest in efforts to reduce consumptions.

The ability and willingness to reduce water consumption is correlated with the following factors:

- How globally competitive the industry is,
- The barriers a given firm faces in potentially relocating local activity elsewhere;
- The ability of the firm to pass the reduction of water capacity on to its customer base (i.e., hotels, restaurants, etc.)
- Conservation efforts that have already been undertaken by that particular firm.

Some manufacturers are the most sensitive to potential shifts in water availability rather than price, with several indicating that even a 10 percent reduction would be very challenging.

Prices Can Be Used to Influence Demand and Allocate Water

We found general agreement that the use of graduated pricing (drought–contingent pricing) would be an appropriate way to influence water usage. This perspective seemed to hold regardless of whether the businesses were large or small, whether they were high or low margin businesses, and whether or not water was a major cost in their activities. Although the policy-makers will have to balance pricing strategies with equity considerations, the participants in these groups did not express an aversion to greater use of pricing mechanisms. Most of the businesses agreed that they would prefer to spend more on water than to reduce their consumption or invest in efforts to conserve.

The ability and willingness to pay more to maintain water availability is correlated with the following factors:

- How globally competitive the industry is,
- The barriers a firm faces in relocating local activity elsewhere,
- The ability of the firm to either pass the increased cost of water on to its customer base and/or absorb the higher price within its cost structure. In general, higher-margin firms who provide service directly to end-use customers are better able and/or more willing to pay higher prices to maintain availability at current levels.
- Conservation efforts that have already been undertaken by that particular firm.

Many participants recognized the importance of demand hardening in their operations, and some had clearly taken extensive steps to reduce demand. They are therefore, very concerned that future policies take account of the savings they have already created. While understanding that demand may have to be further reduced, they suggest that "wasteful" users, who have not taken similar conservation efforts, should be forced to reduce prior to imposing further reductions on everyone else. This idea, while easy to understand in principal, would be difficult to implement in reality. What time period should be considered in looking at past reductions? How would a baseline usage level be established to determine what savings have actually been accomplished? Despite these complications, those sectors who have accomplished some savings in recent years are justifiably concerned that they will be penalized in the future if additional reductions are needed, and believe that this would be unfair when there are other users who have not made similar efforts.

Key Finding #7: Drought-contingent (tiered) pricing would be an effective and appropriate method to influence demand for business customers during droughts.

Improve Communication and Information Flow

Many participants commented on the need for more transparent information regarding costs and usage from wholesale agencies. They felt that they did not pay sufficient attention to water usage during non-drought periods because of its often-low cost in comparison to other factors. They felt that having information comparing their usage not only to themselves but to other similar users would be particularly valuable. For high users, this would show how they may be creating a competitive disadvantage for themselves, even when water was available. Many agreed that they themselves did not do an adequate job of tracking their usage, but were asking for help from the wholesalers in analyzing and controlling their usage.

Provide Technical Assistance and Capital

Particularly for smaller businesses, the availability of technical assistance, information regarding access to capital, and possibly even direct capital assistance, may be important for achieving substantial reductions in water usage. Technical assistance could be important in providing information regarding water-saving technology and methods for promoting behavioral changes necessary to reduce demand. Provision of information regarding access to capital may be valuable for businesses that seldom access capital. Finally, the direct provision of capital may be critical in order to enable improvements that could create long-term savings in water usage. A number of companies said that, although they are generally reluctant to invest in water-saving technologies, the availability of capital assistance would strengthen their interest in such technologies. The direct provision of government capital to private businesses raises both policy and tax issues. Nevertheless, the provision of such support may be economically justified.

It should also be noted that the provision of assistance in multiple languages will likely be needed in order to be effective, particularly with respect to efforts to create behavioral change.

3.b.iii. Literature on Commercial and Industrial Demand

Because BAWSCA and SFPUC do not maintain readily available pricing regarding non-residential consumption at the account level, we use estimated elasticities from prior research to calculate welfare loss from the commercial and industrial sectors of each water agency supplemented by information drawn from the survey, focus group and interview results provided by PFM and TXP. We reviewed industry elasticities estimated for SFPUC by Phillip McLeod in 1994 and compared them to two more recent studies. The McLeod estimates were consistent with this literature. Consequently, we have employed his estimates in our analysis. The McLeod estimates and the more recent study estimates are described below.

"The Economic Impact of Water Delivery Reductions on the San Francisco Water Department Service Area's Commercial and Manufacturing Customers"
Philip W. McLeod
McLeod relied on survey methods to estimate industrial and commercial price elasticities. The survey collected information from 310 firms across six industrial categories. He relied on a relatively simple econometric model that related water consumption to price and industrial (commercial) production. He found that with the exception of Communications and Other Electronic Equipment firms, price elasticities ranged between -0.1 and -0.2. The value for the Communications Equipment firms was -0.297. Across all industries the value was -0.12.

"User Specific Water Demand Elasticities"
Schneider, M.L, and Whitlatch, E.E.
This study uses data from Columbus, Ohio and incorporated suburban communities. Data span 18 years starting in 1959, from a total of 16 communities in the area. Schneider and Whitlach estimated demand elasticities for six categories of metered water demand: residential, commercial, industrial, government, school, and total. Eight generalized least squares models are run, with independent variables price, income, residents per account, housing composition (ratio of single-unit dwellings to total dwelling units), and summer precipitation (which does not vary cross-sectionally).

For the price elasticity of demand, the study found a residential short-run price elasticity of -0.119, and a long-run price elasticity of -0.262. The range of long-run values is from -0.053 to -0.385.

For commercial customers, the authors assert that their best model estimate for short-run elasticity is -0.236 and the long-run elasticity estimate is -0.918, much more elastic than the residential customers. For comparison, the study indicates that Williams and Suh (1986) estimated a commercial price elasticity of -0.141, which is at the low end of estimates; however, the Williams and Suh study grouped commercial with government and school accounts.

Schneider and Whitlatch did not find conclusive results that water demand changed with price for industrial customers. Their best model estimated the long-run industrial price elasticity to be -0.438, but the result was not statistically significant. The authors note that it is prudent to study industrial accounts individually in order to determine the influence of water price on demand by industry.

For all metered accounts, the best model estimated a long-run price elasticity of -0.50 and a short-run price elasticity of -0.14.

"An Econometric Estimation of Industrial Water Demand in France"
Arnaud Reynaud
Reynaud collected data from a mail survey to 51 industrial firms in the Gironde district of southwestern France, from 1994 to 1996. In total, there are 153 observations in the dataset. The study distinguishes three types of water input: network water, which is purchased from a water utility; autonomous water, which is surface or ground water produced on-site; and treated water, which corresponds to the total volume of water treated by an industrial firm before use. Both autonomous and network water may need to be treated prior to any industrial use.

Different industries utilize and rely upon water to different degrees, and so Reynaud estimates price elasticities by industry type. Note that network water most closely approximates the type of water we are interested in. For all industries, network price elasticity was estimated to be -0.290, a statistically significant result unlike Schneider and Whitlatch's estimates. Examining specific industries, we see that the extractive industry, chemicals, food and beverages, commercial and services, and others categories have price elasticities statistically different from zero. The extractive industry and others are the most elastic, with price elasticities larger than -0.7, while the metal fabrication, alcohol, and paper and wood industries appear to have perfectly inelastic demands.

Reynaud concluded that network and autonomous water are complements, and tend to be used for different processes. He further notes that industries with high price elasticities for network water are the ones with high network water cost shares, and that small price elasticities for network water are associated with industries using small volumes of network water.

3.c. Municipal and Other Uses

The number of studies that examined the water responses of government or municipal accounts is extremely sparse. Schneider and Whitlatch's model estimated a long-run price elasticity of -0.781 and a short-run elasticity of -0.438 for government accounts. These elasticity estimates for the government sector are more elastic than for the residential, commercial, and industrial sectors, indicating that government accounts will reduce water consumption when faced with increased prices. Since a large fraction of water consumption is probably used for the upkeep of parks and other public lands, these non-essential water uses are likely to be reduced during a drought scenario and contribute to the higher elasticity for the sector.

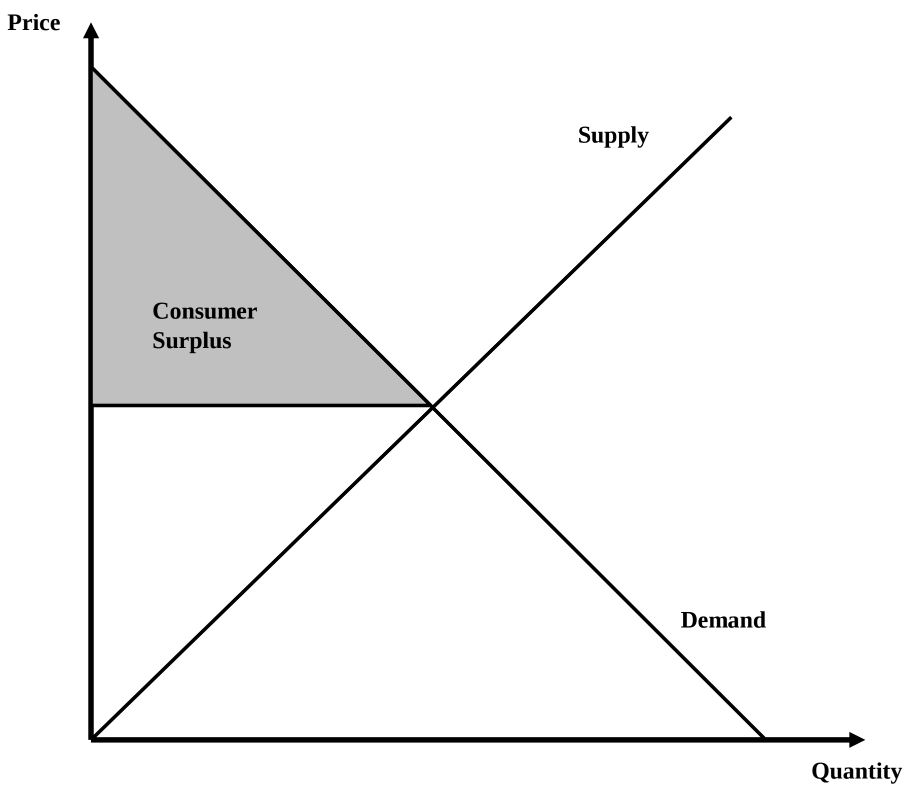
This section lays out several alternatives to allocate water during a drought. The following section of the report calculates economic impacts resulting from implementation of these measures. The measures considered here are a combination of policies to reduce demand, efficiently allocate available supplies and expand the supply of available water.

4.a. Quantity Controls and Rationing

The imposition of water consumption limits have frequently been employed in previous droughts. Studies have showed that such programs can successfully reduce demand. They do so, however, at a cost as some uses of water are no longer enjoyed. Further, policies that dictate behavior are likely to be inefficient. This is the case because consumers and producers faced with specific limits and prohibitions on certain types of water use are unable to maximize the mix of goods and services they consume or produce.

Economists measure the loss resulting from quantity controls by calculating changes in producer and consumer surplus. Consumer surplus is the difference between what a consumer is willing to pay for a good or service and what the consumer actually pays. As shown in Figure 3, it is the shaded area in the shape of a triangle formed by the demand curve and the market price. This area represents the total benefit resulting from consumption of a particular good. As market price rises, surplus falls. As demand falls, surplus also falls.

Figure 3: Supply, Demand, and Consumer Surplus



A rationing policy means that consumer surplus is lost not because price has increased or demand has fallen, but because a restriction has been imposed on the quantity of water consumed. The practical consequence of such a policy is to discourage households from trading the consumption of other goods and services for more water and from making investments that reduce water consumption beyond the mandated levels.

Producer surplus is the analogous concept to consumer surplus for firms. It is defined as the difference between the market price of a good and the marginal cost of production of that good. Imposing a limit on output (or consumption of in input necessary for a given level of output) will be inefficient. In addition, because consumers pay more for less water, the have less income left over to pay for other goods and services. Consequently, demand falls and producer surplus falls.

Welfare loss from rationing and other quantity controls is defined as the sum of consumer and producer surplus losses. We estimate the losses associated with a proportional reduction in water availability across all agencies and sectors in Section 5.

4.b. Drought-Contingent Pricing

Drought contingent pricing has been frequently identified as a drought mitigation strategy. Under this type of policy, agencies alter their retail price schedules to incentivize conservation, but decentralize the decision about how much water to consume. Consumers clearly respond to higher prices by lowering demand as demonstrated by our study, the academic literature and our survey/focus group findings. Although price elasticities are low, price can be an effective and efficient drought management strategy. In addition there is evidence that as water prices rise so do price elasticities.[18]

The most effective water conservation programs appear to appreciate this because they include price penalties for exceeding water consumption quotas. Academic research suggests, however, that the price penalties do not have to be as a severe as those that have been implemented in the past. For example, SFPUC imposed rate 2 times the normal rate for consumption over the rationing limit but by less than 10%, 8 times the normal rate for consumption between 10 and 20% above the limit, and 10 times the normal rate for consumption more than 20% above the limit. Hanemann and Nouges[19] (discussed below) found that a price increase of 58% (about 1.5 times) obtained the same reduction as a 28 percent mandatory cutback for one segment of households.

Since such pricing will result in revenues well in excess of water costs, this may present a regulatory challenge for some agencies. One solution to the problem of over-collection of revenues is increasing block pricing. Tiered pricing programs sometimes include subsidies to low-income households and small businesses to offset hardships caused by higher water prices. Further, revenues from high consumption customers may also be used to subsidize conservation investments (i.e., a rebate on purchases of water-saving sprinklers or automatic controllers).

4.c. Voluntary Water Reduction Programs

Public outreach and notification about drought conditions are also used to reduce short-term water consumption. These efforts have proven to be surprisingly effective, even if not accompanied by price changes designed to influence behavior. The academic literature contains two interesting studies of voluntary conservation programs. The first by Hanemann and Nauges estimated the impacts of voluntary

18 See, for example:

Julie A. Hewitt and W. Michael Hanemann, “A Discrete/Continuous Choice Approach to Residential Water Demand under Block Rate Pricing,” Land Economics, vol 71(2): 173-192, 1995.

Sheila M. Cavanagh, W. Michael Hanemann, and Robert N. Stavins, “Muffled Price Signals: Household Water Demand Under Increasing-Block Prices,” December, 2001. Jasper M. Dalhuisen, Raymond Florax, Henri de Groot and Peter Nijkamp, “Price Elasticities of Residential Water Demand: A Meta-Analysis, Land Economics, vol 79(2): 292-308, 2003.

19 W. Michael Hanemann and Celine Nauges, “Heterogeneous Responses to Water Conservation Programs: The Case of Residential Users in Los Angeles,” CUDARE Working Papers, University of California, Berkeley, 2005.

and mandatory drought management policies imposed by the Los Angeles Department of Water and Power (LADWP) during the 1988-1992 drought. The authors estimated residential water demand reductions associated with a voluntary program calling on households to reduce consumption in 1990. This call, made by the mayor of Los Angeles, was accompanied by a threat of a mandatory reduction. LADWP initially implemented a low flush toilet rebate program. By 1991, however, a mandatory program requiring a 10 % reduction over 1986 consumption levels was imposed. This was followed by a low flush toilet distribution program in 1992.

As shown in Table 12 the mandatory program resulted in substantially greater water demand reductions than the voluntary program. Reductions in percentage terms across lot sizes were very similar for the mandatory program, as expected. Reductions during the summer months were greater than the winter months under the mandatory program. The opposite was true for the voluntary program. The authors also controlled for temperature by dividing customers into three temperature zones, high, medium, and low. The results reported in Table 12 are for the low temperature zone (the closest to the SF Bay area), but results were similar across all three zones.

Table 12: Reduction in Water Consumption in Los Angeles By Program Type Season and Lot Size

Season	Lot Size (sq. ft.)	Voluntary	Mandatory
Summer	< 7499	6.7%	28.8%
	7500-10999	5.2%	29.4%
	11000-17499	2.8%	27.9%
	> 17500	1.9%	27.9%
Winter	< 7499	12.8%	20.5%
	7500-10999	13.3%	24.0%
	11000-17499	11.2%	23.6%
	> 17500	11.8%	23.4%

Source: Hanemann and Nouges, 2005
Voluntary program supplemented with low flow toilet program
Mandatory program requried 10 percent reduction and fines for exceedence

Price also paid an important role in demand management. First, the mandatory program included price penalties for failing to meet the required reduction. Second, during the drought period, water rates almost doubled increasing from $0.776 per HCF in 1988 to $1.545 per HCF in 1992. Over the same period, average daily water use fell by 21%. Hanemann and Nauges estimated the water price increased necessary to obtain the same water savings as the mandatory and voluntary programs. They found, for example, that the price increase necessary to achieve the same level of savings achieved by the mandatory program on large lots in the high temperature zone (28%) was 58%. The price increase to achieve the same savings achieved by the voluntary program for the same lot size in the same zone (1%) was about 2%.

Finally, Hanemann and Nauges compared the impacts of the voluntary and mandatory programs on consumer surplus. The found that the mandatory program resulted in larger consumer surplus losses. This result is consistent with economic theory. In contrast, the voluntary program allows households to make these tradeoffs.

The second study, authored by Renwick and Green, estimated water savings by program for a sample of California water agencies.[20] They found that specific restrictions on use, prohibiting sprinklers during peak evaporation hours for example, resulted in the greatest waster savings. Rationing with a price penalty was the second most effective program. Free showerhead and toilet tank displacement devices were much less effective. They found that rebates for low flush toilets and affidavits attesting to the installation of devices had no significant impact on savings. Their results are summarized in Table 13.

Table 13: Estimated Water Savings By Program

Program	Percent Savings	Comment
Restrictions	29%	Prohibit uses such washing driveways and irrigation during peak evaporation hours.
Rationing	19%	Allocate fixed quantities and impose severe price penalties for exceedence.
Retrofit Kits	9%	Distribute free kits including low flow showerheads, tank displacement devices, and leak detection kits.
Public Information Campaigns	8%	Alert customers to shortages; provide information; motivate behavior changes.
Rebate	No significant impact	Rebates for low flow toilets.
Affidavit Requirement	No significant impact	Require households to file affidvaits attesting that specific devices had been installed.

Source: Renwick and Green, 2000

20 Renwick and Green (2000).

4.d. Regional Water Market

Another type of response to drought conditions is to implement a program of regional cooperation and shortage sharing. The intuition behind this approach following from our earlier observation that there are significant disparities in the availability of water among retail agencies in the SFPUC service area, as well as significant differences in access to water supplies not provided by the SFPUC. Further, there are significant differences among retail agencies in terms of the willingness to pay for water, driven in part by variations in

- Income and demographics
- Housing density and age of development
- Weather
- Economic activity

Trading, or voluntary reallocation of available supplies during a drought, exploits differences in value among agencies and leads to a more efficient allocation of water resources. Water trading is now well accepted in California and is an everyday part of water resource management in a growing number of water agencies. For example, the Santa Clara Valley Water District, which also supplies water to several BAWSCA members, is one of the state's leaders in water trading.

4.e. Supplemental Supplies

As demonstrated during the 1987-1992 drought, willing sellers outside the Bay Area may be induced to provide valuable water supplies under shortage conditions. As discussed in Section 5, our impact model indicates that the value of water during a drought in the Bay Area will rise to levels that are likely to attract supplies from other sources in the State. Much as the SFPUC purchased Delta water in 1991 under California's Drought Water Bank program, opportunities for trading may well emerge again.

5.a. Measuring the Impacts of Drought

Economists typically evaluate the gains and losses from government policies or non-market events such as droughts by measuring consumer and producer surplus.[21] Economic loss is defined as the reduction in consumer and producer surplus. As discussed above consumer surplus is defined as the difference between what a person would pay for a good and its market price. This difference reflects the benefit over and above what the consumer paid for the good. Surplus falls when a consumer is forced to pay more for less. Producer surplus is defined as the sum of over all the units of production between the market price of the good and the marginal cost of production. This difference reflects the benefit the producer enjoys. Although producer surplus is closely related to profit they are not equal.[22]

The McLeod study prepared for the SFPUC in 1994 estimated economic impacts from water shortages in terms of producer surplus losses.[23] McLeod estimated annual producer surplus losses of $10.7 million under a 15% water supply reduction and $80 million producer surplus loss under a 30% water supply reduction. He also estimated that a 15% cutback could result in job losses totaling 6,800.

We have developed a model to measure changes in consumer surplus and producer surplus resulting from drought and to measure the impact of the mitigation policies described above. Since policy makers do not typically evaluate policies with respect to consumer and producer surplus losses we have also estimated impacts in terms of output and employment.

5.b. Model Descriptions

These two definitions of economic impacts, the surplus approach preferred by economists and the regional income and employment approach of interest to local officials, are measured with different types of models. This section describes the two basic approaches taken in this study.

5.b.i Welfare Loss Model

CRA International has designed a model capable of measuring the costs of droughts of various degrees and the impacts of various drought mitigation strategies. These strategies include both demand modification and supply augmentation options. The model accounts for both the demand and supply of water in the region served by SFPUC and BAWSCA member agencies. The model is similar in concept to the LCPSIM (Least Cost Planning Simulation Model) developed by the California Department of Water Resources to evaluate both water conservation and supply investments.[24]

The model requires the description of demand elasticites by end user categories and supply accounting for the marginal cost of water supply and constraints on its transfer. In section II we described residential demand by studying the price responsiveness of SFPUC and BAWSCA member residential customers. We also described commercial and industrial demand based on the survey, focus group, and interview results and a review of the academic literature. Below, we describe supply by reference to SPPUC and BAWSCA member data on current water capacity by source and price. Additional supply cost data was derived from the DWR's LCPSIM. We have also relied on the SFPUC's Wholesale Customer Water Conservation Potential Study to describe both current and potential conservation options with respect to cost and projected water savings supplemented by more recent information on BMP implementation.

A detailed model description with objective function and constraints is provided in Appendix B.

21 See for example, Robert S. Pindyck and Daniel Rubinfeld, Microeconomics, Sixth Edition, Pearson Prentice Hall, 2004.

22 In the short run, producer surplus is greater than profit because profit is reduced by fixed costs that are not present in the long run.

23 Philip McLeod, "The Economic Impact of Water Delivery Reductions on the San Francisco Water Department Service Area's Commercial and Manufacturing Customers," for the San Francisco Public Utilities Commission, June 29, 1994.

24 The LCPSIM draft document is available at: http://www.economics.water.ca.gov/downloads/Models/LCPSIM_Draft_Doc.pdf.

5.b.ii. Estimating Impacts in Sales and Employment Terms

As noted above, although economists typically evaluate the costs and benefits of a proposed program by measuring welfare changes, policy makers are more comfortable considering the impacts of a program in terms of changes in economic output and employment. Consequently, we have also measured the impacts of the mitigation studies under review by employing output and employment elasticities. These elasticities describe the percent change in output (measured as sales) or employment (measured as payroll) resulting from a percent change in water consumption.

The welfare model described above provides estimates of changes in water consumption by sector under the drought mitigation strategies. Applying these changes to the elasticities for the commercial and industrial sectors produces estimates of sales and payroll changes attributable to the water consumption changes.

We rely on output and employment elasticities for the commercial and industrial sectors estimated for the SFPUC in the mid 1990s based on survey data.[25] While these are over a decade old they appear reasonable based on our literature review. The manufacturing sector output elasticities are 0.12 and 0.38 for water shortages of up to 15% and 30% respectively. The manufacturing employment elasticities are 0.15 and 0.13 for water shortages of up to 15% and 30% respectively. The commercial sector output elasticities are 0.03 and 0.32 while the employment output elasticities are 0.0 and 0.17 for water shortages of up to 15% and 30% respectively.

5.c. Economic Impacts of a Drought

5.c.i Water Allocation Policies

We begin our impact analysis by estimating consumer and producer surplus under three water allocation policies scenarios. This is the case because how a shortage is allocated greatly influences the impact of other mitigation strategies. The allocation scenarios are as follows:

Proportional Rationing – the drought induced water shortage is allocated proportionately between agencies and within agencies. Thus, a 20% water reduction results in 20% reduction to all agencies and sectors. This policy is a simple form of rationing.

Drought-Contingent Pricing – the water shortage is allocated by agencies between sectors to minimize surplus loss. This allocation recognizes the difference in water values of the sectors exhibited by the differences in price elasticity. Sectors, in effect, bid for the available water. As a consequence, the shortage is not allocated equally across sectors. Under a 20% shortage, residential consumers may experience a 30% reduction while the industrial sector experiences a 10% reduction depending on the relative price elasticities.

Regional Water Market – the water shortage is allocated between agencies and between sectors within agencies to minimize surplus loss. This allows for trading between agencies. Thus, it recognizes not only the difference in water values between the sectors, but between the agencies. The trading agreement between SFPUC and BAWSCA agencies recognizes the benefit of enabling these trades. Water goes to the customers who value it most highly across the region.

We estimate the change in total surplus resulting from a 10%, 20%, and 30% water reduction under each of these allocation scenarios. Table 14 shows the change in surplus resulting from the shortages under the three allocation scenarios.

25 McLeod, 1994, Tables 13 and 14.

Table 14: Welfare Losses for 10%, 20%, and 30% Drought Scenarios
in thousands of dollars

Agency	10% Reduction Proportional Rationing	10% Reduction Drought-Contingent Pricing	10% Reduction Regional Water Market	20% Reduction Proportional Rationing	20% Reduction Drought-Contingent Pricing	20% Reduction Regional Water Market	30% Reduction Proportional Rationing	30% Reduction Drought-Contingent Pricing	30% Reduction Regional Water Market
SFPUC Retail	$4,679	$4,371	$3,777	$16,327	$15,098	$14,487	$34,946	$32,180	$31,537
Alameda CWD	$36	$36	-$3,588	$73	$73	-$7,353	$109	$109	-$10,963
Brisbane	$56	$46	$55	$140	$110	$122	$252	$192	$205
Burlingame	$584	$562	$453	$1,771	$1,685	$1,300	$3,563	$3,368	$2,548
Coastside CWD	$635	$590	$386	$1,798	$1,541	$919	$3,572	$2,938	$1,694
CWS - Bear Gulch	$3,769	$3,763	$3,341	$6,626	$6,613	$6,345	$10,234	$10,213	$10,011
CWS - Mid Peninsula	$1,264	$1,261	$1,100	$3,633	$3,621	$3,341	$7,106	$7,078	$6,572
CWS - South San Francisco	$508	$506	$403	$1,592	$1,585	$1,427	$3,252	$3,236	$2,972
Daly City	$24	$24	-$2,450	$48	$48	-$3,423	$72	$72	-$3,549
East Palo Alto WD	$79	$79	-$65	$220	$218	-$141	$424	$418	-$251
Estero MID	$76	$74	-$784	$265	$254	-$1,806	$565	$541	-$3,134
Guadalupe Valley									
Hayward	$1,414	$1,326	$1,039	$3,995	$3,707	$2,838	$7,744	$7,144	$6,036
Hillsborough	$581	$576	$733	$1,363	$1,346	$1,560	$2,346	$2,310	$2,496
Menlo Park	$217	$167	-$57	$586	$447	-$139	$1,107	$840	-$279
Mid-Peninsula	$464	$439	$445	$1,201	$1,120	$1,181	$2,211	$2,044	$2,091
Millbrae	$659	$480	$317	$2,348	$1,630	$959	$5,066	$3,449	$1,928
Milpitas	$1,129	$1,109	$1,006	$3,915	$3,595	$3,059	$8,359	$7,457	$6,054
Mountain View	$2,812	$2,697	$1,419	$9,432	$8,569	$4,147	$19,861	$17,616	$8,112
North Coast CWD	$809	$808	$565	$2,245	$2,244	$1,524	$4,308	$4,307	$2,857
Palo Alto	$4,509	$3,189	$1,695	$15,290	$10,012	$4,660	$32,344	$20,469	$9,635
Purissima Hills WD	$228	$228	$237	$597	$597	$605	$1,106	$1,106	$1,111
Redwood City	$2,844	$2,530	$1,678	$9,916	$8,249	$4,993	$21,218	$17,158	$9,962
San Bruno	$421	$370	$358	$1,042	$891	$688	$1,863	$1,563	$1,009
San Jose (North)	$284	$195	$190	$1,004	$648	$651	$2,158	$1,359	$1,368
Santa Clara	$2,582	$1,656	$1,590	$9,215	$5,509	$5,710	$19,899	$11,561	$11,525
Skyline WD	$58	$53	$45	$138	$124	$102	$241	$213	$176
Stanford									
Sunnyvale	$1,110	$1,110	$1,240	$3,408	$3,407	$3,484	$6,956	$6,952	$6,892
Westborough WD	$59	$58	$28	$161	$156	$78	$306	$294	$145
BAWSCA Total	$27,212	$23,931	$11,379	$82,023	$67,998	$36,829	$166,242	$134,008	$77,223
Total	**$31,891**	**$28,303**	**$15,156**	**$98,350**	**$83,096**	**$51,316**	**$201,188**	**$166,188**	**$108,759**

Notes:
Proportional Rationing allocation means that water is allocated by sector and by agency in proportion to FY 2004-05 consumption.
Efficiency Pricing allocation means that water is allocated by agency according to FY 2004-05 consumption, and is efficient among sectors.
Regional Water Market allocation means that water is allocated efficiently across agencies and across sectors through trading.
Guadalupe Valley and Stanford are excluded from welfare loss calculations due to lack of pricing data.

Sources:
BAWSCA Annual Survey, FY 2004-2005.
SFPUC Consumption and Pricing Data <CP Active Accounts.xls>.

While welfare losses provide the most direct measure of economic efficiency, they may not be well understood outside the economics/public policy disciplines. As discussed above, the changes in consumer spending associated with the projected surplus changes can be used to estimate economic impacts in terms of economic output and employment.

These results have important implications for the mitigation strategies under study as discussed below.

5.c.ii Policy Impacts

Quantity Controls and Rationing

Perhaps the simplest way to reduce demand in a drought is to limit consumption by various users. Table 14 shows economic surplus losses (i.e., producer and consumer surplus) under a proportional rationing scenario. This policy would be implemented by restricting consumption by a certain percentage, depending on the supplies available to an individual retail agency. For example, if an agency receives only SFPUC water, then the model calculates the change in surplus from a 20% reduction in consumption. However, if the agency has, say, local groundwater resources that partially offset the loss of Hetch Hetchy water, then the proportional cut in consumption is also less than 20%.

Annual welfare losses under this scenario are large. For the region, welfare losses total nearly $32 million per year under a 10% drought and $100 million per year. Under the 30% cut, losses double to $201 million. Comparing losses under the three reduction scenarios shows that the economic impacts of a drought are not proportional to the magnitude of the water shortage. Rather, the marginal impacts of drought increase rapidly with the severity of the loss of water supplies.

Losses also vary widely by retail agency. SFPUC retail is the hardest hit under the rationing scenario, which is not surprising given its large share of consumption of Hetch Hetchy water. Other agencies with the largest losses include Palo Alto, Redwood City, Santa Clara and Mountain View.

Drought-Contingent Pricing

An alternative to rationing is the use of drought-contingent prices. Under this type of policy, agencies alter their retail price schedules to incentivize conservation, but decentralize the decision about how much water to consume. A major benefit of price allocation is that water is allocated efficiently among customers who know their own unique willingness to pay for water.

Table 14 also shows the economic impacts of a drought when available supplies are allocated by price. Roughly speaking, reducing consumption by price incentives versus direct controls lowers welfare losses by 15 to 20 percent. Under drought-contingent pricing, regional losses are $28 million under a 10% cut, $83 million under a 20% cut, and $166 million under a 30% cut in Hetch Hetchy supplies.

Voluntary Programs

The prior comparison also indicates at a voluntary program where consumers are encouraged to conserve rather than force to limit consumptions will reduce welfare loss. Economic impacts will be similar to those occurring under a price incentive policy.

Regional Water Market

Given the significant differences in water use patterns and economic impacts among regional water agencies, it is intuitive that a program of voluntary trading to reallocate water supplies may provide significant economic benefits. Agencies with the greatest ability to conserve and with the most diverse portfolio of water resources could sell some supplies at a negotiated price. Such sales could relieve pressure on agencies with the least diverse portfolio, or with the highest willingness to pay for water.

BAWSCA member agencies have negotiated a shortage sharing agreement that allows for trading among retail agencies. While this agreement has not been tested under real-world conditions, it is a laudable attempt at regional cooperation to cope with shortage.

Table 14 shows that compared with the simple rationing scheme, a regional approach to shortage sharing including water markets can reduce the economic impacts of a drought by half. In the 10% reduction scenario, welfare losses total $15 million. In the 20% reduction scenario, welfare losses total $51 million when supplies are efficiently allocated among agencies. In the case of a more drastic 30% reduction, yearly losses are reduced from $201 million to $109 million.

Table 15 compares the welfare losses by sector. The largest losses occur in the residential sector reflecting the fact that households demonstrate more inelastic demand than the commercial and industrial sectors. They are willing to pay more for water than the other sectors. The regional approach cuts these losses by more than 50% because it allows trading to provide water to these higher value customers. This reduction comes at a cost, however, to the other sectors. The regional approach also results in a welfare transfer to those agencies able to gain from trade by virtue of low cost or multiple water supply sources. These agencies can further offset losses by providing rate relief or subsidizing investment in water reduction technologies.

Key Finding #8: Welfare losses created by rationing can be lessened by utilizing drought contingent pricing and regional shortage sharing.

Table 15: Welfare Loss Comparison for 10%, 20%, and 30% Drought Scenarios by Sector
in thousands of dollars

	Proportional Rationing			Drought-Contingent Pricing			Regional Water Market		
Scenario	Residential	Commercial	Industrial	Residential	Commercial	Industrial	Residential	Commercial	Industrial
10% Drought	$24,802	$5,165	$1,923	$16,436	$9,252	$2,614	$9,416	$4,436	$1,304
20% Drought	$78,243	$14,492	$5,615	$45,512	$29,327	$8,258	$31,888	$15,013	$4,416
30% Drought	$161,851	$28,236	$11,101	$88,812	$60,424	$16,951	$67,486	$31,893	$9,380

Notes:
Proportional Rationing allocation means that water is allocated by sector and by agency in proportion to FY 2004-05 consumption.
Efficiency Pricing allocation means that water is allocated by agency according to FY 2004-05 consumption, and is efficient among sectors.
Regional Water Market allocation means that water is allocated efficiently across agencies and across sectors through trading.
Guadalupe Valley and Stanford are excluded from welfare loss calculations due to lack of pricing data.

Sources:
BAWSCA Annual Survey, FY 2004-2005.
SFPUC Consumption and Pricing Data <CP Active Accounts.xls>.

We note that these results are stylized in that they do not account for all conveyance constraints, political constraints, and other factors that may limit the actual scope of trading. However, we remain convinced that this is a promising avenue of inquiry, as evidenced by the efforts of the SFPUC and BAWSCA agencies to develop a market-based mechanism for regional cooperation during drought.

Supplemental Supplies

One way to view the results of the economic impact model is in terms of the shortage loss per unit of water. Economists refer to such a figure as a “shadow price” or agencies’ willingness to pay to relax their supply constraints. Not surprisingly, the shadow value of water is large during a drought. Under the regional cooperation scenario, an extra unit of water is worth over $2,100 per acre-foot to retail customers. This figure is in line with previously published estimates of the vale of water under drought conditions.

Even subtracting costs of treatment, distribution and conveyance, it would appear that SFPUC service area customers would be willing to pay more for water during a drought than users outside the region would need to be paid to induce them to sell. Thus, there may be scope for “soft path” supply enhancements like voluntary transfers and banking arrangements.

5.c.iii. Impacts in terms of Output and Employment

Tables 16 and 17 present the impacts of the three allocation strategies in output and employment terms. Sales losses in the industrial sector range from a low of $570 million (or 0.9% of sales) in the proportional rationing strategy during a 10% drought, up to a high of $5.1 billion (or 7.8% of sales) in the regional cooperation strategy during a 30% drought. Sales losses in the commercial sector range from a low of $671 million (or 0.3% of sales) in the proportional rationing strategy during a 10% drought, up to a high of $19.2 billion (or 8.9% of sales) in the drought-contingent pricing strategy during a 30% drought.

Table 16: Industrial and Commercial Sector Sales and Revenue Losses

Sector and Model	Total Sales 2002 (millions $)	10% Drought Scenario: % Change in Industrial Consumption	10%: Elasticity (0-15%)	10%: Sales Loss (millions)	20% Drought Scenario: % Change in Industrial Consumption	20%: Elasticity (0-15%)	20%: Sales Loss (millions)	30% Drought Scenario: % Change in Industrial Consumption	30%: Elasticity (15-30%)	30%: Sales Loss (millions)	Sales Loss %: 10%	Sales Loss %: 20%	Sales Loss %: 30%
	[I]	[II]	[III]	[IV] = [I]x[II]x[III]	[V]	[VI]	[VII] = [I]x[V]x[VI]	[VIII]	[IX]	[X] = 0.15x[I]x[III] + ([VIII]-0.15)x[I]x[IX]	[X] = [IV] / [I]	[XI] = [VII] / [I]	[XII] = [X] / [I]
Industrial													
Proportional Rationing	$64,398	7.8%	0.114	$567	15.4%	0.114	$1,127	23.1%	0.483	$3,607	0.9%	1.8%	5.6%
Efficiency Pricing	$64,398	9.2%	0.114	$670	18.2%	0.114	$1,331	27.3%	0.483	$4,909	1.0%	2.1%	7.6%
Regional Water Market	$64,398	10.2%	0.114	$743	18.9%	0.114	$1,384	27.7%	0.483	$5,050	1.2%	2.1%	7.8%
Commercial													
Proportional Rationing	$215,243	9.0%	0.035	$671	17.4%	0.035	$1,301	25.9%	0.386	$10,156	0.3%	0.6%	4.7%
Efficiency Pricing	$215,243	12.6%	0.035	$940	24.7%	0.035	$1,843	36.8%	0.386	$19,206	0.4%	0.9%	8.9%
Regional Water Market	$215,243	12.7%	0.035	$947	23.6%	0.035	$1,764	34.6%	0.386	$17,395	0.4%	0.8%	8.1%

Notes:
1) The Industrial sector is composed of NAICS codes 31-33.
2) The Commercial sector is composed of NAICS codes 41-82.
3) Total Sales includes all sales, shipments, receipts, and revenues in the industrial and commercial NAICS codes for Alameda, San Francisco, San Mateo, and Santa Clara Counties.
4) To compensate for the fact that BAWSCA and SFPUC do not service the entire counties for which we have data, all of San Francisco and San Mateo County sales are included, while 50% of Alameda County and 80% of Santa Clara County sales are included. (See "Hetch Hetchy and the Bay Area Economy," Bay Area Economic Forum, October 2002.)
5) Weighted-average industrial and commercial output elasticities were calculated using MHB output elasticities and 2002 Economic Census data. The elasticities reported in the MHB study are for 0% to 15% and a 15% to 30% reductions in water supply.
6) Some NAICS codes have data suppressed in the Economic Census to protect anonymity; this may influence the calculated average elasticity.

Sources:
[I]: 2002 Economic Census data
[II], [V], and [VIII]: Welfare Loss Models (Table 14)
[III], [VI], and [IX]: MHB Study and 2002 Economic Census data

Table 17: Industrial and Commercial Sector Payroll and Job Losses

Sector and Model	Total Payroll 2004 (thousands)	Avg Payroll per Employee (thousands)	10% Drought Scenario: % Change in Industrial Consumption	10%: Elasticity (0-15%)	10%: Payroll Loss (thousands)	10%: Equivalent Job Losses	20% Drought Scenario: % Change in Industrial Consumption	20%: Elasticity (0-15%)	20%: Payroll Loss (thousands)	20%: Equivalent Job Losses	30% Drought Scenario: % Change in Industrial Consumption	30%: Elasticity (15-30%)	30%: Payroll Loss (thousands)	30%: Equivalent Job Losses	Payroll Loss %: 10%	Payroll Loss %: 20%	Payroll Loss %: 30%
	[I]	[II]	[III]	[IV]	[V] = [I]x[III]x[IV]	[VI] = [V] / [II]	[VII]	[VIII]	[IX] = [I]x[VII] x[VIII]	[X] = [IX] / [II]	[XI]	[XII]	[XIII] 0.15x[I]x[VIII] + ([XI]-0.15)x[I]x[XII]	[XIV] = [XIII] / [II]	[XV] = [V] / [I]	[XVI] = [IX] / [I]	[XVII] = [XIII] / [I]
Industrial																	
Proportional Rationing	$11,937,389	$72.59	7.8%	0.104	$96,052	1,323	15.4%	0.104	$190,868	2,629	23.1%	0.411	$581,245	8,007	0.8%	1.6%	4.9%
Efficiency Pricing	$11,937,389	$72.59	9.2%	0.104	$113,381	1,562	18.2%	0.104	$225,444	3,106	27.3%	0.411	$786,369	10,832	0.9%	1.9%	6.6%
Regional Water Market	$11,937,389	$72.59	10.2%	0.104	$125,875	1,734	18.9%	0.104	$234,304	3,228	27.7%	0.411	$808,677	11,140	1.1%	2.0%	6.8%
Commercial																	
Proportional Rationing	$87,552,091	$59.83	9.0%	0.009	$73,774	1,233	17.4%	0.009	$143,050	2,391	25.9%	0.251	$2,512,614	41,996	0.1%	0.2%	2.9%
Efficiency Pricing	$87,552,091	$59.83	12.6%	0.009	$103,301	1,727	24.7%	0.009	$202,570	3,386	36.8%	0.251	$4,905,971	81,998	0.1%	0.2%	5.6%
Regional Water Market	$87,552,091	$59.83	12.7%	0.009	$104,156	1,741	23.6%	0.009	$193,877	3,240	34.6%	0.251	$4,427,035	73,993	0.1%	0.2%	5.1%

Notes:
1) The Industrial sector is assumed to be NAICS codes 31-33.
2) The Commercial sector is assumed to be NAICS codes 42-81.
3) Total Payroll includes all payroll in the industrial and commercial NAICS codes for Alameda, San Francisco, San Mateo, and Santa Clara Counties.
4) To compensate for the fact that BAWSCA and SFPUC do not service the entire counties for which we have data, all of San Francisco and San Mateo County sales are included, while 50% of Alameda County and 80% of Santa Clara County sales are included. (See "Hetch Hetchy and the Bay Area Economy," Bay Area Economic Forum, October 2002.)
5) Weighted-average industrial and commercial payroll elasticities were calculated using MHB payroll elasticities and 2004 County Business Patterns payroll data. The elasticities reported in the MHB study are for 0% to 15% and a 15% to 30% reductions in water supply.

Sources:
[I] and [II]: 2004 County Business Patterns data
[III], [VII], and [XI]: Welfare Loss Models
[IV], [VIII], and [XII]: MHB Study and 2004 County Business Patterns data

Payroll losses in the industrial sector range from a low of $96 million (0.8% of payroll) in the proportional rationing strategy during a 10% drought, up to a high of $809 million (6.8% of payroll) in the regional cooperation strategy during a 30% drought. Using the average payroll per employee, the payroll losses equate to an equivalent number of jobs lost ranging from1,300 to 11,100. Payroll losses in the commercial sector range from a low of $73 million (0.1% of payroll) in the proportional rationing strategy during a 10% drought, up to a high of $4.9 billion (5.6% of payroll) in the drought-contingent pricing strategy during a 30% drought. These payroll losses equate to an equivalent number of jobs lost ranging from 1,200 to 82,000.

Key Finding#9: Because residential demand is more inelastic than the industrial and commercial demands for water, the drought-contingent pricing and regional cooperation strategies allocate more water towards the residential sector, resulting in higher sales and payroll losses in the commercial and industrial sectors.

Under all three allocation strategies, a 10% drought scenario will cause sales and payroll losses of 1.2% or less. A 20% drought scenario will cause sales and payroll losses of 2% or less. A 30% drought scenario will cause up to a 9% loss in sales and payroll. The size of the industrial and commercial economies under the jurisdiction of BAWSCA agencies and SFPUC retail, however, imply that even a 1% loss results in billions of dollars of lost sales and revenues.

Key Finding #10: A 10% drought causes payroll losses of between 0.8% and 1.1% in the industrial sector depending on mitigation strategy. A 20% drought causes payroll losses of between 1.6% and 2% in the industrial sector depending on the mitigation strategy; a 30% drought increases those impacts to between 4.9 and 6.8%. Payroll losses in the commercial sector are 0.1% regardless of a strategy in a 10% drought, 0.2% regardless of mitigation strategy under a 20% drought. A 30% drought increases this loss to between 3% and 6% depending on the mitigation strategy.

This analysis suggests that policy makers may wish to protect commercial and industrial water use during periods of drought. Of course, there is a tradeoff in doing so in that residential sector losses are higher than in the base case. It is important to know the incremental welfare cost (i.e. the cost of incremental residential conservation) for each job saved.

Table 18 shows welfare losses by agency when all water conservation occurs in the residential sector. Total welfare losses are considerably higher in this case. Under rationing and drought-contingent pricing, losses for a 10% cutback are $48 million, losses for a 20% cutback are $164 million, and losses jump to $351 million per year for a 30% drought.[26] With regional trading, losses are more than cut in half and total $18 million for a 10% cutback, $71 million for a 20% cutback, and $160 million for a 30% cutback.

Table 19 shows the cost of protecting jobs in a drought by allocating all conservation to the residential sector. The welfare loss difference reflects the difference between welfare losses associated with a drought scenario where water conservation occurs in all sectors (table 14) and where water conservation is imposed only on the residential sector (table 18). For example, under a 20% drought scenario and proportional rationing the welfare loss is is estimated to be $98.4 million (table 14), but when proportional rationing is replaced by imposing the full conservation requirement on the residential sector, the welfare

26 Note that since all water reductions would be imposed on the residential sector, the proportional rationing and drought-contingent pricing allocations no longer differ. The allocation ignores both the proportions of use by sector and the relative price elasticities of the sectors. The regional water market scenario, however, still reflects a different allocation because it allows for trading across agencies to meet residential water demand net of the required water conservation.

loss grows to $164.3 million (table 18) – a $65.9 million increase. This increase avoids job losses totaling 5,020 (2,629 industial jobs + 2,391 commercial jobs as shown in Table 17) associated with the proportional allocation. This translates to $13,131 per job saved ($65,919/5,020). As shown in table 19, these welfare costs per job range from roughly $600 to just over $13,000 per job saved per year. These costs are well within the range of costs of other job creation and preservation programs.

These costs should serve as important measures for policy makers. Imposing additional welfare losses on the residential sector, which may mean brown lawns or smaller gardens could be deemed a modest and reasonable cost to protect jobs.

Key Finding #11: Policy makers can protect commercial and industrial water availability in droughts by allowing or mandating higher losses in the residential sector. This would reduce negative impacts on the industrial and commercial sectors.

Finally, it is important to note that two of three primary drought mitigations strategies reviewed here, rationing and drought contingent pricing were used in some form by local water agencies during the last drought. The third strategy – creating a regional water market – has also been recognized as possible strategy as evidenced by the creation of a water trading system. This analysis provides water policy makers with important information regarding the effectiveness of these strategies and the tradeoffs of choosing between them.

Table 18: Welfare Losses for 10%, 20%, and 30% Drought Scenarios:
No Shortage Allocated to Commercial and Industrial Sectors
in thousands of dollars

	10% Reduction			20% Reduction			30% Reduction		
Agency	**Proportional Rationing**	**Efficiency Pricing**	**Regional Water Market**	**Proportional Rationing**	**Efficiency Pricing**	**Regional Water Market**	**Proportional Rationing**	**Efficiency Pricing**	**Regional Water Market**
SFPUC Retail	$7,468	$7,468	$7,813	$27,485	$27,485	$27,789	$60,052	$60,052	$60,219
Alameda CWD	$41	$41	-$6,960	$70	$70	-$11,543	$99	$99	-$15,427
Brisbane	$45	$45	$52	$109	$109	$101	$193	$193	$153
Burlingame	$832	$832	$557	$2,764	$2,764	$1,797	$5,797	$5,797	$3,832
Coastside CWD	$926	$926	$416	$3,193	$3,193	$1,224	$6,821	$6,821	$2,472
CWS - Bear Gulch	$3,990	$3,990	$4,196	$7,058	$7,058	$7,283	$10,949	$10,949	$10,757
CWS - Mid Peninsula	$1,390	$1,390	$686	$4,136	$4,136	$2,882	$8,237	$8,237	$5,419
CWS - South San Francisco	$860	$860	$997	$2,999	$2,999	$3,096	$6,416	$6,416	$6,469
Daly City	$22	$22	-$3,519	$45	$45	-$5,842	$68	$68	-$7,009
East Palo Alto WD	$80	$80	-$183	$222	$222	-$764	$427	$427	-$1,770
Estero MID	$78	$78	-$1,455	$271	$271	-$4,182	$579	$579	-$6,259
Guadalupe Valley									
Hayward	$1,409	$1,409	$1,254	$4,141	$4,141	$2,693	$8,197	$8,197	$4,143
Hillsborough	$576	$576	$628	$1,347	$1,347	$1,303	$2,313	$2,313	$1,502
Menlo Park	$185	$185	-$169	$515	$515	-$650	$991	$991	-$627
Mid-Peninsula	$444	$444	$452	$1,160	$1,160	$1,074	$2,147	$2,147	$1,794
Millbrae	$875	$875	$406	$3,211	$3,211	$1,362	$7,007	$7,007	$3,012
Milpitas	$1,862	$1,862	$1,242	$7,284	$7,284	$4,142	$16,267	$16,267	$9,421
Mountain View	$3,779	$3,779	$1,372	$13,669	$13,669	$5,312	$29,669	$29,669	$11,511
North Coast CWD	$824	$824	$649	$2,325	$2,325	$1,967	$4,503	$4,503	$3,763
Palo Alto	$7,287	$7,287	$2,011	$26,403	$26,403	$6,864	$57,350	$57,350	$14,473
Purissima Hills WD	$228	$228	$220	$597	$597	$529	$1,106	$1,106	$745
Redwood City	$4,083	$4,083	$2,015	$15,260	$15,260	$6,536	$33,530	$33,530	$14,582
San Bruno	$366	$366	$151	$893	$893	-$267	$1,580	$1,580	-$1,508
San Jose (North)	$1,276	$1,276	$492	$4,973	$4,973	$1,684	$11,090	$11,090	$3,714
Santa Clara	$7,727	$7,727	$3,535	$29,795	$29,795	$12,242	$66,204	$66,204	$26,452
Skyline WD	$52	$52	$55	$123	$123	$133	$212	$212	$227
Stanford									
Sunnyvale	$1,187	$1,187	$1,311	$4,056	$4,056	$3,998	$8,634	$8,634	$7,722
Westborough WD	$61	$61	-$10	$167	$167	-$87	$319	$319	-$257
BAWSCA Total	$40,481	$40,481	$10,399	$136,784	$136,784	$42,887	$290,707	$290,707	$99,305
Total	**$47,949**	**$47,949**	**$18,212**	**$164,269**	**$164,269**	**$70,675**	**$350,759**	**$350,759**	**$159,523**

Notes:
Proportional Rationing allocation means that water is allocated by sector and by agency in proportion to FY 2004-05 consumption.
Efficiency Pricing allocation means that water is allocated by agency according to FY 2004-05 consumption, and is efficient among sectors.
Regional Water Market allocation means that water is allocated efficiently across agencies and across sectors through trading.
Guadalupe Valley and Stanford are excluded from welfare loss calculations due to lack of pricing data.

Sources:
BAWSCA Annual Survey, FY 2004-2005.
SFPUC Consumption and Pricing Data <CP Active Accounts.xls>.

Table 19: Additional Welfare Loss Incurred to Protect Commercial and Industrial Jobs

	10% Drought Scenario			20% Drought Scenario			30% Drought Scenario		
Model	**Welfare Loss Difference (thousands)**	**Job Losses**	**Welfare Loss per Job**	**Welfare Loss Difference (thousands)**	**Job Losses**	**Welfare Loss per Job**	**Welfare Loss Difference (thousands)**	**Job Losses**	**Welfare Loss per Job**
Proportional Rationing	$16,059	2,556	$6,282	$65,919	5,020	$13,131	$149,570	50,002	$2,991
Efficiency Pricing	$19,647	3,288	$5,975	$81,174	6,491	$12,505	$184,571	92,831	$1,988
Regional Water Market	$3,056	3,475	$879	$19,359	6,468	$2,993	$50,764	85,133	$596

Notes:
Job Losses include both Industrial and Commercial sector job losses.
Welfare Loss Difference is the difference in welfare loss between the base model and the No Shortage Allocated to Commercial and Industrial Sectors model.

Sources:
Tables 14, 17, and 18

Economic Impacts and Capital Expenditures

Some observers of the economic impacts of reduced water availability have suggested that there is or should be a direct and mathematical relationship between the economic losses that result from reduced water availability and the appropriate level of capital investment by public agencies. For instance, it has been suggested that an economic loss of $5 billion justifies a capital investment of a like amount in order to avoid that loss. For a number of reasons that we will explain, the relationship between potential economic losses and capital investment decisions is not simple or direct.

First, it is important to understand the nature of the potential economic losses. For industrial and commercial customers, the losses represent reduced revenues, and reductions in employment. The employment reductions in turn represent losses of income to individuals. For residential customers, the losses represent the value of their investment in landscaping and the value they attach to water availability for other residential purposes. Some of the residential losses are out-of-pocket, but some are not. In drought scenarios, which are the major focus of this study, it is important to remember that the reduced availability of water is temporary. The commercial, industrial and residential economic loss is also temporary, although there is variation in the length of the loss. In almost all cases, the length is far less than the thirty year horizon typically used to consider public capital investment.

Second, public agencies have to consider an array of choices of capital investments, and, recognizing the limitations of their balance sheets, must also consider the balance between their operating and capital budgets. Considering only capital investments, public utilities have to consider all of the potential costs and benefits that may accrue from various capital investments. The potential economic losses cited in this study represent one of a number of costs and benefits that water utilities should consider in planning their capital investment program, but it is certainly not the only cost consideration. For example, in considering capital investments that may reduce the potential economic losses from reduced availability, water utilities may also have to consider capital investments that reduce system vulnerability to failures from other events, such as earthquakes. Both of these investments carry costs and benefits that must be considered side by-side.

In reality, there are far more than two choices of capital investments for water utilities. These choices are wide-ranging and complex. They involve political choices as well as financial ones. The information needed to make these choices is seldom perfect or complete. Mitigation of negative economic impacts is one of a number of objectives that must be addressed by water agencies. Therefore, while we believe that the information and analysis that we have posited in this study should be helpful in addressing future capital investment decisions, we must caution that it should not be considered in isolation from other choices and objectives.

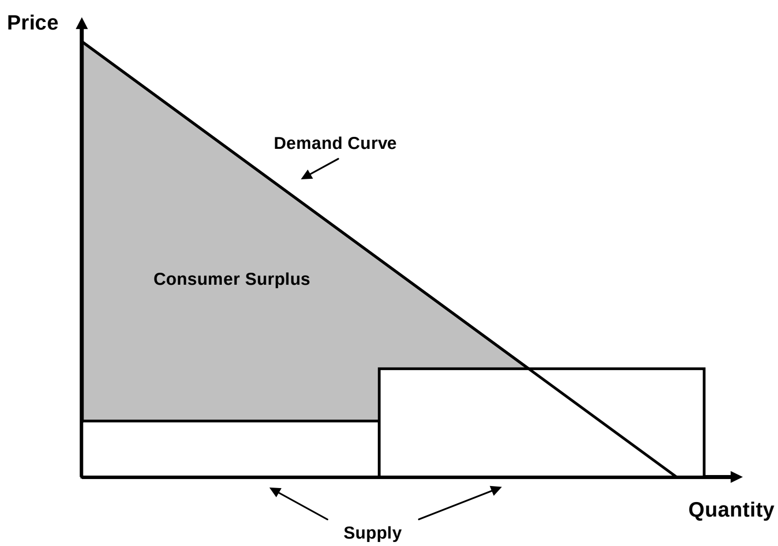
The welfare loss model is set up as a nonlinear maximization problem. The objective function maximizes consumer surplus, subject to the constraints of the supplies of water available to the sector, agency, or region. The data was prepared in Stata. The computer programs to solve the maximization problem were Excel using Solver and What's Best.

Methodology

To calculate welfare loss due to a reduction in water supply, we first calculate a consumer surplus for each level of water reduction we are interested in, including a base level with no reduction in water supply. The consumer surplus measures the aggregate value or benefit that consumers receive due to the fact that they are willing to pay more for water than the amount they actually pay for it. Graphically, it is equal to the area underneath the demand curve and above the supply curve (figure below).

The welfare loss for each level of water reduction is the difference between the consumer surplus at the base level (no water reduction) and the consumer surplus at the reduced level. In our estimations of welfare loss, the demand does not change; only the supply changes due to drought conditions.

$$WL = CS_{normalyear} - CS_{drought}$$



Demand

The BAWSCA Annual Survey has data on water consumption by five different sectors: residential, industrial, commercial, government, and other. For the purposes of our model, we are assuming that the Government and Other sectors have perfectly inelastic demand. For the remaining three sectors (Residential, Commercial, and Industrial), we construct linear demand curves using price elasticities of demand and consumption and price data.

Residential elasticity of demand for each agency is calculated from the regression specification earlier in the report. Agency-specific residential elasticities are calculated from the regression results using variations in BMP implementation among the water agencies. The three agencies with calculated elasticities greater than zero (Mountain View, Palo Alto, and San Jose) had their elasticities set equal to the calculated most inelastic negative elasticity (-0.022). Note that the elasticity regression is based on single-family residential, but is used here for all residential dwellings.

Due to a lack of information regarding the industrial and commercial sectors, we are unable to run elasticity regressions similar to what we have done for the residential sector. Instead, the price elasticities from the MHB study are used for these two sectors (-0.1206 for commercial and -0.1029 for industrial); these elasticities do not differ among the agencies.

Consumption data are taken from the BAWSCA Annual Survey for FY 2004-2005 and the SFPUC retail data file. Prices for each sector and agency are calculated at the average consumption amount using the residential retail rate structures in the annual survey. Slope and intercept are calculated based on the elasticity and the total residential agency consumption and the retail marginal price at the average residential consumption, resulting in a linear demand curve.

$$m = \frac{1}{\varepsilon} \cdot \frac{P}{Q}$$

Where ε is the elasticity, P is the average retail marginal price, and Q is the quantity of water consumed in FY 2004-2005.

Supply

The supply curve is composed of a step function with two steps, the first step being the SFPUC supply and the second step representing the sum of all other water supplies. The SFPUC step has a height equal to the wholesale price of SFPUC water ($1.168 per ccf) and a length equal to the water supply available to the sector, agency, or region. The second step has a height equal to $1.25 (an arbitrary price that is slightly more than the SFPUC price) and a length equal the sum of the non-SFPUC water supplies.

Water supply capacity information for each agency was gathered from a variety of sources, including the BAWSCA Annual Survey and agency Urban Water Management Plans. In general, actually supply capacities are used when available, and when actual supply data are not available, consumption in FY 2004-2005 is used instead. Some of the assumptions regarding water supply capacities are listed below:

Assumptions for Water Supply Capacities

Supplies during a Normal Year:

1 Groundwater capacities are equal to the capacities listed in the Urban Water Management Plans for the agencies during normal years for Alameda CWD, Coastside CWD, Daly City, and Sunnyvale. Alameda CWD groundwater capacity is assumed to be equal to gw storage plus gw recharge minus gw system demands. No groundwater supply information exists for CWS - South SF, San Bruno, San Jose, and Santa Clara; these agencies have supply equal to FY 0405 consumption.

2 Alameda CWD SWP capacity, desalination capacity, and Semitropic banking withdrawals during a normal, non-drought year are from the UWMP. (Alameda CWD Urban Water Management Plan, Table 8-4)

3 Recycled water capacity is assumed to be equal to the actual recycled water consumption for FY 2004-05.

4 Surface water capacity is assumed to be equal to FY 2004-05 consumption.

5 Santa Clara Valley WD capacity is assumed to be equal to the actual SCVWD consumption for FY 2004-05.

6 SFPUC capacity is assumed to be equal to the actual SFPUC consumption for FY 2004-05.

Supplies during a Drought Scenario:

1 For those agencies with groundwater capacities in UWMPs, they are equal to capacity during a multiple year drought scenario. Otherwise, they are reduced by the percentage of total water reduction during a drought scenario. Alameda CWD groundwater capacity is assumed to be equal to max gw storage and min gw recharge less the multiple drought year groundwater system demands. (Table 3-1 and 8-4 of UWMP)

2 SWP water is equal to minimum capacity per Table 3-1 of the Alameda CWD UWMP.

3 Semitropic banking withdrawal is equal to the max available per Table 3-1 of the Alameda CWD UWMP. Desalination remains unchanged from a normal year.

4 Recycled water capacity is not reduced during a drought scenario.

5 Surface water capacity is assumed to be zero during a drought, except for Coastside CWD, where it does not change according to drought level.

6 SCVWD capacity is reduced by the percentage of total water reduction during a drought scenario.

7 SFPUC capacity is reduced by the percentage of total water reduction during a drought scenario.

Scenarios

I. Proportional Allocation

Under the proportional allocation scenario welfare loss is calculated by agency and by sector. The total water supply available to the agency is allocated among the five different sectors according to their share of FY 2004-2005 consumption. Each sector receives a proportionate mix of the water supply sources. Note that Government and Other receive reductions in water supply, but no welfare loss is calculated for those water losses.

II. Drought-Contingent Pricing

Under the drought-contingent pricing allocation welfare loss is calculated by agency, and assumes an efficient allocation of water among the different sectors in that agency. As in the proportional allocation scenario, total water supply available to the agency is allocated among the five different sectors according to their share of FY 2004-2005 consumption. Similarly, a proportionate mix of the water supply sources is subtracted for Government and Other.

III. Regional Water Market

For the regional water market scenario, overall welfare loss is calculated across all agencies and sectors. This mimics a scenario where trading among agencies is allowed. Water thus gets allocated to the specific sectors and agencies where it is most valued at the margin. Similar to the other models, a proportionate mix of the water supply sources is subtracted for Government and Other.

Residential Demand Model

The basic linear regression equation used to calculate consumer elasticity of demand has the following form:

$$\ln(consumption) = \alpha + \beta_1 \cdot \ln(rate) + \beta_2 \cdot BMP + \beta_3 \cdot lotsize + \beta_4 \cdot hhinc$$
$$+ \beta_5 \cdot summertemp + \beta_6 \cdot precipitation + \beta_7 \cdot year + \varepsilon$$

The results of the regression are presented below.

Estimation Results for Residential Water Demand Model

Dependent Variable: ln(water consumption)

	[I]		[II]		[III]		[IV]	
	Base Specification		With Rate-BMP Interaction		With Rate-BMP and Rate-Income Interactions		With Rate-BMP, Rate-Income, and Rate-Lotsize Interactions	
Variable	**coeff.**	**|t-statistic|**	**coeff.**	**|t-statistic|**	**coeff.**	**|t-statistic|**	**coeff.**	**|t-statistic|**
ln(rate per ccf at average use)	-0.1759	4.89	-0.5477	4.94	-1.1263	5.37	-0.9381	3.59
percent of BMPs implemented	-0.1845	2.45	-0.6988	4.08	-0.7524	4.55	-0.6018	3.11
average lot size (thousand sq. ft.)	0.0351	10.23	0.0361	10.11	0.0347	11.50	0.0548	5.97
"average median" household income (thousand dollars)	0.0053	8.82	0.0050	7.43	-0.0003	0.20	-0.0019	1.16
average daily maximum summer temperature (July, August, September)	0.0093	3.72	0.0120	4.88	0.0132	5.43	0.0146	5.70
annual precipitation (inches)	-0.0013	0.81	-0.0016	0.96	-0.0007	0.43	-0.0005	0.28
year	0.0041	0.90	0.0040	0.91	0.0036	0.84	0.0041	0.96
Rate-BMP Interaction			0.6067	3.76	0.6770	4.50	0.4627	2.26
Rate-Income Interaction					0.0062	3.66	0.0078	5.19
Rate-Lotsize Interaction							-0.0218	2.27
R-squared	0.78		0.80		0.81		0.81	

Notes:
Robust t-statistics shown.

Sources:
BAWSCA Annual Survey
SFPUC data (<CP Accounts.xls>)
DataQuick lot size data
Census data for household income
Weather data from WRCC

An R-squared value of 0.78 indicates that the model is a strong fit for the data. Roughly 78% of the variation in residential water consumption can be explained by the seven factors we have examined (marginal rate/price, BMP implementation, lot size, household income, summer temperature, annual precipitation, and year).

The regression specification including the demand hardening term is:

$$\ln(consumption) = \alpha + \beta_1 \cdot \ln(rate) + \beta_2 \cdot BMP + \beta_3 \cdot lotsize + \beta_4 \cdot hhinc$$
$$+ \beta_5 \cdot summertemp + \beta_6 \cdot precipitation + \beta_7 \cdot year + \beta_8 \cdot (\ln(rate) * BMP) + \varepsilon$$

The results, summarized in specification II of Table 8, indicate that demand hardening does in fact exist: as an agency implements more BMPs, the price elasticity becomes smaller (i.e. more inelastic). Customers are thus less likely to respond to price increases by decreasing water consumption as more BMPs are put in place. Note that the coefficient of the first term ("*ln(rate per ccf at average use)*") no longer represents the elasticity of demand because price is interacted with BMP implementation.

The third specification tested the relationship between income and rate in addition to the BMP rate interaction. A fourth specification tested the relationship between lot size and rate in addition to the other interactions above. Neither specification affected price elasticity materially.

We would expect some multicollinearity because the variables we have selected would be expected to be correlated to some degree. However, given that none of the variance inflation factors (VIFs) are over 10, multicollinearity does not appear to be a specification problem with our regression model.

The Breusch-Pagan heteroskedasticity test does not indicate any problems with heteroskedasticity. However, to be conservative, Huber-White robust standard errors are displayed in Table 8.

The Ramsey specification error test was also run to detect omitted variables. With a p-value of 0.0025, this test indicates that the specification may have omitted variable biases.