TOTAL REGIONAL ECONOMIC LOSSES FROM WATER SUPPLY DISRUPTIONS TO THE LOS ANGELES COUNTY ECONOMY

by

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Financial support for this study was provided by the Metropolitan Water District, Los Angeles Department of Water and Power, Water Replenishment District and Veolia Corporation through Woodbury University. We wish to thank several members of these organizations for providing us with data, helping to specify the disruption scenarios, and commenting on our study. We are also grateful to the Los Angeles Economic Development Corporation Water Subgroup, our Project Advisory Board, and Ryan Merrill for feedback on earlier versions of this report. However, any errors or omissions are solely those of the authors.

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EXECUTIVE SUMMARY

I. INTRODUCTION

Water is the lifeblood of the Los Angeles economy. It is a necessary input to every producing sector, is a key ingredient to sustaining life for its population, and is indispensable to fire protection and other specialized uses. The reality is that Southern California is far from self-sufficient in its fresh water supplies. Moreover, the aqueducts that import water into the region are vulnerable to natural disasters, terrorist attacks, technological accidents, and regulatory changes. A major disruption of these external water supplies could potentially have devastating effects on the LA County Economy and the quality of life of its people.

This study estimates the total regional economic impacts of one major set of disruption scenarios stemming from a Bay Delta earthquake that would cause the closure of the California Aqueduct (State Water Project) for 6, 24, or 36 months. The results can be generalized to any event that would reduce fresh water imports through any of the three major aqueducts serving Los Angeles County, including a regulatory decree stipulating a sizeable reduction in its allocation of Colorado River water.

The study is based on the use of a computable general equilibrium (CGE) model, the state-of-the-art approach to regional macroeconomic impact analysis of severe shocks to a system. Essentially, CGE models the economy as a set of integrated supply chains in relation to behavioral responses of businesses and consumers to market price signals and resource constraints. The LA County CGE Model is specifically designed to focus on water production and use. Moreover, it is constructed using primary data from wholesale and retail water providers in LA County. The model is used to estimate the impacts of potential water supply disruptions on output, employment, and prices.

A novel feature of the study is the incorporation of resilience, or tactics that households and businesses use to cushion the blow of a disruption. That is, water customers do not just react passively or in a business as usual manner, but act first by invoking a set of coping strategies inherent in the water delivery and use system, such as storage and diversion of replenishment water. Moreover, they can adapt to the crisis with various forms of ingenuity, such as undertaking extra levels of conservation and recycling, and implementing technological innovations.

II. DATA AND METHODS

Water is a necessary input into every major production process of the Los Angeles County economy. Moreover, it is critical to sustaining a high quality of life in the area. It also has indispensable uses such as fire protection. The supply and demand for fresh water in LA Country is presented in Tables ES-1 and ES-2. These tables provide both historical data and projected data utilized in our analysis, which is pegged to the 2013 calendar year. Hydrologic factors are included in our analysis through the water supply demand forecast provided by MWD. The factors include projected rainfall and ground water recharging. All water-related data used in this study were obtained from water service agencies operating in the County.

Computable general equilibrium (CGE) analysis is the state-of-the-art in regional economic modeling, especially for impact and policy analysis. CGE is defined as a multi-market simulation model based on the simultaneous optimizing behavior of individual businesses and consumers, subject to economic account balances and resource constraints. The CGE formulation incorporates many of the best features of other popular model forms, but without many of their limitations. For example, CGE models retain the major strengths of input-output models (full accounting of all inputs, multi-sector detail, and ability to capture interdependencies), but overcome the limitations of linearity, lack of behavioral content, and difficulty of incorporating resource constraints. This modeling approach has been shown to represent an excellent framework for analyzing natural and man-made hazard impacts and policy responses, including disruptions of utility lifeline services (see, e.g., Rose and Liao, 2005; Rose et al., 2007). The CGE model used in this study is a combination of similar models used successfully for water service disruptions in Southern California (Rose et al., 2011a; Sue Wing, 2011).

For this study, we constructed a static, regional CGE model of the LA County economy consisting of 29 producing sectors. The sector classification was designed to highlight the sensitivity of production processes to water availability. Institutions in the model are households, government, and external agents. There are nine household income groups and two categories each of government (State/Local and Federal) and external agents (Rest of the U.S. and Rest of the World).

The major source of the data for the model is a detailed Social Accounting Matrix for LA County, derived from the Impact Planning and Analysis (IMPLAN) database (MIG, 2012). The IMPLAN system consists of an extensive set of economic data, algorithms for generating regional input-output (I-O) tables and social accounting matrices (SAM), and algorithms for performing impact analysis. IMPLAN is the most widely used database for generating regional I-O models and SAMs in the U.S. Because the IMPLAN system uses a non-survey approach to down-scale national and state economy indicators to the county level, it is important to verify the IMPLAN figures in key sectors for small area I-O tables. That is the reason we have been so careful in specifying water account balances for LA County.

III. SIMULATION SCENARIOS

In this study, we examine several major scenarios related to the timing of the disruption, hydrologic conditions, resilience, rationing and pricing. Although the specific cause on which we focus would be a Bay Delta earthquake that causes a shutdown of the California Aqueduct due to the threat or actuality of saltwater intrusion, a similar disruption could be caused by several other actions, including a terrorist attack, technological accident, or some other natural hazard such as an ocean storm surge. In addition, our disruption analysis methodology and results would be applicable to other actions, such as a regulatory decree reducing Los Angeles County's allocation of Colorado River water. The disruption levels for our 24-month Reference Case Scenario under three different hydrologic conditions and various types of resilience are presented in Table ES-3.

**Table ES-1. LA County Sources of Water (Acre Feet)
(Forecast Year 2013)**

	City of LA	All Other	Total
Groundwater Production	78,500	515,190	593,690
Surface Water Production	0	16,070	16,070
Los Angeles Aqueduct Supply	222,872	0	222,872
Recycled Water Production	7,658	125,487	133,145
Groundwater Recovery	0	26,423	26,423
Imported MWD Deliveries	355,785	469,507	825,292
Total Wholesale Supply	664,815	1,152,677	1,817,492

*Data source: MWD.

**Table ES-2. LA County Demand of Water (Acre Feet)
(Forecast Year 2013)**

	City of LA	All Other	Total
Single-Family Retail	251,536	529,316	780,852
Multi-Family Retail	165,484	166,721	332,205
Commercial, Industrial, Institutional	191,962	239,981	431,943
Non-Metered Uses	52,955	78,924	131,879
Retail Agricultural	0	399	399
Retail Seawater Barrier	2,878	33,161	36,039
Retail Replenishment	0	104,175	104,175
Total Retail Demand after Conservation	664,815	1,152,677	1,817,492

*Data source: MWD.

Hydrologic Conditions:

The characteristics of our "Reference Case" were developed by MWD, LADWP and others. They are based on a distribution of historical weather/hydrologic conditions and use actual estimated water storage levels for January 1, 2012. In addition to the Reference Case, we will also run simulations for extreme dry weather conditions and simulations excluding storage. Comparing the impact results of the Reference Case and the case excluding storage use enables us to evaluate storage as a resilience tactic and to expressly measure the value of storage capacity.

Time Periods:

The time periods for water supply disruptions from the California Aqueduct are 6, 24, and 36 months. We run the model for the appropriate time periods, and report the results on an annual basis. The 24-month disruption is our Reference Case.

Table ES-3. Water Constraints for Alternative Hydrologic Condition Cases, with and without Resilience, 24-month Disruption Scenario

Case Description	Water Constraint Level (%)					
	Normal-Year Case		Moderately Unfavorable Hydrologic Condition Case		Severe Hydrologic Condition Case	
	2013	2014	2013	2014	2013	2014
No Water Storage	18.2	18.2	24.6	23.2	27.8	29.8
Storage (Reference Case)	4.9	10.9	10.6	16.0	11.4	21.2
Phase II Conservation	0	5.3	5.2	10.4	6.1	15.8
Phase II Conservation Plus	0	0.2	0.2	5.3	1.1	10.8
Water Unimportance	1.9	4.2	4.1	6.1	4.4	8.1
Diversion of Replenishment Use	2.7	8.8	8.4	13.9	9.3	19.3
Production Recapture	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Simultaneous Resilience	0	0	0	1.4	0	3.5

Customers Affected:

- All customers (Reference Case)
- Residential customers only

Pricing:

- Price of water free to find its market equilibrium (Reference Case). This allocates water to highest value uses.
- Price of water held constant

Rationing:

- Rationing through pricing. A constraint is placed on overall water use and market responses determine water use (Reference Case)
- Rationing through decree either across the board or for household customers only

Resilience Analysis:

- Storage
- Conservation
- Water unimportance (portions of business operation not dependent on water)
- Diversion of replenishment use
- Production recapture (making up lost production once water service is restored)

Reconstruction Paths:

- Discrete jump, i.e., the entirety of the Bay Delta damage must be repaired before water is allowed to flow through the California Aqueduct (Reference Case)
- Linear resumption of service

IV. MACROECONOMIC IMPACT ANALYSIS

We examine the effects of the water supply disruption on major macroeconomic indicators: net output (Gross Domestic Product for the County), gross output (sales revenue), employment and prices. Note that these are market-based economic indicators of most interest to policymakers. They include impacts on businesses (gross and net output and their share of income) and on households (employment and their share of income). We also compute measures of lost economic welfare (well-being) of households from the loss of utility of decreases in water use, and the reallocation of their spending. This computation is distinct from the formal GDP accounts and provides a separate perspective from that of households' lost income and employment.

Macroeconomic impacts can be very complex. First, water used by businesses is extensive and goes far beyond the obvious uses in food processing, restaurant drinking and dishwater, and various purification processes. Many businesses use water for cooling and vacuum pumps. Additionally, production creates extensive indirect demands for water upward along successive stages of supply chains. If a firm has to cut back its production because of disruption of its water supply, it will demand fewer inputs. This in turn reduces the production of all of its suppliers, who in turn reduce their orders through a successive round of upstream demands. Moreover, lower production levels at each round translate into lower income payments, which then translate into a further dampening of economic activity from decreases in consumer and investment spending.

Water disruptions also magnify themselves downstream along successive supply chain stages in a similar manner. The lack of availability of an input will cause its users to reduce their output, even if they have a very low demand for water in the first place and can make up for the entire shortfall through various resilience tactics. The sum total of all these chain reactions is referred to as multiplier effects when only considering output quantities, as in an I-O model, and general equilibrium effects when both price and quantity responses are taken into account, as in a CGE model.

V. SUMMARY OF RESULTS

Some results of our simulations are presented in Tables ES-4 to ES-8. They are a snapshot of the many tables in the text, which include various sensitivity tests. The Reference Case is consistent with the following conditions:

- flexible water pricing in the face of market conditions
- aggregate water constraint (no sectoral rationing)
- 24-month disruption period
- water storage included, but no other resilience

For disruptions lasting more than one year, we present results for each applicable year, as well as a summary total. Note that the Reference Case results are presented for a recovery path that assumes no incremental repair and reconstruction of the infrastructure damage affecting the flow of water through the California Aqueduct, so that the full outage is felt during the relevant time period, and then the water flow returns to normal at the end of the period. If a linear recovery path is assumed, the impacts would be one-half the size of those reported below.

This study provides a range of estimates for the economic impacts of a disruption of the California Aqueduct on the Los Angeles County economy. A range is needed to account for the variability and the key assumptions and parameters related to weather, hydrology, recovery patterns and the effectiveness of resilience.

Table ES-4. Total Two-Year Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-14 (percentage changes)

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
Storage (Reference Case): Year 2013	4.9	-4.19	-4.03	12.39	-3.83
Storage (Reference Case): Year 2014	10.9	-9.44	-9.08	29.89	-8.63
Storage (Reference Case): Weighted Avg	n.a.	-6.84	-6.57	n.a.	n.a.

Table ES-5. Total Two-Year Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-14 (changes in levels)

Case Description	Disruption Level (% change)	GDP change (B 2013$)	Employment change (job-years)	Water Price (% change)	Welfare (B 2013$)
Storage (Reference Case): Year 2013	4.9	-23.08	-228,125	12.39	-17.83
Storage (Reference Case): Year 2014	10.9	-51.99	-513,910	29.89	-40.18
Storage (Reference Case): Total	n.a.	-75.07	-742,035	n.a.	n.a.

Table ES-6. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, with and without Storage (Reference Case: Flexible Price and Economy-Wide Rationing), 2013

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
No Storage (6-month)	4.35	-3.79	-3.64	10.92	-3.40
Storage (6-month)	0.24	-0.20	-0.19	0.57	-0.19
No Storage (24-month)	18.2	-16.10	-15.48	55.91	-14.72
Storage (24-month)	4.9	-4.19	-4.03	12.39	-3.83
No Storage (36-month)	18.2	-16.10	-15.48	55.91	-14.72
Storage (36-month)	4.9	-4.19	-4.03	12.39	-3.83

Table ES-7. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (level change), 2013

Scenario Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	4.9	-23.08	-228,125	12.39
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	10.6	-51.61	-510,549	29.03
Severe hydrologic condition (Reference Case) flexible price/general constraint	11.4	-55.62	-550,197	31.59

Table ES-8. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (level change), 2014

Scenario Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	10.9	-51.99	-513,910	29.89
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	16.0	-78.71	-778,703	47.31
Severe hydrologic condition (Reference Case) flexible price/general constraint	21.2	-106.14	-1,050,233	68.50

For a 24-month total disruption of the California Aqueduct, Los Angeles County would have an expected shortage of 4.9 percent in 2013 and 10.9 percent in 2014 given current levels in storage and a historical range of potential hydrologic and climatic conditions. This shortage would increase to 10.6 and 16.0 percent under moderately unfavorable hydrologic and climatic conditions and to 11.4 and 21.2 percent under severe hydrologic and climatic conditions. The absence of storage would increase the shortage to nearly 30 percent by 2014 under the worst case scenario.

The basic conclusions of the study are:

- The 6-month shutdown of the California Aqueduct in normal years relating to weather and hydrology conditions and reasonable levels of resilience, primarily conservation and production recapture, will result in no negative economic impacts.
- For the Reference Case (flexible water pricing, economy-wide constraint and use of storage water), a 24-month shutdown of the California Aqueduct could lead to a total two-year loss of 742,000 job-years of employment, $75 billion of GDP, and $135 billion of sales revenue for businesses in LA County. Reasonable levels of several types of resilience could reduce this outcome significantly.
- Under the most adverse hydrological conditions, the negative impacts for a 24-month shutdown could be as large as $160 billion of GDP and 1.6 million job-years of employment.
- For the Reference Case, a 36-month shutdown of the California Aqueduct could lead to employment losses of 1,315,000 job-years, GDP losses of $133 billion, and total revenue losses of $240 billion over the three years. Even with a major resilience effort, the losses would likely be in the tens of thousands of job-years and tens of billions of losses in GDP and sales revenue.
- The negative impacts of the supply disruptions analyzed would be half the size of those noted above if the restoration of California Aqueduct supplies were to proceed incrementally in a linear fashion, rather than the Reference Case assumption that no water would flow from it to LA County until the Bay Area levee system was completely repaired.
- The negative impacts of the supply disruptions could be reduced significantly if water prices were held constant during the disruption.
- Existing water storage is able to mute the potential impacts considerably. Maximum potential losses would be doubled for the 24-month and 36-month scenarios with zero storage, and even more in the cases of adverse hydrological conditions, such as extreme dry years.
- Resilience tactics other than water storage can reduce losses considerably if implemented close to their maximum potential. This includes conservation, water unimportance, diversion of replenishment water for other uses, and production recapture. Under adverse hydrological conditions, however, even the full implementation of these tactics would still result in GDP losses in the tens of billions of dollars and employment losses in the tens of thousands of job-years. Moreover, these factors have limited capability to deal with the consequences of a catastrophic scenario during an extended drought period.
- Los Angeles County can become less vulnerable to water disruptions in two major ways. One is to have the major federal-state initiative to improve the Bay Area conveyance system to make it more capable of withstanding a major earthquake. The ongoing Bay Delta Conservation Plan is proposing such an improvement. The other way is to continue to invest in storage and alternative water supply systems. For example, Orange County recently commissioned the building of a small desalination plant. In addition to existing approaches to the problem, and the potential of both inherent and adaptive resilience, LA County also needs to consider a broad range of

alternatives. At the same time, water agencies in LA County should continue to be vigilant in protecting their groundwater and reservoir supplies. Overall, the key to maintaining water reliability is a diverse portfolio of water supply sources.

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I. INTRODUCTION

Water is the lifeblood of the Los Angeles economy. It is a necessary input to every producing sector, is a key ingredient to sustaining life for its population, and is indispensable to fire protection and other specialized uses. The reality is that Southern California is far from self-sufficient in its fresh water supplies. Moreover, the aqueducts that import water into the region are vulnerable to natural disasters, terrorist attacks, technological accidents, and regulatory changes. A major disruption of these external water supplies could potentially have devastating effects on the LA County Economy and the quality of life of its people.

This study estimates the total regional economic impacts of one major set of disruption scenarios stemming from a Bay Delta earthquake that would cause the closure of the California Aqueduct (State Water Project) for 6, 24, or 36 months. The results can be generalized to any event that would reduce fresh water imports through any of the three major aqueducts serving LA County, including a regulatory decree stipulating a sizeable reduction in its allocation of Colorado River water.

The study is based on the use of a computable general equilibrium (CGE) model, the state-of-the-art approach to regional macroeconomic impact analysis of severe shocks to a system. Essentially, CGE models the economy as a set of integrated supply chains in relation to behavioral responses of businesses and consumers to market price signals and resource constraints. The LA County CGE Model is specifically designed to focus on water production and use. Moreover, it is constructed using primary data from wholesale and retail water providers operating in LA County. The model is used to estimate the impacts of water supply disruptions on output, employment, and prices.

A novel feature of the study is the incorporation of resilience, or tactics that households and businesses use to cushion the blow of a disruption. That is, water customers do not just react passively or in a business as usual manner, but act first by invoking a set of coping strategies inherent in the water delivery and use system, such as storage and diversion of replenishment water. Moreover, they can adapt to the crisis with various forms of ingenuity, such as undertaking extra levels of conservation and recycling, and implementing technological innovations.

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Not only is resilience operative at the microeconomic level, but it is also effective at the market level. Prices reflect the value of resources, and hence water price changes stemming from a disruption represent an alternative rationing mechanism that can allocate water to its highest value use and thereby further reduce the impacts of the shock to the system. Overall, the analysis of resilience helps to avoid overstating the disruptive impacts and offers useful insights into how society can best cope with any serious disruption of fresh water supplies.

II. WATER AND THE LOS ANGELES COUNTY ECONOMY

A. Water Supply and Demand Accounts.

Water is a necessary input into every major production process of the Los Angeles County economy. Moreover, it is critical to sustaining a high quality of life in the area. It also has indispensable uses such as fire protection.

The supply and demand for fresh water in LA Country is presented in Tables 1 through 4. These tables provide both historical data and projected data utilized in our analysis, which is pegged to the 2013 calendar year (see also Appendix A). Table 0 provides the major data sources.

Table 0. Data Sources

Variable	**Source**	**Date**
Source of Supply (Historical)	MWD	2009/10
Source of Supply (Projected)	MWD	2013, 2014, 2015
Wholesale Prices (Historical)	MWD	2009, 2010, 2011
Wholesale Prices (Projected)	MWD	2012, 2013, 2014, 2015
Sources of Demand (both LA City and non-LA)	MWD	2009/10
Sources of Demand (LA City)	LADWP	2009/10, 2010/11, & 2011/12
Sources of Supply (LA City)	LADWP	2009/10, 2010/11, 2011/12 & 2012/13
Retail Prices (LA City)	LADWP	2009/10 & 2010/11
SIC Decomposition of Demand (LA City)	LADWP	2009/10 & 2010/11

* I-O Table is 2010 base year.

Table 1a. LA County Sources of Water (Acre Feet)
(Forecast Year 2013)

	City of LA	All Other	Total
Groundwater Production	78,500	515,190	593,690
Surface Water Production	0	16,070	16,070
Los Angeles Aqueduct Supply	222,872	0	222,872
Recycled Water Production	7,658	125,487	133,145
Groundwater Recovery	0	26,423	26,423
Imported MWD Deliveries	355,785	469,507	825,292
Total Wholesale Supply	664,815	1,152,677	1,817,492

*Data source: MWD.

Table 1b. LA County Sources of Water (Percent)
(Forecast Year 2013)

	City of LA	All Other	Total
Groundwater Production	12%	45%	33%
Surface Water Production	0%	1%	1%
Los Angeles Aqueduct Supply	34%	0%	12%
Recycled Water Production	1%	11%	7%
Groundwater Recovery	0%	2%	1%
Imported MWD Deliveries	54%	41%	45%
Total Wholesale Supply	100%	100%	100%

*Data source: MWD.

Table 1c. LA County Sources of Water (Million $)
(Forecast Year 2013)

	City of LA	All Other	Total
Groundwater Production	66	436	503
Surface Water Production	0	14	14
Los Angeles Aqueduct Supply	189	0	189
Recycled Water Production	6	106	113
Groundwater Recovery	0	22	22
Imported MWD Deliveries	301	398	699
Total Wholesale Supply	563	976	1,539

*The MWD forecasted 2013 water rate ($847/AF) is used to convert the quantity data in Table 1a to dollar values in this table.

Table 2a. LA County Demand for Water (Acre Feet)
(Forecast Year 2013)

	City of LA	All Other	Total
Single-Family Residential Retail	251,536	529,316	780,852
Multi-Family Residential Retail	165,484	166,721	332,205
Commercial, Industrial, Institutional	191,962	239,981	431,943
Non-Metered Uses	52,955	78,924	131,879
Retail Agricultural	0	399	399
Retail Seawater Barrier	2,878	33,161	36,039
Retail Replenishment	0	104,175	104,175
Total Retail Demand after Conservation[1]	664,815	1,152,677	1,817,492

*Data source: MWD.

[1] Conservation here refers to efforts towards the goal of 20x2020 Water Use Efficiency. Shortage year mandated water conservation, such as LADWP Phase II Conservation, is not included.

Table 2b. LA County Demand for Water (Percent)
(Forecast Year 2013)

	City of LA	All Other	Total
Single-Family Residential Retail	38%	46%	43%
Multi-Family Residential Retail	25%	14%	18%
Commercial, Industrial, Institutional	29%	21%	24%
Non-Metered Uses	8%	7%	7%
Retail Agricultural	0%	0%	0%
Retail Seawater Barrier	0%	3%	2%
Retail Replenishment	0%	9%	6%
Total Retail Demand after Conservation	100%	100%	100%

*Data source: MWD.

Table 2c. LA County Demand for Water (Million $)
(Forecast Year 2013)

	City of LA	All Other	Total
Single-Family Residential Retail	437	920	1,357
Multi-Family Residential Retail	272	274	545
Commercial, Industrial, Institutional	346	433	779
Non-Metered Uses	95	142	238
Retail Agricultural	0	1	1
Retail Seawater Barrier	4	44	48
Retail Replenishment	0	139	139
Total Retail Demand after Conservation	**1,154**	**1,953**	**3,107**

*Projected LADWP Year 2013 retail rates are used to convert the quantity data in Table 2a to dollar values in this table.

Table 3. Wholesale Water Rates (Effective January 1)

	2009	2010	2011	2012	2013	2014
Full Service Treated Volumetric Cost ($/AF)	$579	$701	$744	$794	$847	$890

*Data source: MWD.

Table 4. Retail Water Rates

	2009/10 ($/HCF)	Price Increase from 2009/10 to 2012/13*	2012/13 ($/HCF)	2012/13 ($/AF)
Single-Family Residential	$3.76	6.09%	$3.99	$1,737.46
Multi-Family Residential	$3.55	6.07%	$3.77	$1,641.56
Commercial	$3.90	5.92%	$4.13	$1,797.69
Industrial	$3.96	5.92%	$4.19	$1,826.09
Governmental	$2.93	4.43%	$3.06	$1,333.40

*The 3-year water rate increases between FY09/10 and FY12/13 are calculated as the average percentage increase of the 1st quarter & 2nd quarter water rates from FY09/10 to the same periods FY12/13.

Water use (in 2013 dollars) for individual producing sectors can be read from row 6 of the Input-Output Table accounts presented in Table A2 in Appendix A. These figures are consistent with totals by major customer class obtained from the Metropolitan Water District (MWD), with sectoral detail calculated from a separate Los Angeles Department of Water and Power (LADWP) file that provides sectoral water use details at 4-digit Standard Industrial Classification (SIC) level. Total production/sales of LA County retail water deliveries is $3.107 billion (row sum). This matches the total production costs of delivering the water, including wholesale water purchases, imputed value of stored water, and mark-up related to delivery costs by LA County retail suppliers (column sum). When we construct the water accounts in the I-O table, we consider water delivered by MWD and related sources to be domestic imports (from elsewhere in California and the rest of the U.S.) into the County equal to $1.539 billion. This is the vast majority of the $1.551 billion of all imported inputs to Water Services Sector, Sector 6, which also includes non-water inputs.

We use the Full Service Treated wholesale price obtained from MWD to compute the total value of imported water for LA County. We use retail prices differentiated according to customer class obtained from LADWP to represent the retail prices for LA County as a whole.[1]

[1] The LADWP average retail water rates by customer class data are used for LA County as a whole because we were not able to obtain compatible rate data (weighted average water rates across various tiered uses for individual customer classes) for other municipalities. Note that LADWP retail water sales accounts for more than one-third of the county total.

Note some abstractions from reality in our methodology. Within each customer class there are differential block rates for varying quantities, typically increasing with demand. Note that most studies also abstract from this consideration (see, e.g., BEC, 2010). Also, we only calculate limited water supply cost changes from the disruption. However, lower delivery volumes can result in lower per unit delivery costs, assuming an upward sloping supply and the underlying marginal cost curve. We factor in cost changes in water supply in relation to the constant elasticity of substitution (CES) production function choice of input in response to relative price changes. Note, that the delivery costs represent only a very small percentage of total costs other than wholesale water imports and fixed charges associated with pipeline infrastructure.

Section I of Appendix A presents the data and assumptions we used to construct the water supply and demand accounts.

The price elasticity of demand for water reflects how sensitive water demand is to a change in its price. Estimates used in MWD's Econometric Water Demand Model and in LADWP's water demand forecast are presented below:

- Single-Family = -0.131
- Multifamily = -0.109
- Commercial/Government = -0.107
- Industrial = -0.107

The values in the area of 0.1 reflect the fact that water is a dire necessity and that even large increases in price will result in a minimal cutback in demand. These price elasticities are also translated into the CGE model's elasticities of substitution, or the ease at which businesses can substitute other inputs for water. These substitution elasticity values are thus very low as well.

Hydrologic factors are included in our analysis through the water supply demand forecast provided by MWD. The factors include projected rainfall and ground water recharging. Some added costs are associated with hydrologic-related actions. For example, BEC (2010) explicitly calculated increased extraction costs from existing storage (essentially the value of storage loss), and also calculated the difference in replenishment water deliveries which is also translated into a decrease in storage value. We implicitly include these costs in relation to scenario data provided by MWD, which factors in changes in storage in relation to future deliveries. This is a more indirect approach but adequate for our purposes.

B. The LA County Input-Output Table

A useful tool for collecting and tabulating data on water delivery and its uses is an input-output (I-O) table. This is a double-entry set of accounts of all purchases and sales within a regional economy. The concept of an I-O table was developed by Nobel Laureate Wassily Leontief, and served as the basis for both simple I-O models, and more sophisticated models such as the one being used in this study (see Rose and Miernyk, 1989; Rose, 1995).

The LA County I-O table is presented in Table A2 in Appendix A.[2] Each row in the table represents the dollar value of sales of the sector listed at the left (row labels) to the sectors of the economy listed at the top (column labels), including government, households, and the production of goods for capital formation.

[2] The basic I-O accounts for the model are for Year 2010. They are updated to 2013 by applying historical and short-term projected economic growth rates from Kleinhenz (2012). We assume the 2012 to 2013 growth rate will continue for simulations for 2014 and 2015. Growth rates are applied to adjust water availability constraints in the model for their effect in those years and to scale its results for them as well.

Each column represents the dollar value of purchases of inputs used to produce the output of each sector in the economy. The row and columns labels are identically labeled and ordered, and the total uses of each good and service equals the total production of each in the economy, with the designation "Total Gross Output."

The LA I-O table clearly displays how much water is used in each sector of the LA economy. It also presents a stylized picture of water production, i.e., delivery. In effect, we have modeled all water flows from the three major California aqueducts as imports of water (the lion's share of the value import row in the water sector column -- Sector #6). In the table we have also included groundwater and all other local sources in the import row for purpose of simplification. Essentially, the import row represents water at wholesale prices, while the sum of all the elements in the water production column represents the value of retail sales. In effect, water deliveries into the various retail providers is entered at wholesale prices and the various costs of production listed in the Sector 6 column provide information on other costs that are incurred in establishing an average retail price of water. Note that these prices are implicit in these sets of accounts, since each entry in the table represents a value (price times quantity) figure.

Note also that the I-O table is a major component of the CGE model that we describe below. The table presented above is a modified version of the set of I-O accounts obtained from the IMPLAN System, the major provider of such accounts in the U.S. (IMPLAN, 2012). It should be mentioned that while the entries for the water sectors is based on primary data, the other entries in the table, except for total gross outputs, are based on a data-reduction methodology (secondary data from downscaling national and state data to the county level). Still, IMPLAN tables are considered reasonably accurate, and have been used in literally thousands of major economic impact studies (see, Sue Wing et al. 2010; Rose et al., 2011; Rose and Wei, 2011).

Appendix A Section II presents in detail how we adjust the water sector row and column in the IMPLAN I-O table using the water supply and demand accounts we established based on primary water data from water service providers in LA County.

III. THE LA COUNTY COMPUTABLE GENERAL EQUILIBRIUM MODEL

Computable general equilibrium (CGE) analysis is the state-of-the-art in regional economic modeling, especially for impact and policy analysis (Partridge and Rickman, 2010). CGE is defined as a multi-market simulation model based on the simultaneous optimizing behavior of individual businesses and consumers, subject to economic account balances and resource constraints (see, e.g., Shoven and Whalley, 1992). The CGE formulation incorporates many of the best features of other popular model forms, but without many of their limitations (Rose, 2005). For example, CGE models retain the major strengths of input-output models (full accounting of all inputs, multi-sector detail, and ability to capture interdependencies), but overcome the limitations of linearity, lack of behavioral content, and difficulty of incorporating resource constraints. This modeling approach has been shown to represent an excellent framework for analyzing natural and man-made hazard impacts and policy responses, including disruptions of utility lifeline services (see, e.g., Rose and Liao, 2005; Rose et al., 2007). The CGE model used in this study is a combination of models used successfully for water service disruptions in Southern California (Rose et al., 2011a; Sue Wing, 2011).

For this study, we constructed a static, regional CGE model of the LA County economy consisting of 29 producing sectors. The sector classification was designed to highlight the sensitivity of production processes to water availability. Institutions in the model are households, government, and external agents. There are nine household income groups and two categories each of government (State/Local and Federal) and external agents (Rest of the U.S. and Rest of the World).

The major source of the data for the model is a detailed Social Accounting Matrix (SAM) for LA County, derived from the Impact Planning and Analysis (IMPLAN) database (MIG, 2012). The IMPLAN system consists of an extensive set of economic data, algorithms for generating regional input-output tables and social accounting matrices, and algorithms for performing impact analysis. IMPLAN is the most widely used database for generating regional I-O models and SAMs in the U.S. Because the IMPLAN system uses a non-survey approach to down-scale national and state economy indicators (output, income, employment) to the county level, it is important to verify the IMPLAN figures in key sectors for small area I-O tables. That is the reason we have been so careful in specifying water account balances for LA County

The I-O table provides the basic data for sectoral production functions in terms of input coefficients or shares. However, flexibility in the production process (e.g., input substitution) requires the specification of a set of elasticities of substitution. These parameters for regionally produced inputs and for imports, other than water, were based on a synthesis of the literature (see, e.g., Rose et al., 2011a), and other major parameters were specified during the model calibration process. Note that the various types of resilience can be incorporated into the model by modifying key production function parameters.

IV. DISRUPTION SCENARIOS

In this study, we examine three major scenarios related to the timing of the disruption of the California Aqueduct. Although the specific cause on which we focus would be a Bay Delta earthquake that causes a shutdown due to the threat or actuality of saltwater intrusion, this disruption could be caused by many other actions, including a terrorist attack, technological accident, or some other natural hazard such as an ocean storm surge. In addition, our disruption analysis methodology and results would be applicable to other actions, such as a regulatory decree altering Los Angeles County's allocation of Colorado River water.

Table 5 presents the assumptions of the 24-month scenario, which we refer to as our “Reference Case.” The details are the same for the 6-and 36-month scenarios, except for the durations. The varying lengths depend primarily on the extent and timing of repair and reconstruction activities. Various sub-cases distinguished in Section VI are also simulated. These pertain to the effectiveness of various resilience tactics, alternative polices regarding price and non-price rationing, and differences in the shape of the reconstruction paths.

A major timing consideration in the scenarios is the repair/reconstruction schedule. We analyze two alternatives: 1) a schedule where resumption of California Aqueduct does not take place until all repair/reconstruction has been completed (i.e., at the end of the disruption period), and 2) a linear continuous resumption of service. Needless to say, the latter decreases the disruption, and thereby the impacts, over time.

V. RESILIENCE TO WATER SERVICE DISRUPTIONS

Individuals and communities facing water shortages do not just react passively. Instead, they make various types of adjustments to mute the potential losses. This behavior is known as "resilience," and it has been documented as being effective in reducing losses from natural disasters and other types of disruptions to water systems (see, e.g. Tierney, 1997; Kajitani and Tatano, 2007). Static economic

Table 5. MWD 24-Month Catastrophic Bay Delta Failure Analysis

This scenario is consistent with Metropolitan's IRP planning approach and includes the following assumptions:
Assumes a catastrophic failure beginning January 1, 2013 that interrupts all supplies that rely on the Delta for a period of 24 months
Scenario begins in 2012 and runs through 2035, uses actual estimated storage levels for January 1, 2012
Applies historical hydrologic impacts from 1922-2004 to supplies and demands
Full use of Metropolitan's storage portfolio is available to manage water supplies
Full use of CRA supplies, programs, and transfers as needed and available
SWP supplies, programs, and transfers are reduced to 0 during the catastrophic delta failure

resilience refers to the ability of an entity or system to maintain function in the aftermath of a disaster through the efficient allocation of resources, which is exacerbated in the context of disasters. Dynamic resilience refers to the speed at which an entity or system recovers from a disaster and involves investment associated with repair and reconstruction. Resilience can be inherent, or already in place to be used when needed, or adaptive, or inspired by the crisis. Finally, resilience can take place at the micro, mesa (industry or market), or macroeconomic levels (Rose, 2009).

Below we summarize the various types of resilience relevant to our study at the micro level and explain briefly how we intend to model them:

1. Conservation. This refers to actions to reduce water use per person or per unit of economic activity beyond baseline trends (e.g., beyond normal progress on mandated “20x2020” water use efficiency). There are two ways to model conservation. The first is to consider existing and back-up conservation programs of various municipalities, such as the City of Los Angeles, and simply adjust water availability to account for them. The second pertains to adaptive behavior that may extend to Draconian measures not otherwise thought possible during normal circumstances. This type of conservation is likely to vary by type of user. For this type, one would adjust the productivity term related to water in the sectoral constant elasticity of substitution (CES) production functions (Rose and Liao, 2005) by an estimate of a reasonable potential level of adaptive conservation. Some Draconian measures may be difficult to sustain over a longer period of time, but there is also the likelihood that new ways will be found to maintain this momentum in a less onerous fashion. However, because adaptive conservation possibilities are extremely limited, and because we lack information on them, we do not explicitly model this type of resilience.[3] See more detailed assumptions on Conservation in Table 6.

2. Storage. This refers both to underground and surface reservoirs. The underground resources are deemed to include groundwater that might be used in an emergency situation. These alternatives can be modeled as loosening the water availability constraints. They are measured in terms of data on actual storage volume availabilities in LA County.

[3] A study by Rose and Liao (2005), based on survey results from Tierney (1997), found that adaptive conservation was rather minor for a disruption to the water supplies following an earthquake.

3. Water Unimportance. This refers to an inherent form of resilience operative in most sectors in terms of what portion of production does not require water. It pertains to those aspects of the production process that are separable from water use. Examples would be many aspects of construction company activity or mining. It should be noted, however, that many companies require water to operate in more subtle ways. For example, high-rise office buildings may have to be closed if water is not available for fire-protection sprinkler systems. The first major study of this type of resilience assumed that a disruption of up to 5% would not have any effect on the business and also that there was an upper threshold of water loss that would force the business to shut down (ATC, 1991). We will use the ATC importance factors, but not include the lower or upper thresholds. The lower one is subsumed into Conservation, and the upper one (typically above 45%) is irrelevant to this study because it exceeds the likely percentage water disruption.

4. Input Substitution. This refers to utilizing other products in place of water obtained from municipal delivery systems. This would include bottled and trucked water, various beverages, and possibly even chemicals. Some of the substitution is inherent in the economy, but under stressful conditions there is the potential to find additional substitutes or ease the ability use any substitutes. The latter represents a type of adaptive input substitution. We model the inherent aspect of this resilience tactic through the ordinary elasticities substitution between water and other inputs in the CES production functions; these parameters are related to the price elasticities of demand, provided by the water service agencies, which we use in this report. However, because enhanced substitution possibilities are extremely limited, and because we lack information on them, we do not explicitly model adaptive substitution.[4]

5. Import Substitution. If water cannot be delivered by local suppliers, there is a possibility of increasing supplies from providers elsewhere. This can be modeled by simply relaxing the water availability constraint. In our study, we deem these possibilities to be negligible given the strong demand for water throughout the state of California, which is unlikely to lead to water being diverted to Southern California from other aqueducts.

6. Recycling. As in the case of conservation, this pertains only to amounts of recycling over and above normal levels. It might be achieved in a number of ways, and it is also likely to differ by user. If the recycling is done internal to the production process, it can be modeled like conservation—an adjustment of the productivity term of the CES production functions; however, this is beyond the scope of this study. If it pertains to water delivery systems, it can be modeled by a relaxation of the general water availability constraint if recycling does not differ by user. Otherwise, sectoral constraints must be entered into the model and adjusted for this resilience tactic.

7. Water Replenishment Diversion. Water replenishment refers to injecting water into the ground for the purpose of natural purification. This resilience tactic pertains to reducing replenishment levels below normal conditions, and diverting water intended for replenishment use (including both groundwater spreading and seawater barrier uses) to other non-potable uses. Again, this can be modeled by changing the overall water availability constraint. Note that our study does not account for any harm to existing groundwater rights that may arise from reduced replenishment activities.

8. Technological Change. This refers to tactics separate from input (technical) substitution and conservation. Examples would be altering production processes to utilize less water or increasing the availability of the desalination plants. Changes in the production process of water users would be modeled as changes in the productivity term of the CES production function (a general productivity term if the technological change is factor neutral, or productivity terms associated with individual inputs if

[4] The Rose and Liao (2005) and Tierney (1997) studies also found that adaptive input substitution was rather minor for a major disruption to the water supplies following an earthquake.

there is factor bias). These are especially difficult to evaluate and to model. In the case of a desalination plant, the production of fresh water would be modeled as changes in the water availability constraint. There is little information on the former, and it is unlikely that major desalination plants will be in place in the near term. Therefore, we have not modeled this resilience factor.

9. Business Relocation. This refers to two possibilities. First is the explicit geographic move of existing businesses to avoid having to cope with a water shortage. It is likely to be minimal because a disruption to the California Aqueduct would affect not only LA County but the entire Southern California region, so businesses would have to move beyond that area, and thus incur some significant costs. The second interpretation of business relocation is a change in geographic preferences of water users to avoid the disruption. For example, this would pertain to restaurant customers going to areas other than LA County to avoid being charged for drinking water in the County. Again, there is unlikely to be any nearby geographic relief. Hence, we do not explicitly model this tactic.

10. Production Recapture. This refers to the ability to defer production to a date following the water service disruption. It would involve running production lines overtime or extra shifts. The potential of this resilience tactic is strong for short periods of time following a disruption, because customers are unlikely to abandon their established suppliers or may not be able to use the water in any case because of their own disruption-related slow-downs in production activity. This can be modeled a number of ways. The most straightforward is to increase production activity after the disruption period, thereby extending the time horizon for the study. We utilize recapture factors found in FEMA's (2012) hazard loss estimation tool, HAZUS, and modified in Rose and Lim (2002). Note, however, that these recapture factors are intended for use only up to three months, after which there is likely to be an increasing number of cancelled orders over time. We therefore reduce the recapture factors by 25 percent for each of the subsequent three-month periods. Thus, after the first year, there is no production recapture. Effectively, this means that the recapture factor is only relevant to the 6-month disruption scenario. In the two longer disruption scenarios, recapture cannot be implemented until after the recapture factors have dropped to zero.

Note that most of these various resilience tactics are potentially cost-effective. Conservation more than pays for itself, input substitution is likely to take place under only a limited cost penalty, and production recapture involves only the payment of overtime to workers.

Note also that resilience at the meso and macro levels is exemplified by the workings of markets. Prices reflect the value of goods and services, and increased scarcity drives prices up. Not all price increases represent gouging, as some are justified by such changes in market conditions. The ability of the market to reallocate water to its highest value use is an inherent source of resilience.

The major assumptions and data sources of resilience tactics operative in the case of the Bay Delta disruption are presented in Table 6. The figures are a combination of those computed by water service providers, refinement of water provider data, and data and parameters used successfully in other studies and adapted to this one. Each row in the table represents scenarios with one of the three disruption periods. The first column presents the retail level water shortage assuming that MWD storage was not used. The second column presents the retail level shortage after taking MWD storage and LADWP storage use into consideration.[5] The next five columns present the major assumptions and data sources

[5] The retail level water shortage data we obtained from MWD does not account for economic growth. We have therefore adjusted water demand, and hence the water constraint percentage upward by 1.6 percent to account for economic growth in Year 2014 in the tables and simulations. For Year 2015, we applied 1.6 percent compounded over two years to adjust for economic growth. Note that these adjustments reflect only a tightening of the water constraints relative to demand; the supply of water in acre feet and dollars remains unaffected.

Table 6. Major Assumptions and Data Sources for Calculating LA County Water Availability with and without Resilience

Disruption Period	CA Aqueduct Disruption (no MWD storage water use)[1]	CA Aqueduct Disruption (with MWD and LADWP storage water use)[2,3,4]	Conservation I	Conservation II	Water Unimportance	Water Replenishment	Production Recapture
6-month	Retail Level Shortage (without use of MWD storage): 2013: 79,111 AF (4.35%)	Retail Level Shortage (including use of MWD storage): 2013: 4,410 AF (0.24%)	Analyze effect of LADWP Phase II Conservation (15% conservation) on reducing the demand shortages under the three SWP disruption scenarios.[5]	In addition to LADWP Phase II Conservation, for the 24-month and 36-month disruption scenarios, we assume that 5% additional conservation efforts can be anticipated to further cope with the water supply shortage. The additional conservation effort under the SWP disruption scenarios is calculated as the difference of the conservation levels between LADWP Phase III and Phase II Conservation.[6]	Use ATC-25 water importance factors by sector	Assume that all imported water used for replenishment can be diverted to other uses in the disruption period.[7]	Use recapture factors from HAZUS and Rose and Lim (2002)[8]
24-month	2013: 330,158 AF (18.2%) 2014: 325,634 AF (18.2%)	2013: 88,516 AF (4.9%) 2014: 194,165 AF (10.9%)					
36-month	2013: 330,158 AF (18.2%) 2014: 325,634 AF (18.2%) 2015: 326,223 (18.5%)	2013: 88,516 AF (4.9%) 2014: 194,165 AF (10.9%) 2015: 213,510 (12.1%)					

[1] MWD storage water uses are excluded in this column but included under the separate Storage column.

[2] This column show water constraints taking MWD and LADWP storage water uses in each outage year into account. The MWD storage includes both the water that is drawn from storage and the water that would have been recharged into storage in the Base Case.

[3] LADWP reservoir storage, in addition to MWD storage, can provide 12,000 AF potable and 5,000 AF non-potable water. In addition, we assume that in the 24-month and 36-month disruption scenarios, the reservoir storage is not resumable in the second and third years of disruption after the depletion of the storage in the first year.

[4] LADWP groundwater production cannot be increased even in water supply shortage conditions. This is mainly because 50% of LADWP's wells have been inactivated due to contamination and the remaining active wells are not operated at their full capacity due to the regional contamination issues.

[5] According to the LADWP Emergency Water Conservation Plan (EWCP), City of LA has different conservation phases or stages of actions that can be implemented in response to shortages in water supply (LADWP, 2010). Phase II Conservation, which is implemented with Moderate Water Supply Shortage (roughly corresponding from zero to 15 percent), has been in effect in the City of LA since 2009. Phase II actions can achieve up to 15% conservation (LADWP, 2010). In this resilience analysis case, the 15% conservation is only applied to the total water demand of the LA City.

[6] According to LADWP EWCP, Phase III Conservation measures, which would be implemented with Severe Water Shortage (corresponding from 15 to 20 percent), can achieve up to 20% conservation (LADWP, 2010). Therefore, we assume that in addition to the LADWP Phase II Conservation, the additional conservation potential under the SWP disruption is 5% for both the 24-month and 36-month disruption scenarios. In addition, we assume that the current water rates will be increased by 5% in association with the incremental conservation level based on the assumption of revenue neutral for the water retail suppliers. Different from the resilience case presented in the previous column, we assume that the 5% incremental conservation and the 5% water rates increase are applied to the entire County.

[7] Currently both imported water and recycled water are used by WRD for water recharge purposes. According to WRD, 100% of imported water that is used for water recharge can be diverted for other uses in emergency cases. For recycled water used in groundwater replenishment, it is unlikely that this could be diverted to other non-potable use. Customers using non-potable recycled water typically require designated distribution pipeline (purple pipe) and already have a surplus of treated wastewater supply. Currently, 71,000 AF of water is used by WRD for groundwater spreading, of which 21,000 AF is imported water and 50,000 AF is recycled water. Therefore, we calculated that 21,000AF/71,000AF =29.6% of the water used for groundwater spreading can be diverted to other uses in the outage scenarios based on the WRD data. For seawater barrier, 30,000 AF of water is used by WRD, of which 11,000 AF is imported water and 19,000 AF is recycled water. Therefore, we calculated that 11,000AF/30,000AF =36.7% of the water used for seawater barrier can be diverted to other uses in the outage scenarios. Note that we assume there are no permitting or other regulatory barriers to diverting imported water away from described replenishment activities while still using recycled water in those replenishment activities.

The following example shows in detail how we derived the amount of water recharge use that can be diverted to other uses in Year 2013 in the 24-month disruption case: According to MWD data, the total replenishment demand in LA County in 2013 is 108,382AF. Applying the % of imported water use in groundwater spreading by WRD, 108,382 x 29.6% = 32,057AF imported water is used in the Base Case for water replenishment. In the 24-month disruption case, the shortage of imported water is 12.8% in Year 2013 (this is calculated by dividing the retail level shortage of 105,516 AF by the total demand for imported supply of 825,292 in this year). Therefore, the total imported water that can be diverted from water replenishment use to other uses is: 32,057 x (1-12.8%) = 27,958AF. In addition, according to MWD data, in 2013, seawater barrier demand in LA County in the Base Case is 37,494AF. A similar calculation indicates that in Year 2013 of the 24-month disruption case, with the 12.8% import water shortage, 37,494 x 36.7% x (1-12.8%) = 11,990AF imported water can be diverted from seawater barrier use to other uses.

[8] The recapture factors from these data sources are intended for use only up to three months. We reduce the recapture factors by 25 percent for each of the subsequent three-month periods. In other words, after the first year, there is no production recapture potential.

Table 7. Summary of Water Constraints for Scenarios and Sub-Cases

Disruption Period	No Storage	w/ Storage (Reference Case)[1]	LADWP Phase II Conservation	LADWP Phase II Conservation Plus Incremental Conservation	Water Unimportance	Diversion of Water Replenishment	Production Recapture[2]	Simultaneous Resilience[3]
6-month	2013: 4.35%	2013: 0.24%	2013: 0.00%	2013: 0.00%	2013: 0.00%	2013: 0.00%	Adjust results rather than input constraints	2013: 0.00%
24-month	2013: 18.2% 2014: 18.2%	2013: 4.9% 2014: 10.9%	2013: 0.0% 2014: 5.3%	2013: 0.0% 2014: 0.2% (5% water rate increase in 2014)	2013: 1.9% 2014: 4.2%	2013: 2.7% 2014: 8.9%		2013: 0.0% 2014: 0.0% (5% water rate increase in 2014)
36-month	2013: 18.2% 2014: 18.2% 2015: 18.5%	2013: 4.9% 2014: 10.9% 2015: 12.1%	2013: 0.0% 2014: 5.3% 2015: 6.4%	2013: 0.0% 2014: 0.2% 2015: 1.3% (5% water rate increase in 2014 and 2015)	2013: 1.9% 2014: 4.2% 2015: 4.7%	2013: 2.7% 2014: 8.9% 2015: 10.1%		2013: 0.0% 2014: 0.0% 2015: 0.0% (5% water rate increase in 2014 and 2015)

[1] All the other resilience tactics presented in the following columns are assumed to be implemented after the use of storage).

[2] See Appendix Table B11 for sectoral levels.

[3] Note that all the resilience adjustments in the previous columns are not additive. When we evaluate the simultaneous effects of implementing all these resilience tactics together, LADWP Phase II Conservation and the 5% additional conservation under the Bay Delta disruptions are first considered to reduce the water constraints after storage use. Next we further reduce the water constraints by taking into consideration the diversion of replenishment water use to other uses. If there are any remaining demand shortages after conservation and replenishment water diversion, water importance factors and production recapture would be applied. However, the calculation indicates that after the use of storage water, conservation, and replenishment water division, there would be zero water constraints. Therefore, the only effect we simulate for the simultaneous case is the 5% water rate increase associated with the 5% incremental conservation.

we use to compute the direct effect of alleviating the disruption by the relevant resilience tactics: conservation, water unimportance, input substitution, recycling, water replenishment and production recapture factors. Table 7 presents the water constraints for all scenarios and sub-cases with the assumption of normal-year hydrological and weather conditions. Extreme year constraint values are presented below.

VI. SIMULATIONS

A. Scenarios

In this study, we examine several major scenarios related to the timing of the disruption, hydrologic conditions, resilience, rationing, pricing, and restoration of service.

Hydrologic Conditions:

The characteristics of our "Reference Case" were developed by MWD, LADWP and others. They are based on a distribution of historical weather/hydrologic conditions and use actual estimated storage levels for January 1, 2012. In addition to the Reference Case, we will also run simulations for extreme dry weather conditions and simulations excluding storage. Comparing the impact results of the Reference Case and the case excluding storage use enables us to evaluate storage as a resilience tactic and to expressly measure the value of storage capacity.

Time Periods:

The time periods for water supply disruptions from the California Aqueduct are 6, 24, and 36 months. We run the model for the appropriate time periods, and report the results on an annual basis. The 24-month disruption is our Reference Case.

Customers Affected:

- All customers (Reference Case)
- Residential customers only

Pricing:

- Price of water free to find its market equilibrium (Reference Case). This allocates water to highest value uses.
- Price of water held constant

Rationing:

- Rationing through pricing. A constraint is placed on overall water use and market responses determine water use (Reference Case)
- Rationing through decree either across the board or for household customers only

Resilience Analysis:

Each of the five operative resilience factors identified in Section IV are simulated individually and together. Note that there are some overlaps between the resilience factors, so that the sum of the individuals is not equal to them all being implemented at the same time. Our Reference Case includes water storage.

Reconstruction Paths:

- Discrete jump, i.e., the entirety of the Bay Delta damage must be repaired before water is allowed to flow through the California Aqueduct (Reference Case)
- Linear resumption of service

Other Assumptions:

- Limited technological change
- Current water utilization levels
- Current water prices (except in scenarios where the price of water is allowed to vary)
- Use of average rather than marginal water rates (since we are analyzing a major rather than a marginal disruption)
- Absence of dynamic considerations relating to productivity improvements associated with investment losses (due to the disruption) or investment gains (associated with repair and reconstruction)

B. Water Constraint Levels for Various Scenarios

Appendix B presents how we compute the water constraint levels for the Reference Case (the case that includes storage water use) and for the various resilience cases for the three disruption scenarios. In Appendix B tables, we present the retail water shortage in both quantity terms and percentage terms for different scenarios and subcases. The water constraint percentages are summarized in Table 7.

C. Macroeconomic Impact Analysis

We examine the effects of the water supply disruption on major macroeconomic indicators: Net output (Gross Domestic Product for the County), gross output (sales revenue), employment and prices. Note that these are market-based economic indicators of most interest to policymakers. They include impacts on businesses (gross and net output and their share of income) and on households (employment and their share of income). We also compute measures of lost economic welfare (well-being) of households from the loss of utility of decreases in water use, and the reallocation of their spending. This is distinct from the formal GDP accounts and provides a separate perspective from that of households' lost income and employment.

Macroeconomic impacts can be very complex. First, water used by businesses is extensive and goes far beyond the obvious uses in food processing, restaurant drinking and dishwater, and various purification processes. Many businesses use water for cooling and vacuum pumps. Additionally, production creates extensive indirect demands for water upward along successive stages of supply chains. If a firm has to cut back its production because of disruption of its water supply, it will demand fewer inputs. This in turn reduces the production of all of its suppliers, who in turn reduce their orders through a successive round of upstream demands. Moreover, lower production levels at each round translate into lower income payments, which then translate into a further dampening of economic activity from a decrease in consumer and investment spending.

Water disruptions also magnify themselves downstream along successive supply chain stages in a similar manner. The lack of availability of an input will cause its users to reduce their output, even if they have a very low demand for water in the first place and can make up for the entire shortfall through various resilience tactics. The sum total of all these chain reactions is referred to as multiplier effects when only considering output quantities, as in an I-O model, and general equilibrium effects when both price and quantity responses are taken into account, as in a CGE model (Rose, 1995; Dixon and Rimmer, 2001).

VII. RESULTS

The results of our simulations are contained in the text, tables and figures below, as well in Appendix C. We present them in three groupings: 6-, 24-, and 36-month disruption cases. In each, we present "Reference Case" results and results that include various types of resilience individually and together (see Appendix B for details on resilience adjustments). We also present results of sensitivity tests relating to assumptions about water prices (flexible vs. fixed) and applicability of restrictions on water availability (all sectors vs. residential only). A summary of the characteristics of these alternative scenarios is presented in Table 8. Note that our Reference Case is consistent with Scenario S1A:

- flexible water pricing in the context of market conditions
- aggregate water constraint (no sectoral rationing)
- 24-month disruption
- water storage included, but no other resilience

For disruptions lasting more than one year, we present results for each applicable year, as well as a summary total. Note that the Reference Case results are presented for a recovery path that assumes no incremental repair and reconstruction of the infrastructure damage affecting the flow of water through the California Aqueduct, so that the full outage is felt during the relevant time period, and then the water flow returns to normal at the end of the period. If a linear recovery path is assumed, the impacts would be one-half the size of those reported below.[6]

TABLE 8. LA WATER VULNERABILITY STUDY SIMULATION SCENARIOS

Scenario	Pricing	Rationing
1A	flexible	aggregate; not sectoral
1B*	flexible	household sector only
2A	fixed	aggregate; not sectoral
2B*	fixed	household sector only
3	fixed	equaproportional across sectors
4	fixed	sector constraints mimic S1A water demand

*B refers to the variant where the constraint only applies to households (residential customers).

[6] The "one-half" adjustment stems from the geometry of comparing the rectangular shape of the "full outage until repaired" path with the triangular path of the linear resumption of services path.

A. Reference Case

1. 24-Month Disruption Reference Case

Our main case is the 24-Month Disruption. In this disruption scenario, LA County would lose over 300,000 AF of imported water from the State Water Project each of 2013 and 2014. Aggregate results for Year 2013 are presented in Table S1A/'13,[7] and sectoral results presented in Appendix C. The results in each table pertain to impacts on Gross Domestic Product (GDP), employment, welfare (well-being), and prices.

The first case presented in Table S1A/'13 is for a 24-month Bay Delta Disruption of California Aqueduct Water supplies if there were *no water storage*. The disruption level for this case would be a reduction of water availability of 18.2 percent. Of course, this is a stylized case because stored water (both surface reservoirs and underground), does exist and is available whether there is a disruption or not. We run this simulation to compare to the Reference Case below to gauge the value of ground water and reservoir water holdings in LA County. In effect, they are a source of inherent resilience, i.e., they are already built into the system.

Our Reference Case results for the 24-Month Disruption are presented in the second row of Table S1A/'13. Allowing for *storage* reduces the water supply disruption level to 4.9 percent in the Year 2013. Running this simulation through our computable general equilibrium (CGE) model yields estimates of a 4.19 percent decrease in GDP and a 4.03 percent decrease in employment. This represents a loss of $23.1 billion in GDP and 228.1 thousand jobs in 2013. The change in the market equilibrium price of water is projected to be 12.39 percent, stemming from the increased water scarcity. The change in the overall price level in the economy, however, would be only 0.04 percent (see Appendix C tables), owing to the fact that water is only a small proportion of production costs in most sectors and because the decline in overall economic activity places downward pressure on prices. Note that if we do not include the 12.39% increase in the price of water, the economy-wide price increase averages only 0.01 percent.

We can now compare the results in rows 1 and 2 of Table S1A/'13 to gauge the value of stored water, which is essentially the difference in the results of the two scenarios. First, the existence of groundwater and reservoir water reduces the potential disruption level from 18.2 to 4.9 percent. This has the effect of reducing the estimated decline in GDP from $88.6 billion to $23.1 billion, or a saving of $65.5 billion due to water storage. On the employment side, the existence of storage reduces the potential loss from 876.2 thousand jobs to 228.1 thousand jobs, or a savings of 648.1 thousand jobs. Thus, overall water storage is the major source of resilience in the LA County water system.

Table S1A/'13 does not list *conservation* as a resilience option. Due to recent drought conditions Phase II conservation is already in place. There are also more intense phases of conservation in case of emergency such as the Bay Delta disruption of the California Aqueduct supply. Both of these cases would reduce demand for water sufficiently to offset the potential supply disruption. This means that there are no negative economic impacts if conservation practices are put into place in 2013 for our Reference Case. We should note, however, that this overall economic finding is based on the assumption that water conservation pays for itself. For example, any increase in expense from using less water is offset entirely from the reduced expenditure of water. If conservation involves some net expense, then there will be a negative impact, though likely far smaller than those presented for our Reference Case. Also, going to the enhanced version of Phase II conservation assumes a 5% increase in water prices.

[7] The notation refers to Scenario number/year.

Taking into consideration *water unimportance*, the fact that certain sectors can operate to some extent without water, the water supply disruption level is reduced to 1.9 percent. This yields a projected decline in GDP of only 1.64 percent and the decline of employment of only 1.58 percent. The projected water price increase would be only 4.62 percent.

Diversion of replenishment use of water as a resilience tactic would decrease the Reference Case water supply constraint from 4.9 percent to 2.7 percent. This would result in a GDP percentage change of 2.3 percent and an employment change of 2.2 percent. The water price change would be 6.63 percent.

Note that *production recapture* is not relevant in the 24-month disruption because, by the time water is restored customers for the goods that could not be delivered have shifted to other suppliers. This tactic is only relevant to the 6-month disruption.

The simultaneous application of all applicable forms of resilience would also overcome the disruption.

The water price changes are presented in Figures S1A/'13 and '14. Results indicate the beginning of an exponential trend in water prices and hence value, as the severity of the disruption increases. The 55.91 percent increase in prices associated with the no water storage case might be an untenable outcome. This might warrant some capping of price increases or even keeping water prices at a pre-disruption level. Of course, such interference with the market can lead to inefficiencies and cause even greater declines in GDP and employment. Here, policymakers are faced with an important equity-efficiency tradeoff. The preferred solution to most economists is to let prices adjust freely in order to represent the value of scarce water and hence provide the best signal for their efficient allocation, and then taking any concerns for the well-being of lower income groups into account by providing them with subsidies or rebates. However, this equity-efficiency tradeoffs are likely to be moot from the results of our analysis, because the fixed-price policies would yield lower negative impacts than the flexible-price policies.

Sectoral impacts of the Reference Case for Year 2013 are presented in Appendix C, Table S1A2/'13/Sectoral. First, water demand levels are projected to vary by sector. They are not exactly 4.9 percent for all but the Water Utilities sector. Some sectors decrease their demand for water even more than 4.9 percent due to a combination of decreases in the demand for their products and the ability to substitute away from higher priced water without a great cost penalty in doing so. The sectors with the greatest percentage changes in water use are Agriculture, Mineral/Metal Processing, Motion Picture and Manufacturing. The sectors with the lowest percentage reductions are Schools, Government, Colleges/Universities, and three Medical sectors. Similarly, GDP and employment impacts vary by sector. Sectors that have a relatively high demand for water per unit of output and for which it is difficult to substitute away from water will tend to suffer greater production declines than other sectors. Thus, the sectors with the largest economic losses are the ones mentioned above that decrease their water use the most. The final column of Appendix C, Table S1A2/'13/Sectoral includes sectoral price changes. The output price change for the Water sector is 12.39 percent. Price changes in the various sectors vary, again depending on the relative water intensity of production and changes in demand for their output. The sectoral price changes range from -0.02 to 0.08 percent. Again, the aggregate price level in the economy is estimated to change at a level of only 0.04 percent.

Simulations similar to those for Year 2013 are performed for 2014 as well and are presented in Table S1A/'14. The main distinction is that the reduction of water availability for the Reference Case rises from 4.9 to 10.87 percent, owing to the reduction in stored water, which now makes additional conservation operative. The impacts for this and other cases in the table increase accordingly. With respect to GDP and employment impacts, they increase linearly, in aggregate and sectoral terms, with the increase in the severity of the constraint. However, the price increase begins a slightly exponential trend. The sectoral impacts for Year 2014 are presented in Appendix C, Table S1A2/'14/Sectoral.

Table S1A/'13. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, with and without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
No Water Storage	18.2	-16.10	-15.48	55.91	-14.72
Storage (Reference Case)	4.9	-4.19	-4.03	12.39	-3.83
Water Unimportance	1.9	-1.64	-1.58	4.62	-1.47
Diversion of Replenishment Use	2.7	-2.30	-2.21	6.63	-2.10
Production Recapture	n.a.	n.a.	n.a.	n.a.	n.a.
Simultaneous Resilience	0	0	0	0	0

Table S1A/'14. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, with and without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2014

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
No Water Storage	18.2	-16.09	-15.46	55.85	-14.71
Storage (Reference Case)	10.9	-9.44	-9.08	29.89	-8.63
Phase II Conservation	5.3	-4.52	-4.35	13.43	-4.14
Phase II Conservation Plus	0.2	-0.17	-0.17	0.48	-0.15
Water Unimportance	4.2	-3.62	-3.49	10.43	-3.25
Diversion of Replenishment Use	8.8	-7.64	-7.34	23.61	-6.98
Production Recapture	n.a.	n.a.	n.a.	n.a.	n.a.
Simultaneous Resilience	0	0	0	0	0

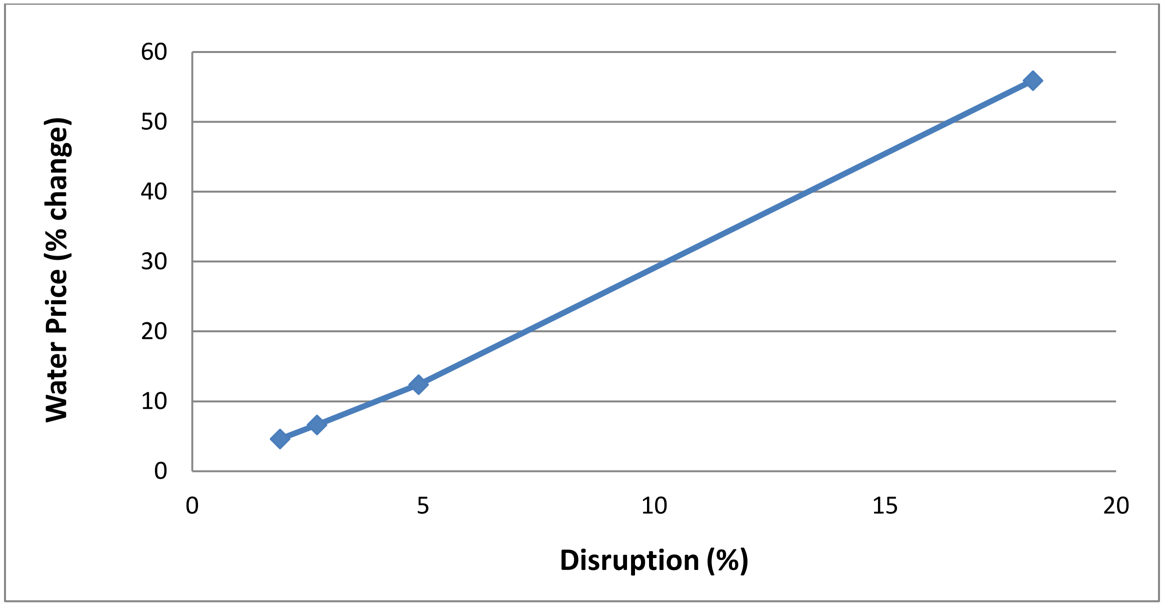

Figure S1A/'13. Price Impacts of Water Supply Disruptions on the LA County Economy (flexible price), 2013

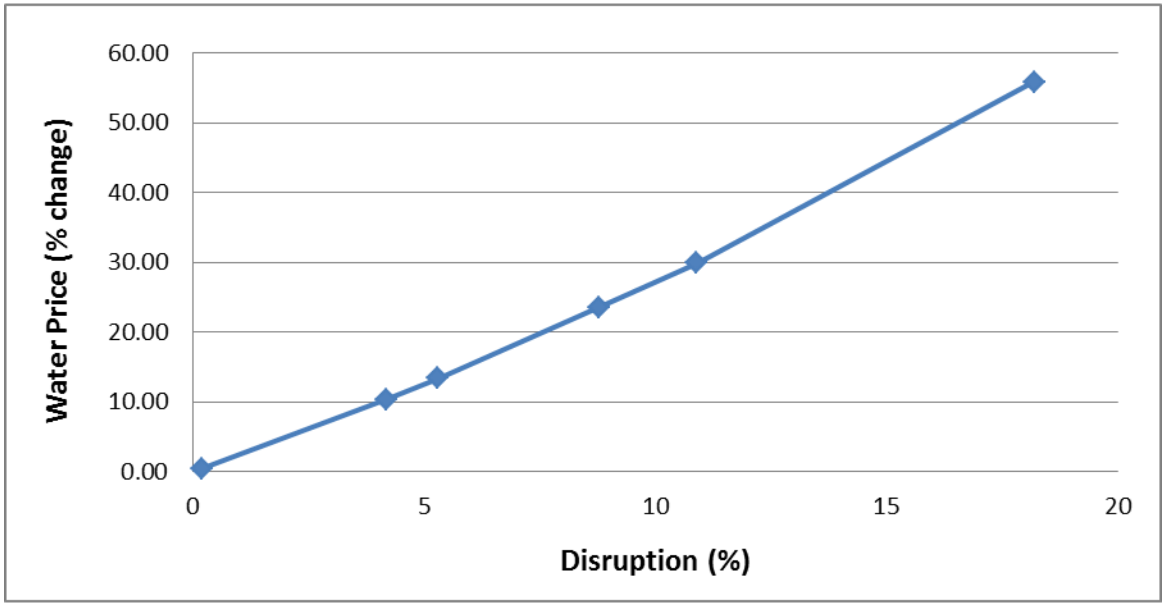

Figure S1A/'14. Price Impacts of Water Supply Disruptions on the LA County Economy (flexible price), 2014

Totals for the 24-month case are presented in Table S1A/'13 & '14 in percentage terms and Table S1AL/'13 & '14 in terms of levels of change. The negative impacts for a 24-month shutdown could be as large as $75 billion in GDP and nearly 750 thousand job-years of employment.

Note that these results represent an upper bound on the impacts because they do not take resilience into account aside from the built-in resilience of water storage. On the other hand, the sum total of all possible resilience factors could possibly reduce losses to zero in Year 2013 and to very small amounts in 2014.[8] However, this assumes all resilience tactics will be implemented to their maximum extent. The likely impact will fall somewhere in-between, depending on the effectiveness of resilience.

2. 6-Month Disruption Case

For the 6-Month Case, the Reference Case water disruption level is at a much smaller constraint level of 0.24 percent, owing to the greater ability of the water system to adjust and for the fact that the disruption covers only half of one year (see Table B3). Any minimal amount of resilience is likely to bring the economic impacts to zero. At the same time, if stored water were not available, the negative impacts would be almost as high as those for the 24-month Reference Case (with storage) for 2013.

3. 36-Month Disruption Case

The first two years of this case are essentially the same as for the 24-Month Case. The third year, however, is likely to yield more negative impacts since the constraint increases from 10.9 to 12.1 percent and because most types of resilience will not be as effective because of the longer duration. The results of this case are presented in Table S1A/'13 & '14 & '15 in percentage terms and Table S1AL/'13 & '14 & '15 in terms of levels of change. The negative impacts for a 36-month shutdown could be as large as $133 billion in GDP and over 1.3 million job-years of employment.

B. Alternative Rationing and Pricing Strategies

In coping with the disruption, water service agencies have some policy tools they can use to attain alternative objectives such as keeping regional economic losses to a minimum, easing the administrative burden, or promoting fairness. For example, the price of water can be held constant or allowed to reach its market equilibrium, where prices are considered to reflect the true value of this key resource that has now become even more scarce. Holding the price constant is administratively easier and will help avoid significant market price increases that will have disproportionately greater impacts on small businesses and lower income groups. On the other hand, letting the price of water achieve its market equilibrium will lead to a more efficient allocation of water resources, as well as other resources in a general equilibrium sense, and will likely reduce overall negative economic impacts, all other things being equal.

Similarly, the manner of water rationing can attain alternative objectives. Confining the disruption to residential household demand is likely to minimize the negative impacts on typical economic indicators such as GDP and employment. Otherwise, requiring equaproportional cutbacks in water demand is considered to be more fair, but, all other things equal, more likely to lead to more negative impacts than if

[8] In the simultaneous resilience simulation, although the water disruption is potentially zero, moving to the enhanced version of Phase II conservation assumes a 5% increase in water prices. However, since in the Reference Case, it is assumed that the water price is free to find its market equilibrium, a 5% water rate increase on the input side would not result in any impacts on the equilibrium water price on the output side, and thus does not have any impacts on the economy. Note that an increase in the water rate will affect its equilibrium price if it is applied to cases where the price of water is assumed to be fixed.

Table S1A/'13 & '14. Total Two-Year Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-14 (percentage changes)

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
Storage (Reference Case): Year 2013	4.9	-4.19	-4.03	12.39	-3.83
Storage (Reference Case): Year 2014	10.9	-9.44	-9.08	29.89	-8.63
Storage (Reference Case): Weighted Avg	n.a.	-6.84	-6.57	n.a.	n.a.

Table S1AL/'13 & '14. Total Two-Year Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-14 (changes in levels)

Case Description	Disruption Level (% change)	GDP (change) (B 2013$)	Employment (change) (job-years)	Water Price (% change)	Welfare (B 2013$)
Storage (Reference Case): Year 2013	4.9	-23.08	-228,125	12.39	-17.83
Storage (Reference Case): Year 2014	10.9	-51.99	-513,910	29.89	-40.18
Storage (Reference Case): Total	n.a.	-75.07	-742,035	n.a.	n.a.

Table S1A/'13 & '14 & '15. Total Annual Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-15 (percentage changes)

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
Storage (Reference Case): Year 2013	4.9	-4.19	-4.03	12.39	-3.83
Storage (Reference Case): Year 2014	10.9	-9.44	-9.08	29.89	-8.63
Storage (Reference Case): Year 2015	12.1	-10.52	-10.11	33.80	-9.62
Storage (Reference Case): Weighted Avg	n.a.	-8.09	-7.77	n.a.	n.a.

Table S1AL/'13 & '14 & '15. Total Annual Impacts of Water Supply Disruptions on the LA County Economy without Resilience (Reference Case: Flexible Price and Economy-Wide Rationing), 2013-15 (changes in levels)

Case Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Water Price (% change)	Welfare (B 2013$)
Storage (Reference Case): Year 2013	4.9	-23.08	-228,125	12.39	-17.83
Storage (Reference Case): Year 2014	10.9	-51.99	-513,910	29.89	-40.18
Storage (Reference Case): Year 2015	12.1	-57.93	-572,669	33.80	-44.77
Storage (Reference Case): Total	n.a.	-133.00	-1,314,704	n.a.	n.a.

the market rations the disruption through pricing in response to an overall constraint on water availability. In this analysis we simulate the various combinations of water pricing and rationing presented in Table 8.

The results of our alternative pricing/constraint simulations are presented in Tables 9 and 10 for the Year 2013. We present eight simulations, but with each referring to the Reference Case (water disruption with access to MWD and LADWP water storage) for the 24-month scenario.

The initial Scenario S1A consists of a flexible (market) price and general supply-side constraint, with no sector-specific rationing. It is presented in the first row of Table 9, and simply repeats our previous Reference Case for the Year 2013. In comparison Scenario S2A keeps the price of water constant with the general constraint. The reader will note that the GDP and employment impacts for this scenario are actually lower than those for Scenario S1A, owing primarily to the direct and indirect stimulus effect of muting any price increase outweighing the resource misallocation effect of not letting the water price attain its market equilibrium. From Table 10, we see that this can translate into a saving of nearly $10 billion in GDP and 90,000 jobs in the Year 2013 in comparison with Scenario S1A.

The greatest reduction in losses can be attained if the disruption is limited to the residential (household) sector only. In this instance, Scenario 1B (flexible price) outperforms Scenario 2B (fixed price), though in both cases, the overall GDP and employment changes are less than one percent. Scenario 1B represents more than a ninety percent improvement over the negative impacts of our Reference Case Scenario (1A). Note, however, that the results measure only market economic indicators, and do not include the fact that a large amount of inconvenience is shifted to the residential sector.

Aside from a general overall constraint, there are two other possibilities. Scenario S3 presents the results for equaproportional, or across-the-board, rationing among all sectors (including government and households), and yields a percentage decline in GDP of 2.20 percent and a decline in employment of 2.11 percent in the Year 2013. Both of these are just slightly more than half of their values for the Reference Case Scenario (1A). Another popular alternative is to keep the price of water constant, but to mimic the rationing of the market solution in S1A. This simulation is presented as S4, and yields slightly more negative results than S3. The reason is that the equaproportional case shifts more of the burden to government and households, where the latter does not show up in the economic accounts.

Counterparts to S3 and S4 for the case of flexible water pricing are not presented. The case of flexible pricing and rationing that mimics the market solution of S1A, of course, yields identical results to S1A. The case of equaproportional rationing and flexible water pricing constrains our model to the point that it cannot yield a unique solution. However, this is not likely to be a serious case for policy discussion, because equaproportional rationing defeats the purpose of allowing prices to reach their market equilibrium.

Note that the policy combination of fixed water price and general constraint of S2A makes it very attractive, in that it provides a lower negative economic impact, while likely being more equitable than S1A. Scenarios S1B and S2B are also relatively more attractive on the surface because they are projected to result in the lowest negative impacts on GDP and employment. However, this must be balanced against potential complaints from residential customers on whom the entire burden is imposed.

C. Alternative Hydrological Conditions

We also evaluate the effects of alternative hydrological conditions over the 2013-2015 simulation periods on the impacts of water supply disruption. For the normal-year cases presented in Section VII.A., MWD model runs are performed for 83 individual hydrological sequences extracted from the historical

Table 9. Total Annual Impacts of Water Supply Disruptions on the LA County Economy for Alternative Water Pricing and Rationing Scenarios (percentage changes), 2013

Scenario Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
S1A - Storage (Reference Case) flexible price/general constraint	4.9	-4.19	-4.03	12.39	-3.83
S2A - Storage (Reference Case) fixed price/general constraint	4.9	-2.44	-2.34	0.00	-2.23
S1B - Storage (Reference Case) flexible price/HH only constraint	4.9	-0.39	-0.40	-1.14	-0.32
S2B - Storage (Reference Case) fixed price/HH only constraint	4.9	-0.73	-0.72	0.00	-0.62
S3 - Storage (Reference Case) fixed price/equaproportional	4.9	-2.20	-2.11	0.00	-2.02
S4 - Storage (Reference Case) fixed price/mimic S1A	4.9	-2.72	-2.61	0.00	-2.44

Table 10. Total Annual Impacts of Water Supply Disruptions on the LA County Economy for Alternative Water Pricing and Rationing Scenarios (changes in levels), 2013

Scenario Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Welfare (B 2013$)
S1A - Storage (Reference Case) flexible price/general constraint	4.9	-23.08	-228,125	-17.83
S2A - Storage (Reference Case) fixed price/general constraint	4.9	-13.43	-132,529	-10.38
S1B - Storage (Reference Case) flexible price/HH only constraint	4.9	-2.17	-22,649	-1.48
S2B - Storage (Reference Case) fixed price/HH only constraint	4.9	-4.02	-40,877	-2.90
S3 - Storage (Reference Case) fixed price/equaproportional	4.9	-12.12	-119,691	-9.39
S4 - Storage (Reference Case) fixed price/mimic S1A	4.9	-14.98	-147,925	-11.37

hydrological data for the period 1922-2004. Then the average water constraint levels during the disruption years are computed based on the results of the 83 individual runs. For the sensitivity analysis on hydrological conditions, MWD model results for two runs assuming extended dry periods for 2013-2015 are used: 1) severe hydrologic condition case, which assumes 1989-1991 hydrological conditions (the single worst 3-year hydrology trace or sequence) applies to 2013-2015; and 2) moderately unfavorable hydrologic condition, which assumes 1976-1978 hydrological conditions, representing a tenth percentile worst hydrology trace or sequence, apply to 2013-2015.

These alternative hydrological conditions are translated into water disruption constraints for our model in Table 11. Effectively they more than double the previous 4.9 percent Reference Case constraint for Year 2013. Their economic impacts are presented in Tables 13 to 16. For the Year 2013, the moderate and severe cases result in price increases of 29 and 32 percent, respectively. The GDP declines are projected at 9.37 percent and 10.10 percent, respectively, and the employment declines only slightly lower. However, it is very important to note that at these higher water constraint levels, even the application of all resilience tactics will not eliminate the disruption. Referring to Table 11, the constraint in Year 2014 would still be 1.4 percent for the moderately severe case and 3.5 percent for the severe case. This means that for the latter, the negative impacts will be more than two-thirds of the Reference Case impacts, or a loss of $35 billion of GDP and 350,000 job-years.

In addition, all of the scenarios we analyze (both those presented in Section VII.A. and the ones with alternative assumptions on hydrological conditions) use the actual level of 2012 MWD storage in the Reference Case analysis. The actual 2012 storage levels could be described as "good," but definitely not full (maximum). With full initial storage conditions, it is likely that all of the shortage impacts would be eliminated for the Reference Case for the assumption of normal-year hydrological conditions. On the other hand, the additional scenarios that did not include the use of storage water, are effectively the same as having zero storage in the event of the disruption. A scenario with "low" initial storage levels would fall somewhere between these two cases—the Reference Case and the case of zero storage. A comparison of cases of zero water storage and our Reference Case for 6-, 24- and 36-month scenarios are presented in Table 12 for the Year 2013. Looking at the 24-month case, the disruption level for no storage, and no other types of resilience, are nearly four times greater than the storage case and thus so are the results for the GDP and employment. If stored water were not available, the negative impacts for even the 6-month disruption would be almost as high as those for the Reference Case (with storage) for 2013. For the 24-month case, the price increase is projected to be more than four times as great, at a level of 55.91 percent. Even if water rates are held constant this price still provides an indication of the value of water under extreme scarcity.

Again, overall the results for our model show a roughly linear relationship between water disruption levels and impacts on GDP, employment and welfare over the relevant range of our analysis. Hence the reader can readily use our Reference Case results as a base and make some quick calculations of impacts for disruption levels deemed to be appropriate for other types of considerations.

Table 11. Water Constraints for Alternative Hydrologic Condition Cases, with and without Resilience, 24-month Disruption Scenario, 2013 and 2014

Case Description	Water Constraint (%)					
	Normal-Year Case		Moderately Unfavorable Hydrologic Condition Case		Severe Hydrologic Condition Case	
	2013	2014	2013	2014	2013	2014
No Water Storage	18.2	18.2	24.6	23.2	27.8	29.8
Storage (Reference Case)	4.9	10.9	10.6	16.0	11.4	21.2
Phase II Conservation	0	5.3	5.2	10.4	6.1	15.8
Phase II Conservation Plus	0	0.2	0.2	5.3	1.1	10.8
Water Unimportance	1.9	4.2	4.1	6.1	4.4	8.1
Diversion of Replenishment Use	2.7	8.8	8.4	13.9	9.3	19.3
Production Recapture	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Simultaneous Resilience	0	0	0	1.4	0	3.5

Table 12. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, with and without Storage (Reference Case: Flexible Price and Economy-Wide Rationing), 2013

Case Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)	Welfare (% change)
No Storage (6-month)	4.35	-3.79	-3.64	10.92	-3.40
Storage (6-month)	0.24	-0.20	-0.19	0.57	-0.19
No Storage (24-month)	18.2	-16.10	-15.48	55.91	-14.72
Storage (24-month)	4.9	-4.19	-4.03	12.39	-3.83
No Storage (36-month)	18.2	-16.10	-15.48	55.91	-14.72
Storage (36-month)	4.9	-4.19	-4.03	12.39	-3.83

Table 13. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (percentage changes), 2013

Scenario Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	4.9	-4.19	-4.03	12.39
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	10.6	-9.37	-9.02	29.03
Severe hydrologic condition (Reference Case) flexible price/general constraint	11.4	-10.10	-9.72	31.59

Table 14. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (percentage changes), 2014

Scenario Description	Disruption Level (% change)	GDP (% change)	Employment (% change)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	10.9	-9.44	-9.08	29.89
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	16.0	-14.30	-13.75	47.31
Severe hydrologic condition (Reference Case) flexible price/general constraint	21.2	-19.28	-18.55	68.50

Table 15. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (level change), 2013

Scenario Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	4.9	-23.08	-228,125	12.39
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	10.6	-51.61	-510,549	29.03
Severe hydrologic condition (Reference Case) flexible price/general constraint	11.4	-55.62	-550,197	31.59

Table 16. Total Annual Impacts of Water Supply Disruptions on the LA County Economy, Alternative Hydrological Conditions (level change), 2014

Scenario Description	Disruption Level (% change)	GDP (B 2013$)	Employment (job-years)	Water Price (% change)
Normal-year hydrologic condition (Reference Case) flexible price/general constraint	10.9	-51.99	-513,910	29.89
Moderately unfavorable hydrologic condition (Reference Case) flexible price/general constraint	16.0	-78.71	-778,703	47.31
Severe hydrologic condition (Reference Case) flexible price/general constraint	21.2	-106.14	-1,050,233	68.50

VIII. CONCLUSIONS

This study provides a range of estimates for the economic impacts of a disruption of the California Aqueduct on the Los Angeles County economy. A range is needed to account for the variability and the key assumptions and parameters related to weather, hydrology, recovery patterns and the effectiveness of resilience.

For a 24-month total disruption of the California Aqueduct, Los Angeles County would have an expected shortage of 4.9 percent in 2013 and a 10.9 percent in 2014 given current levels in storage and a historical range of potential hydrologic and climatic conditions. This shortage would increase to 10.6 and 16.0 percent under moderately unfavorable hydrologic and climatic conditions and to 11.4 and 21.2 percent under severe hydrologic and climatic conditions. The absence of storage would increase the shortage to nearly 30 percent by 2014 under the worst case scenario.

The basic conclusions of the study are:

- The 6-month shutdown of the California Aqueduct in normal years relating to weather and hydrology conditions and reasonable levels of resilience, primarily conservation and production recapture, will result in no negative economic impacts.
- For the Reference Case (flexible water pricing, economy-wide constraint and use of storage water), a 24-month shutdown of the California Aqueduct could lead to a total two-year loss of 742,000 job-years of employment, $75 billion of GDP, and $135 billion of sales revenue for businesses in LA County. Reasonable levels of several types of resilience could reduce this outcome significantly.
- Under the most adverse hydrological conditions, the negative impacts for a 24-month shutdown could be as large as $160 billion of GDP and 1.6 million job-years of employment.
- For the Reference Case, a 36-month shutdown of the California Aqueduct could lead to employment losses of 1,315,000 job-years, GDP losses of $133 billion, and total revenue losses of $240 billion over the three years. Even with a major resilience effort, the losses would likely be in the tens of thousands of job-years and tens of billions of losses in GDP and sales revenue.
- The negative impacts of the supply disruptions analyzed would be half the size of those noted above if the restoration of California Aqueduct supplies were to proceed incrementally in a linear fashion, rather than the Reference Case assumption that no water would flow from it to LA County until the Bay Area levee system was repaired.
- The negative impacts of the supply disruptions could be reduced significantly if water prices were held constant during the disruption.
- Existing water storage is able to mute the potential impacts considerably. Maximum potential losses would be doubled for the 24-month and 36-month scenarios with zero storage, and even more in the cases of adverse hydrological conditions, such as extreme dry years.
- Resilience tactics other than water storage can reduce losses considerably if implemented close to their maximum potential. This includes conservation, water unimportance, diversion of replenishment water for other uses, and production recapture. Under adverse hydrological conditions, however, even the full implementation of these tactics would still result in GDP losses in the tens of billions of dollars and employment losses in the tens of thousands of job-years. Moreover, these factors have limited capability to deal with the consequences of a catastrophic scenario during an extended drought period.

- Los Angeles County can become less vulnerable to water disruptions in two major ways. One is to have the major federal-state initiative to improve the Bay Area conveyance system to make it more capable of withstanding a major earthquake. The ongoing Bay Delta Conservation Plan process is proposing such an improvement. The other way is to continue to invest in storage and alternative water supply systems. For example, Orange County recently commissioned the building of a small desalination plant. In addition to existing approaches to the problem, and the potential of both inherent and adaptive resilience, LA County also needs to consider a broad range of alternatives. At the same time, water agencies in LA County should continue to be vigilant in protecting their groundwater and reservoir supplies. Overall, the key to maintaining water reliability is a diverse portfolio of water supply sources.

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Appendix A. LA County Water Account and I-O Table Modification

I. Construction of LA County Water Account

We have obtained water supply and demand data from Metropolitan Water District (MWD) and Los Angeles Department of Water and Power (LADWP). Data on water storage, ground water, and conservation (from MWD for the baseline condition) are incorporated as well.

The following steps and assumptions are used to put together the water service account (please refer to Table A1 for more details):

a. LADWP Water Service Account:
   i. A sample of FY 2010/2011 water demand data (in Acre Feet, AF) by 4-digit SIC sector for Los Angeles City are obtained from LADWP. These 4-digit SIC data are translated to the 29 CGE sectors.
   ii. Sectoral weights for LA City for the 29 CGE model sectors are computed based on the data in step a.i. Weights are calculated separately for the Industrial sector and the Commercial sector based on the step a.i. data.
   iii. We applied the weights calculated in Step a.ii to the MWD forecast data on sectoral water demand (our control totals) for Year 2013 for City of LA to get the Acre Feet water demand for each CGE sector.
   iv. Projected retail water rates (prices) for 2012/13 (see the detailed calculation in Table 4)) are used to convert the demand in Acre Feet to million dollars. For Ag sectors, the Industrial water rate is used.

b. MWD (excluding LADWP) Water Service Account:
   i. The 2013 Base Case projected non-residential water demand (in Acre Feet) is disaggregated among CGE producing sectors using the weights computed based on the LADWP SIC data.
   ii. Sectoral water demand calculated in step b.i is adjusted for water efficiency (i.e., baseline water use efficiency to achieve 20x2020) based on the data provided by MWD.
   iii. Projected LADWP water rates (prices) data for 2012/13 are used to convert water demand by sector in Acre Feet to million dollar values. For Ag sectors, the Industrial water rate is used again.

c. LA County Total Water Service Account (total retail sales):
   i. County totals are derived as the sum of LADWP and residual MWD (excluding LADWP) Demand. The Water sector control total is $3.106 billion, which represents the total production/sales of LA County retail water deliveries.

d. Domestic import of water:
   i. We consider water delivered by MWD and related sources to be domestic imports (from elsewhere in California and the rest of the U.S.) into the County. The value of domestic water import is calculated to be $1.54 billion using the projected Full Service Treated wholesale price for Year 2013 obtained from MWD.

Table A1. Calculation of the LA County Water Service Account (Year 2013)

#	CGE Sector	IMPLAN Sector	LADWP			MWD (Excluding LADWP)				County Total
			Water Demand (AF)[1]	Weights for LADWP[2]	Demand (M$)[3]	Weights for MWD[4]	Demand (AF)[5]	Demand After Conservation (AF)[6]	Demand After Conservation (M$)[7]	LA County Demand (M$)[8]
1	aag agriculture--annual crops	1-3; 7-10	23.41	0%	$0.06	4%	15.83	15.21	$0.03	$0.08
2	pag agriculture--perennial crops	4-6	47.77	0%	$0.11	8%	32.29	31.04	$0.06	$0.17
3	oag agriculture--other	11-19	543.55	2%	$1.28	88%	367.42	353.16	$0.64	$1.92
4	mmp metals + minerals processing (incl mining)	20-30; 153-180	1,253.66	4%	$2.95	1%	3,402.92	3,270.83	$5.97	$8.92
5	ele electric power	31; 428; 431	1,222.28	4%	$2.88	1%	3,317.74	3,188.95	$5.82	$8.70
6	wat water and wastewater utilities	33	867.98	3%	$2.04	1%	2,356.03	2,264.57	$4.14	$6.18
7	cns construction	34-40	1,342.56	5%	$3.16	1%	3,644.24	3,502.78	$6.40	$9.56
8	fdc food + drugs + chemicals	41-73; 115-141	18,095.39	62%	$42.59	15%	49,118.05	47,211.38	$86.21	$128.80
9	lin light industry	74-114; 142-152; 216; 257-275; 295-304; 309-318; 341-344	3,684.12	13%	$8.67	3%	10,000.15	9,611.96	$17.55	$26.22
10	hin heavy industry	181-191; 193-208; 210; 212-215; 217-233; 276-283; 289-294	1,196.97	4%	$2.82	1%	3,249.05	3,122.93	$5.70	$8.52
11	hti high tech industry	192; 209; 211; 234-256; 284-288; 305-308; 345; 350; 352-353	1,090.53	4%	$2.57	1%	2,960.14	2,845.23	$5.20	$7.76
12	wst wholesale trade	319	2,386.60	3%	$9.50	2%	6,478.18	6,226.70	$11.19	$20.70
13	ret retail trade	320-331; 362-364	14,932.22	16%	$59.46	12%	40,531.94	38,958.56	$70.04	$129.50
14	pts professional + technical services	32; 332-340; 365-390	8,362.61	9%	$33.30	7%	22,699.42	21,818.27	$39.22	$72.52
15	mpv motion picture + video	346	2,011.47	2%	$8.01	2%	5,459.93	5,247.99	$9.43	$17.44
16	enr entertainment + recreation	347-349; 402-410; 413	9,570.33	10%	$38.11	8%	25,977.66	24,969.25	$44.89	$83.00
17	tco telecommunications	351	419.49	0%	$1.67	0%	1,138.67	1,094.47	$1.97	$3.64
18	bfi banking + finance	354-359	1,495.70	2%	$5.96	1%	4,059.91	3,902.31	$7.02	$12.97
19	res real estate	360-361; 411-412; 426	15,012.39	16%	$59.78	12%	40,749.55	39,167.73	$70.41	$130.19
20	scl schools + libraries	391; 393; 438	5,834.57	6%	$23.23	5%	15,837.32	15,222.55	$27.37	$50.60
21	uni colleges + universities	392	4,925.43	5%	$19.61	4%	13,369.56	12,850.57	$23.10	$42.72
22	med medical	394-396	1,511.96	2%	$6.02	1%	4,104.05	3,944.73	$7.09	$13.11
23	hsp hospitals	397	3,874.82	4%	$15.43	3%	10,517.79	10,109.51	$18.17	$33.60
24	nrs nursing homes	398	2,544.73	3%	$10.13	2%	6,907.41	6,639.27	$11.94	$22.07
25	prs personal + repair services	399-400; 416-422	9,064.58	10%	$36.10	7%	24,604.85	23,649.73	$42.51	$78.61
26	prk parking services	414-415	1,790.19	2%	$7.13	1%	4,859.29	4,670.66	$8.40	$15.53
27	rnp religious activities	423-425	3,356.64	4%	$13.37	3%	9,111.24	8,757.56	$15.74	$29.11
28	gvt government industry	427; 429-430; 432--427; 439-440	6,373.72	7%	$25.38	5%	17,300.79	16,629.21	$29.89	$55.28
29	crs community food + housing + relief services (in	401	10.46	0%	$0.04	0%	28.40	27.29	$0.05	$0.09
	Residential				$708.69		724,147.03	696,036.94	$1,193.35	$1,902.03
	Gov Final Demand				$3.84		142,882	137,335.58	$183.12	$186.96
	Total				**$1,153.88**		**1,199,228.83**	**1,152,676.93**	**$1,952.62**	**$3,106.51**

[1] FY 2010/2011 4-digit SIC water demand data provided by LADWP are used to disaggregate the figures aggregate sector (Ag, Industrial, and Commercial) demand to the 29 CGE sub-sectors.

[2] Sectoral weights are computed based on the Acre Feet number in the previous column. Weights are calculated separately for Industrial sector and Commercial sector.

[3] Projected water rates (prices) data for 2012/13 are used to convert the demand in Acre Feet to million dollars. For Ag sectors, the Industrial water rate is used.

[4] Data in the "LADWP Water Demand" column is used to compute the weights for MWD demand. Since for MWD total water demand by Industrial and Commercial users is aggregated into a single sector, consumption weights in this column are also computed with Industrial and Commercial uses combined.

[5] The 2013 Base Case projected non-residential water demand (in Acre Feet) is distributed among CGE producing sectors using the weights computed in the previous column; Gov Final Demand includes "Seawater Barrier Demand" and "Replenishment Demand".
[6] Demand is adjusted for water efficiency based on the data provided by MWD.
[7] Projected LADWP water rates (prices) data for 2012/13 are used to convert water demand by sector in Acre Feet to million dollar values. For Ag sectors, the Industrial water rate is used.
[8] County totals are derived as the sum of LADWP and residual MWD (excluding LADWP) Demand.

II. I-O Table Modification

1. The following steps are adopted to revise the 2010 IMPLAN LA county I-O table with primary data on water
    a. Overwrite the original Water row and column (CGE Sector #6) with the numbers computed from the primary data on water. This sector now represents all retail water services.
    b. Wastewater treatment in LA County is performed by the Sanitation Districts of Los Angeles County (LACSD). It is assumed that this is subsumed in the Government Industry row and column in the I-O Table.
    c. Revisions to the Rows of the IMPLAN I-O Table:
        i. Use the LA County water demand by sector numbers calculated in the last column of Table A1 to adjust the numbers in the original water row of the I-O table. The total residential water use is divided among the 9 household groups based on the weights in the original water row. The total government water use is divided among the 6 government categories based on the weights in the original water row.
        ii. The difference between each entry in the adjusted water row and the original water row is calculated. The difference in each column is then subtracted from the corresponding number in the Government (gov't enterprises) row.
        iii. Any negative number resulting from the calculation in Step 1c.ii is set to zero in the adjusted Government row. The Inventory row is next adjusted to make up the difference.
        iv. Any negative number resulting from the calculation in Step 1c.iii is set to zero in the adjusted Inventory row. The Foreign Trade row is next adjusted to make up the difference.
        v. Aggregate the institution rows including the 9 household rows, 6 government rows, and the capital row into the new "Errors/Omissions" row (all are small numbers). The institutional transfers from households to government (i.e., taxes) are included in the "Indirect Business Taxes" row of the household columns.
    d. Revisions to the Columns of the IMPLAN I-O Table:
        i. We consider all water supply to be domestic imports into the County in the I-O table. Based on the MWD Year 2013 wholesale water rate, the total dollar value of water import is $1.539 billion.
        ii. In the adjusted water column, set the amount of purchases by Sector 6 from Sector 6 (i.e., own uses of water that is available from within LA County) to zero, and set the domestic import to $1,539 million. Distribute the value difference between the retail water and wholesale water ((3,106.51-1,539.42) = $1,567.09 million) among all the other elements in the column based on the weights calculated from the technical coefficient in the original IMPLAN water column. We have considered adjusting the accounts so that the non-MWD groundwater and storage within LA County are subtracted from imports and entered into the in-region portion of the I-O table. Locally produced water is generally less costly than the wholesale MWD water. However, when any of these local sources are decreased, additional MWD water need to be purchased at the wholesale price.

Therefore, in this analysis, it is reasonable to assume that the retail water suppliers value the locally produced water at the same price as the MWD wholesale water (based on our conversation with LADWP staff), and thus we decided to maintain the distinction between retail and wholesale water transactions. This also avoids us having to further adjust other non-water purchases in the Water Services Sector column.

iii. The difference between each entry in the adjusted water column and original water column is calculated. The difference in each row is then subtracted from the corresponding number in the Government (enterprises) column.

2. Scale up the 2010 LA County I-O table to 2013 I-O table.
    a. The 2010 historical and 2013 projected Total Personal Income data for the LA County are collected from the LAEDC 2012-2013 Mid-Year Economic Forecast and Industry Outlook Report. Since the Total Personal Income numbers from the LAEDC Report are in nominal dollars, we compute that the 3-year growth rate between 2010 and 2013 is 11.7%, without the adjustment of inflation.
    b. We apply the 11.7% 3-year growth rate to every number (expect for the numbers in the Water Row and Water Column, which are already computed for Year 2013 and are in 2013$) in the 2010 I-O table (which is in 2010 dollars) to get the 2013 I-O table (which is in 2013 dollars).
3. Calculate the economic growth rate between 2013 and 2014
    a. Based on the LAEDC Forecast Report, the economic growth rate between 2012 and 2013, after the adjustment of inflation using the BLS Producer Price Indices, is 1.6%.
    b. We assume that the economic growth rate between 2013 and 2014 is same as the growth rate between 2012 and 2013.

Table A2. LA County I-O Table

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
		aag	pag	oag	mmp	ele	wat	cns	fdc	lin	hin	hti	wst	ret	pts	mpv	enr	tco	bfi	res	scl	uni	med	hsp	nrs	prs	prk	rnp	gvt	crs
1	aag agriculture--annual crops	0.1	0.0	0.2	0.0	0.0	0.0	0.5	19.4	1.8	0.0	0.0	0.0	0.0	0.2	0.0	0.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	pag agriculture--perennial crops	0.0	0.4	0.0	0.0	0.0	0.0	0.2	17.9	0.1	0.0	0.0	0.0	2.2	0.9	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	oag agriculture--other	0.2	0.5	0.6	0.0	0.0	0.0	0.0	58.9	8.8	0.0	0.0	0.0	0.2	0.3	0.0	3.9	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	mmp metals + minerals processing (incl mining)	0.1	0.1	0.2	298.9	142.8	0.8	305.4	2,498.2	218.9	351.1	235.8	9.9	11.1	462.1	6.4	54.7	7.5	1.0	16.7	2.3	1.2	16.6	6.1	2.0	18.0	1.7	3.0	105.5	1.2
5	ele electric power	0.7	1.8	1.1	66.6	1.9	1.4	54.6	372.0	189.6	51.9	125.1	76.9	270.6	286.8	85.5	373.5	24.2	60.8	245.9	9.8	105.1	50.9	88.7	27.4	71.3	16.5	24.9	56.1	3.4
6	wat water services	0.1	0.2	1.9	8.9	8.7	0.0	9.6	128.8	26.2	8.5	7.8	20.7	129.5	72.5	17.4	83.0	3.6	13.0	130.2	50.6	42.7	13.1	33.6	22.1	78.6	15.5	29.1	61.5	0.1
7	cns construction	0.8	1.3	0.8	148.4	117.9	132.6	34.7	329.8	170.6	60.1	130.9	61.3	219.5	620.6	86.1	202.3	216.7	528.4	1,040.7	19.2	0.1	65.4	41.3	22.2	63.3	6.4	104.9	653.8	4.1
8	fdc food + drugs + chemicals	7.1	8.7	17.6	80.9	35.7	3.5	683.0	8,103.9	1,796.0	147.5	463.3	132.7	80.7	1,518.0	43.5	1,702.4	26.1	38.4	83.9	20.7	137.1	553.2	487.8	79.4	143.9	15.1	32.6	257.7	7.3
9	lin light industry	0.3	1.1	0.5	48.9	7.4	2.4	703.5	706.5	1,511.7	253.7	498.0	200.7	250.5	654.5	292.5	394.6	74.4	206.2	172.4	28.6	34.9	145.1	93.2	22.7	177.3	31.4	69.4	152.5	8.0
10	hin heavy industry	0.2	0.3	0.5	52.0	8.0	0.4	380.9	196.1	170.0	810.6	240.5	41.0	74.3	242.7	2.5	77.3	21.2	5.4	19.4	7.3	5.5	6.4	2.9	0.5	54.9	120.3	6.3	71.7	2.7
11	hti high tech industry	0.1	0.1	0.1	29.4	4.3	3.0	83.7	209.3	240.2	144.6	3,346.4	96.4	98.4	485.0	97.3	97.9	121.2	151.5	41.6	32.2	33.6	153.0	73.4	11.2	78.1	15.3	21.6	36.1	2.3
12	wst wholesale trade	1.4	2.4	3.4	115.3	6.9	1.2	415.9	1,604.4	763.6	396.4	1,162.1	512.3	288.2	415.4	29.2	500.5	40.3	47.4	47.1	23.7	38.5	213.4	129.2	25.7	115.5	39.9	28.2	98.3	3.7
13	ret retail trade	0.6	0.6	0.5	24.6	0.3	0.7	872.9	317.7	151.2	93.5	230.1	160.6	233.5	612.4	183.7	231.8	43.3	183.8	123.3	12.5	8.2	187.4	93.0	13.5	124.1	66.2	22.0	5.0	2.9
14	pts professional + technical services	3.4	6.1	7.1	944.7	266.5	107.2	3,231.0	7,957.0	3,472.4	1,290.1	6,796.9	4,055.1	4,898.9	17,455.1	3,403.3	5,060.8	1,683.1	7,064.6	2,719.9	401.9	598.4	2,780.4	1,252.4	352.3	1,640.5	299.4	847.7	1,454.1	76.6
15	mpv motion picture + video	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	75.6	1.7	0.4	158.1	6,070.4	953.9	499.8	4.3	6.2	15.1	1.4	4.7	0.3	15.7	95.6	1.6	16.1	0.0	4.6
16	enr entertainment + recreation	0.2	0.4	0.4	40.6	42.8	4.0	149.9	335.0	238.4	88.6	382.4	250.5	417.2	2,237.1	1,063.2	3,073.2	615.8	1,160.0	320.0	84.5	74.3	389.7	117.9	74.6	267.4	31.6	151.3	117.9	13.1
17	tco telecommunications	0.1	0.3	0.2	29.9	9.6	8.8	310.5	190.2	253.4	95.2	542.1	329.2	515.9	2,682.0	264.3	481.0	2,521.9	1,853.4	171.7	57.1	80.5	364.2	135.0	35.4	293.6	42.7	140.3	137.5	9.9
18	bfi banking + finance	4.3	5.9	4.5	100.6	49.0	21.6	427.2	271.0	354.1	167.1	504.4	768.7	1,620.9	4,006.7	442.3	1,185.6	209.0	18,903.2	5,345.5	104.4	28.4	1,106.6	470.6	149.8	622.9	94.9	1,409.6	559.3	37.7
19	res real estate	11.1	4.6	5.7	39.7	19.1	11.5	230.1	308.2	378.3	119.0	565.0	620.3	2,357.3	3,852.7	1,202.5	2,127.9	304.6	2,110.5	2,467.3	411.6	686.7	1,156.2	1,698.0	237.7	822.5	126.5	570.5	402.1	80.0
20	scl schools + libraries	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.2	0.2	0.1	0.4	4.6	25.7	6.9	0.0	21.9	0.0	4.8	0.0	20.6	25.6	0.0	0.0	0.0	0.1	0.0	76.2	0.7	0.0
21	uni colleges + universities	0.3	0.4	1.0	0.0	0.2	0.0	1.1	0.4	1.5	0.0	0.0	12.1	67.5	10.2	0.0	0.0	12.9	0.0	0.0	0.0	0.0	2.1	4.3	0.0	0.0	0.0	0.6	0.4	0.0
22	med medical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	0.0	3.9	0.0	0.0	0.0	0.0	0.0	534.5	306.1	0.6	0.0	0.0	3.1	0.0	0.0
23	hsp hospitals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	18.1	0.0	0.0	0.0	0.0	0.0	0.0
24	nrs nursing homes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	prs personal + repair services	0.0	0.1	0.2	15.7	3.5	7.7	190.5	123.2	78.7	29.9	75.3	134.1	159.0	537.0	50.3	271.4	85.5	272.7	73.9	15.9	43.2	107.4	102.0	17.0	200.2	23.7	15.9	55.3	2.7
26	prk parking services	0.1	0.1	0.2	13.1	0.1	0.1	165.9	113.6	69.8	23.3	57.6	61.1	105.4	280.0	39.6	102.7	41.8	243.6	23.3	7.6	10.8	53.2	59.5	4.3	24.7	3.1	5.2	12.5	1.4
27	rnp religious activities	0.2	0.2	0.1	6.0	1.3	1.1	67.7	28.4	32.3	7.7	25.0	24.2	60.7	269.4	16.6	71.7	22.3	263.3	330.2	15.3	6.0	63.7	6.9	5.2	58.6	6.7	24.5	4.6	0.8
28	gvt government industry	0.7	1.1	0.2	192.1	3.7	3.2	45.0	429.3	264.3	76.5	301.3	373.0	137.5	1,354.1	122.6	345.9	225.5	1,414.3	15.2	5.9	163.5	109.1	52.8	2.6	31.0	37.3	34.3	294.2	4.1
29	crs community food + housing + relief services (institutional dormitories)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5001	Employee Compensation	17.0	86.9	65.9	2,317.9	1,446.5	289.4	8,371.5	5,646.6	9,192.9	4,938.0	13,973.0	16,547.5	17,785.5	60,586.7	15,982.9	18,958.3	3,045.6	22,440.5	6,445.8	23,848.0	3,854.3	13,640.0	9,743.9	2,688.1	4,644.8	1,234.4	3,907.0	30,890.9	474.3
6001	Proprietary Income	33.3	106.2	60.8	832.2	154.0	137.9	3,786.6	1,001.3	328.3	70.6	564.3	2,967.2	2,998.4	18,428.9	-279.5	3,592.9	73.3	1,986.0	2,587.9	83.3	203.2	4,146.7	191.2	189.8	3,822.4	1,198.5	62.6	-146.2	161.5
7001	Other Property Income	6.3	-13.8	15.4	1,156.7	2,488.3	701.3	2,792.7	10,243.5	4,004.5	2,267.0	9,298.9	8,499.6	2,822.1	29,444.6	15,202.3	8,086.4	6,285.6	14,100.4	69,726.5	2,612.2	-96.6	1,100.5	684.1	207.3	431.3	51.7	-102.1	3,824.8	-27.9
8001	Indirect Business Taxes	1.9	2.8	5.4	351.2	732.2	115.3	216.2	667.7	346.8	148.7	487.7	7,548.1	7,021.5	4,524.8	1,559.5	2,617.4	1,169.3	1,480.1	10,401.3	101.6	192.8	357.6	282.4	223.5	568.4	317.8	108.7	-1,383.5	7.1
14002	Inventory Additions/Deletions	0.0	0.1	0.0	3.0	0.5	0.1	35.6	51.7	71.6	24.6	79.9	7.5	9.2	28.5	11.1	19.3	4.2	5.3	5.4	0.0	2.0	7.9	5.4	0.0	8.6	3.1	2.7	7.5	0.4
25001	Foreign Trade	5.0	10.7	11.6	1,044.0	409.8	11.1	2,728.9	11,177.4	3,967.2	2,856.9	5,992.1	628.1	741.3	3,896.1	602.7	1,557.5	368.8	1,528.1	594.7	72.6	148.3	640.2	402.2	73.2	559.0	286.6	209.8	787.9	25.3
28001	Domestic Trade	26.9	50.6	77.5	1,156.7	356.9	1,539.4	4,973.2	23,018.7	8,254.7	4,794.1	12,157.6	1,817.7	2,425.8	8,682.1	1,412.0	5,003.8	815.7	4,827.1	2,309.0	289.6	609.4	2,024.6	1,407.8	279.3	1,381.7	632.6	640.4	-176.0	64.0
	Errors/Omissions	0.1	0.1	0.3	44.9	1.1	0.7	7.4	124.1	62.5	17.3	67.4	88.1	61.8	307.8	27.2	80.3	50.5	317.5	18.7	3.1	8.3	32.1	21.1	2.2	18.5	10.8	11.3	42.8	0.6
Gross Output		**122.3**	**280.1**	**283.8**	**9,163.0**	**6,321.3**	**3,106.5**	**31,275.7**	**76,250.2**	**36,621.0**	**19,332.4**	**58,386.8**	**46,050.9**	**45,890.7**	**164,129.0**	**48,037.8**	**57,338.8**	**18,613.9**	**81,215.5**	**105,484.3**	**28,357.3**	**7,047.5**	**30,029.1**	**18,011.4**	**4,785.4**	**16,416.5**	**4,731.3**	**8,477.7**	**38,384.8**	**971.7**

Table A2. LA County I-O Table (cont'd)

		10001 Households LT10k	10002 Households 10-15k	10003 Households 15-25k	10004 Households 25-35k	10005 Households 35-50k	10006 Households 50-75k	10007 Households 75-100k	10008 Households 100-150k	10009 Households 150k+	11001 Federal Government NonDefense	11002 Federal Government Defense	11003 Federal Government Investment	12001 State/Local Govt NonEducation	12002 State/Local Govt Education	12003 State/Local Govt Investment	14001 Capital	14002 Inventory Additions/Deletions	25001 Foreign Trade	28001 Domestic Trade	Errors/ Omissions	**Gross Output**
1	aag agriculture--annual crops	0.2	0.2	0.4	0.5	0.7	1.1	0.8	0.8	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	81.1	0.0	**122.3**
2	pag agriculture--perennial crops	1.9	1.4	2.9	3.8	5.9	8.3	6.0	6.7	11.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	9.8	199.7	0.0	**280.1**
3	oag agriculture--other	0.4	0.3	0.7	0.9	1.4	2.1	1.5	1.7	2.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	39.1	159.2	0.0	**283.8**
4	mmp metals + minerals processing (incl mining)	6.0	4.6	10.7	12.1	18.3	26.2	20.4	22.5	32.0	4.0	1.0	0.1	9.0	0.2	0.1	90.4	12.4	772.1	3,342.1	0.1	**9,163.0**
5	ele electric power	97.5	86.2	180.5	207.0	279.9	390.9	259.3	278.0	349.3	13.6	14.1	0.3	48.3	3.1	0.1	7.6	0.0	30.1	1,330.4	0.2	**6,321.3**
6	wat water services	77.1	50.0	142.1	168.3	233.7	347.3	236.9	266.9	379.6	28.1	18.9	0.0	137.5	2.3	0.1	0.0	0.0	0.0	0.0	0.0	**3,106.5**
7	cns construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	126.6	63.7	407.3	357.2	9.0	2,127.1	18,095.7	0.0	1.8	4,987.5	15.5	**31,275.7**
8	fdc food + drugs + chemicals	662.3	577.8	1,276.0	1,565.6	2,121.9	2,964.5	2,134.0	2,188.4	2,860.8	52.8	43.3	0.3	337.6	16.3	0.1	20.3	1,727.7	6,832.5	34,160.1	0.4	**76,250.2**
9	lin light industry	146.6	98.2	213.7	249.7	420.7	648.2	500.4	577.2	974.8	58.5	31.9	13.9	129.6	12.1	16.0	498.7	211.9	3,673.7	21,402.4	0.3	**36,621.0**
10	hin heavy industry	11.5	22.1	48.0	59.8	124.2	201.8	171.5	185.4	319.3	6.0	24.5	63.4	21.9	1.2	28.5	589.6	36.8	2,519.6	12,275.4	0.0	**19,332.4**
11	hti high tech industry	75.8	49.1	119.4	123.1	227.4	344.8	315.0	335.7	475.9	52.9	148.0	196.7	79.3	46.9	31.9	3,105.5	616.4	9,509.3	36,826.0	0.3	**58,386.8**
12	wst wholesale trade	207.7	112.8	220.7	352.4	1,098.8	2,061.0	1,527.6	1,618.4	1,397.9	44.3	25.5	44.5	136.7	10.5	35.5	2,890.8	0.2	7,369.5	19,826.8	0.1	**46,050.9**
13	ret retail trade	1,187.1	609.7	1,821.2	1,707.3	3,627.2	5,507.0	5,294.0	6,519.2	10,092.2	4.9	4.0	0.0	27.0	1.6	0.0	764.5	0.0	444.3	4,279.8	0.1	**45,890.7**
14	pts professional + technical services	532.5	269.5	816.3	919.0	1,421.9	2,101.3	1,456.9	1,778.0	3,248.3	1,320.5	1,046.1	249.7	1,591.2	119.8	49.0	5,831.6	0.4	14,231.6	47,006.2	12.6	**164,129.0**
15	mpv motion picture + video	31.3	16.8	27.6	40.5	67.9	113.9	84.6	101.4	187.1	3.2	21.6	0.0	3.3	0.1	0.0	0.0	0.0	8,098.8	31,313.8	0.0	**48,037.8**
16	enr entertainment + recreation	971.3	514.5	1,142.6	1,511.8	2,530.9	4,365.4	3,289.8	3,747.0	6,276.6	62.0	52.5	6.0	295.4	4.7	1.2	140.7	0.0	650.1	20,033.9	0.5	**57,338.8**
17	tco telecommunications	218.4	166.9	328.3	369.7	519.6	840.3	562.9	599.0	810.6	166.8	54.4	2.7	263.8	24.6	0.4	159.1	7.8	449.5	1,511.9	1.0	**18,613.9**
18	bfi banking + finance	721.5	824.7	1,354.9	2,137.2	3,693.7	6,011.8	5,026.6	5,380.6	8,066.4	81.6	1.6	0.3	194.5	0.6	0.1	55.7	0.0	2,297.0	6,388.5	2.5	**81,215.5**
19	res real estate	2,474.8	1,432.9	3,544.9	3,955.9	5,856.9	10,519.7	7,603.5	9,093.3	16,021.1	181.2	28.1	0.0	321.7	3.9	0.0	0.0	0.0	67.1	21,450.5	1.4	**105,484.3**
20	scl schools + libraries	95.3	43.5	91.1	125.9	304.3	807.5	396.7	662.7	1,632.2	4.3	4.9	0.0	28.0	23,451.7	0.0	0.0	0.0	0.0	519.2	0.0	**28,357.3**
21	uni colleges + universities	954.4	277.9	306.6	436.8	464.8	804.9	504.8	799.8	1,862.2	132.3	0.0	0.0	93.4	0.0	0.0	0.0	0.0	41.4	253.5	0.0	**7,047.5**
22	med medical	980.9	871.7	2,118.0	2,082.2	3,219.4	4,861.2	3,956.9	3,955.9	6,599.9	9.8	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.1	499.5	0.0	**30,029.1**
23	hsp hospitals	500.3	501.9	1,591.3	1,578.3	1,928.7	3,613.0	1,904.5	2,231.2	4,122.5	3.2	0.0	0.0	6.7	0.0	0.0	0.0	0.0	4.8	3.3	0.0	**18,011.4**
24	nrs nursing homes	150.0	79.4	315.1	519.0	683.5	813.0	367.0	612.6	1,230.7	4.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	4.7	0.0	**4,785.4**
25	prs personal + repair services	371.2	210.4	520.7	686.7	1,130.5	1,541.0	962.7	1,210.9	2,692.2	26.4	56.4	0.0	217.3	13.4	0.0	0.0	0.0	1.5	4,082.3	0.9	**16,416.5**
26	prk parking services	96.0	49.6	124.5	141.6	233.3	397.2	295.3	334.1	658.2	6.4	0.4	0.0	28.6	3.0	0.0	0.0	0.0	0.6	838.9	0.0	**4,731.3**
27	rnp religious activities	204.0	120.7	258.3	548.8	898.0	1,243.6	735.6	884.5	2,154.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	4.3	0.1	**8,477.7**
28	gvt government industry	161.7	135.5	316.3	386.9	589.3	1,049.6	766.9	768.7	1,173.1	2,754.0	2,152.4	1.8	13,843.5	3.4	19.8	86.7	-46.1	4,795.8	3,748.8	-363.4	**38,384.8**
29	crs community food + housing + relief services (institutional dormitories)	26.0	11.0	31.2	83.4	134.6	164.2	91.9	114.0	303.1	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	**971.7**
5001	Employee Compensation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6001	Proprietary Income	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7001	Other Property Income	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8001	Indirect Business Taxes	271.5	-69.7	487.6	1,469.7	3,454.3	8,591.3	7,734.1	11,297.4	23,593.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
14002	Inventory Additions/Deletions	8.8	6.5	14.3	16.6	27.5	41.8	33.1	36.8	58.2	2.4	3.5	4.8	6.1	0.5	1.6	5,417.2	-18.0	366.4	1,782.6	0.0	**8,205.8**
25001	Foreign Trade	1,316.2	1,059.2	2,282.0	2,857.6	4,523.7	7,022.9	5,393.9	5,804.2	9,029.4	3,970.7	3,290.5	502.0	18,560.5	64.3	173.0	8,287.9	2,365.0	0.0	0.0	-24.8	**117,815.3**
28001	Domestic Trade	1,951.2	1,448.9	3,498.0	4,088.2	6,321.3	9,771.3	6,999.2	7,869.0	11,955.6	-2,229.7	-1,546.5	638.2	-11,613.3	514.9	256.2	123,273.7	3,291.2	0.0	0.0	21,857.4	**279,197.5**
	Errors/Omissions	236.5	128.8	251.0	346.5	531.0	966.0	1,076.0	1,605.0	14,645.1	86,649.2	495.5	0.4	41,131.7	100.6	4.6	80,990.6	0.2	55,592.3	884.9	31,428.8	
Gross Output		**14,747.8**	**9,712.9**	**23,456.8**	**28,752.5**	**46,695.1**	**78,144.2**	**59,710.3**	**70,886.9**	**133,216.4**	**93,540.7**	**6,036.3**	**2,132.5**	**66,291.4**	**24,408.7**	**2,745.2**	**250,306.1**	**8,205.8**	**117,815.3**	**279,197.5**		

Appendix B. Calculation of Water Constraint Levels

No Storage Case

Table B1 presents the retail water shortage in both quantity terms and percentage terms for the three disruption periods in the case without MWD storage water use. These results are provided by MWD through the simulations run in MWD "Sales Model 20a2".

Table B1. Water Constraint Levels – without Storage Water Use

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	79,111		330,158	325,634		330,158	325,634	326,223
Percent Retail Shortage	4.35%		18.2%	18.2%		18.2%	18.2%	18.5%

Storage Water Use — Reference Case

Table B2 presents the retail water shortage after the use of MWD storage. Again, these results are provided directly by MWD through the simulations run in MWD "Sales Model 20a2".   Table B3 presents the retail water shortage after the use of both MWD storage water and LADWP storage water. The total level of LADWP reservoir storage water is 17,000 AF. It is assumed that the LADWP reservoir water is not resumable. In other words, in the 24-month and 36-month disruption scenarios, it is assumed that after the depletion of reservoir water in the first year to alleviate the water shortage, no LADWP reservoir storage water would be available in the second and third years of water disruption. In the 6-month disruption scenario, since the water shortage level is only 6,954 AF after the use of MWD storage water, we assume that LADWP reservoir storage can only further reduce the supply shortage by 36.6%, which equals the percentage water demand of LADWP with respect to the total water demand of the County. In other words, we assume no inter-jurisdictional sharing of the reservoir storage water.

In our following analyses of various resilience cases, the "with Storage Use" results shown in Table B3 will be used as the Reference Case. In other words, the effects of various resilience measures on reducing the water demand shortages are computed based on the assumption of MWD and LADWP storage water use.

Table B2. Water Constraint Levels – with MWD Storage Water Use

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	6,954		105,516	194,165		105,516	194,165	213,510
Percent Retail Shortage	0.38%		5.8%	10.9%		5.8%	10.9%	12.1%

Table B3. Water Constraint Levels – with MWD and LADWP Storage Water Use

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	4,410		88,516	194,165		88,516	194,165	213,510
Percent Retail Shortage	0.24%		4.9%	10.9%		4.9%	10.9%	12.1%

Conservation

1. LADWP Phase II Conservation

Table B4 presents the water constraint levels after the implementation of LADWP Phase II Conservation. According to the LADWP Emergency Water Conservation Plan (EWCP), City of LA has different conservation phases or stages of actions that can be implemented in response to shortages in water supply (LADWP, 2010). Phase II Conservation, which is implemented with Moderate Water Supply Shortage (roughly corresponding from zero to 15 percent), has been in effect in the City of LA since 2009. Phase II actions can achieve up to 15% conservation (LADWP, 2010). In this resilience analysis case, we apply the 15% conservation to the total water demand of the LA City to get the water constraints under the Bay Delta disruption scenarios after taking Phase II Conservation of the City of LA into consideration.

2. LADWP Phase II Conservation Plus Incremental Conservation

In addition to the Phase II Conservation of LADWP, in this conservation resilience case, we assume that for both the 24-month and 36-month disruption scenarios, additional conservation efforts can be anticipated to further cope with the shortage of water supply. We calculate the effect of the additional conservation efforts under the Bay Delta disruption scenarios as the potential conservation level difference between LADWP Phase III Conservation and Phase II Conservation. According to LADWP EWCP, Phase III Conservation measures, which would be implemented with Severe Water Shortage (corresponding from 15 to 20 percent), can achieve up to 20% conservation (LADWP, 2010). Therefore, compared with the Phase II Conservation, Phase III Conservation can achieve 5% incremental conservation. In addition, we assume that the current water rates will be increased by 5% in association with the incremental conservation level based on the assumption of revenue neutral for the water retail suppliers. In this resilience analysis case, above and beyond the 15% conservation that is applied to the total water demand of the LA City, we assumed that the 5% incremental conservation and the 5% water rates increase are applied to the entire County. Table B5 presents the water constraint results for this resilience analysis case.

Table B4. Water Constraint Levels with LADWP Phase II Conservation

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	0		0	94,423		0	94,423	113,719
Percent Retail Shortage	0.00%		0.0%	5.3%		0.0%	5.3%	6.4%

Table B5. Water Constraint Levels with LADWP Phase II Conservation Plus 5% Incremental Conservation

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	0		0	3,561		0	3,561	22,684
Percent Retail Shortage	0.00%		0.0%	0.2%		0.0%	0.2%	1.3%

Water Importance

Table B6 presents the Water Importance Factor by sector (ATC, 1991). The percentage values in the table indicate the percentage of production of each sector affected by the disruption of water. For example, the Water Importance Factor for Sector 10 (Heavy Industry) is 60 percent. That means that 60 percent of the production of this sector is dependent on water, and the remaining production of this sector is separable from water use. The weighted average Water Importance Factor is computed for the economy using sectoral water demands as weights.

Table B7 presents the retail water shortage levels for the with storage case after we take water importance into consideration.

Table B6. Water Importance Factors

Sector	
1. aag agriculture--annual crops	70.00%
2. pag agriculture--perennial crops	70.00%
3. oag agriculture--other	45.00%
4. mmp metals + minerals processing (incl mining)	61.67%
5. ele electric power	40.00%
6. wat water services	40.00%
7. cns construction	50.00%
8. fdc food + drugs + chemicals	62.50%
9. lin light industry	53.75%
10. hin heavy industry	60.00%
11. hti high tech industry	90.00%
12. wst wholesale trade	20.00%
13. ret retail trade	20.00%
14. pts professional + technical services	20.00%
15. mpv motion picture + video	80.00%
16. enr entertainment + recreation	80.00%
17. tco telecommunications	30.00%

18. bfi banking + finance	20.00%
19. res real estate	20.00%
20. scl schools + libraries	40.00%
21. uni colleges + universities	40.00%
22. med medical	40.00%
23. hsp hospitals	40.00%
24. nrs nursing homes	40.00%
25. prs personal + repair services	23.33%
26. prk parking services	10.00%
27. rnp religious activities	40.00%
28. gvt government industry	25.00%
29. crs community food + housing + relief services	40.00%
Weighted Average	38.47%

Table B7. Water Constraint Levels with Water Unimportance Adjustment

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
Retail Level Shortage (acre feet)	893		34,054	74,700		34,054	74,700	82,143
Percent Retail Shortage	0.0%		1.9%	4.1%		1.9%	4.2%	4.7%

Diversion of Replenishment Water Use

Table B8 presents the projected amount of water that will be used for Groundwater Replenishment and Seawater Barrier in LA County in the Base Case for Years 2013 to 2015. Both imported water and recycled water are used for water replenishment purpose. According to WRD, all imported water originally used for water replenishment can be diverted to other uses in the emergency of water supply shortage. If we apply the percentage of WRD total water replenishment use that come from imported water (29.6% for Groundwater Spreading and 36.7% for Seawater Barrier) to the total replenishment water use of the County, we obtain the amount of water that can be diverted to other uses in our water disruption scenarios. These numbers are presented in Table B9.

Table B8. Replenishment Water Use (acre feet)

	6-mon Disruption	24-mon Disruption	36-mon Disruption
Groundwater Spreading Use			
2013	108,382	108,382	108,382
2014		109,575	109,575
2015			113,968
Seawater Barrier Use			
2013	37,494	37,494	37,494
2014		37,571	37,571
2015			37,648
Total Replenishment Water Use			
2013	145,876	145,876	145,876
2014		147,146	147,146
2015			151,616

Table B9. Diversion from Replenishment Water Use (acre feet)

	6-mon Disruption	24-mon Disruption	36-mon Disruption
Diversion from Groundwater Spreading Use			
2013	28,984	19,232	19,232
2014		19,511	19,511
2015			20,261
Diversion from Seawater Barrier Use			
2013	12,430	8,248	8,248
2014		8,293	8,293
2015			8,297
Total Diversion			
2013	41,414	27,480	27,480
2014		27,804	27,804
2015			28,558

Table B10 presents the retail water shortage levels for the with storage case after the diversion of replenishment water use to other uses.

Table B10. Water Constraint Levels with Replenishment Water Use Diversion

	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		**2013**	**2014**		**2013**	**2014**	**2015**
Retail Level Shortage (acre feet)	0		48,567	158,940		48,567	158,940	178,402
Percent Retail Shortage	0.00%		2.7%	8.9%		2.7%	8.9%	10.1%

Production Recapture

Table B11 presents the Production Recapture factor by sector. The Recapture factors for the 3-month period are obtained from FEMA's (2012) hazard loss estimation tool, HAZUS, and Rose and Lim (2002). For example, the Production Recapture Factor for Sector 9 (Light Industry) for 3months is 95. That means if the water disruption lasts for three months, Production Recapture for Sector 9 can potentially reduce 95 percent of total output losses of this sector if the water supply disruption is ended within three months. We then reduce the Recapture Factors by 25 percent for each of the subsequent three-month periods, since, as the disruption period becomes longer, there will be an increasing number of cancelled orders. Therefore, after the first year, there is no Recapture. Note that in contrast to the analysis of other resilience tactics, the Production Recapture factors are not applied on the input side (i.e., water supply constraints), rather they are applied directly to the economic impact results of the Reference Case. Table B12 presents sectoral Production Recapture factors adjusted for different time periods and expressed in terms of the proportion of production that can be retained by rescheduling production to a later date. Note that after the first year, there is no production recapture. Effectively, this means that the recapture factor is only relevant to the 6-month disruption scenario. In the two longer scenarios, Recapture cannot be implemented until after the Recapture Factors have dropped to zero.

Table B11. Production Recapture Factors

Sector	3-mon	6-mon	9-mon	12-mon	After First Year
1. aag agriculture--annual crops	75	56	38	19	0
2. pag agriculture--perennial crops	75	56	38	19	0
3. oag agriculture--other	75	56	38	19	0
4. mmp metals + minerals processing (incl mining)	99	74	50	25	0
5. ele electric power	75	56	38	19	0
6. wat water services	90	68	45	23	0
7. cns construction	95	71	48	24	0
8. fdc food + drugs + chemicals	95	71	48	24	0
9. lin light industry	95	71	48	24	0
10. hin heavy industry	99	74	50	25	0
11. hti high tech industry	97	73	49	24	0
12. wst wholesale trade	99	74	50	25	0
13. ret retail trade	80	60	40	20	0
14. pts professional + technical services	70	53	35	18	0
15. mpv motion picture + video	95	71	48	24	0
16. enr entertainment + recreation	30	23	15	8	0
17. tco telecommunications	40	30	20	10	0
18. bfi banking + finance	90	68	45	23	0
19. res real estate	90	68	45	23	0
20. scl schools + libraries	99	74	50	25	0
21. uni colleges + universities	99	74	50	25	0

22. med medical	50	38	25	13	0
23. hsp hospitals	50	38	25	13	0
24. nrs nursing homes	50	38	25	13	0
25. prs personal + repair services	60	45	30	15	0
26. prk parking services	70	53	35	18	0
27. rnp religious activities	50	38	25	13	0
28. gvt government industry	80	60	40	20	0
29. crs community food + housing + relief services	50	38	25	13	0

Table B12. Sectoral -Production Recapture Impact Adjustment Factor*

Sector	6-Mon Disruption		24-Mon Disruption			36-Mon Disruption		
	2013		2013	2014		2013	2014	2015
1. aag agriculture--annual crops	34.38%		100.00%	100.00%		100.00%	100.00%	100.00%
2. pag agriculture--perennial crops	34.38%		100.00%	100.00%		100.00%	100.00%	100.00%
3. oag agriculture--other	34.38%		100.00%	100.00%		100.00%	100.00%	100.00%
4. mmp metals + minerals processing	13.38%		100.00%	100.00%		100.00%	100.00%	100.00%
5. ele electric power	34.38%		100.00%	100.00%		100.00%	100.00%	100.00%
6. wat water services	21.25%		100.00%	100.00%		100.00%	100.00%	100.00%
7. cns construction	16.88%		100.00%	100.00%		100.00%	100.00%	100.00%
8. fdc food + drugs + chemicals	16.88%		100.00%	100.00%		100.00%	100.00%	100.00%
9. lin light industry	16.88%		100.00%	100.00%		100.00%	100.00%	100.00%
10. hin heavy industry	13.38%		100.00%	100.00%		100.00%	100.00%	100.00%
11. hti high tech industry	15.13%		100.00%	100.00%		100.00%	100.00%	100.00%
12. wst wholesale trade	13.38%		100.00%	100.00%		100.00%	100.00%	100.00%
13. ret retail trade	30.00%		100.00%	100.00%		100.00%	100.00%	100.00%
14. pts professional + technical services	38.75%		100.00%	100.00%		100.00%	100.00%	100.00%
15. mpv motion picture + video	16.88%		100.00%	100.00%		100.00%	100.00%	100.00%
16. enr entertainment + recreation	73.75%		100.00%	100.00%		100.00%	100.00%	100.00%
17. tco telecommunications	65.00%		100.00%	100.00%		100.00%	100.00%	100.00%
18. bfi banking + finance	21.25%		100.00%	100.00%		100.00%	100.00%	100.00%
19. res real estate	21.25%		100.00%	100.00%		100.00%	100.00%	100.00%
20. scl schools + libraries	13.38%		100.00%	100.00%		100.00%	100.00%	100.00%
21. uni colleges + universities	13.38%		100.00%	100.00%		100.00%	100.00%	100.00%
22. med medical	56.25%		100.00%	100.00%		100.00%	100.00%	100.00%
23. hsp hospitals	56.25%		100.00%	100.00%		100.00%	100.00%	100.00%
24. nrs nursing homes	56.25%		100.00%	100.00%		100.00%	100.00%	100.00%
25. prs personal + repair services	47.50%		100.00%	100.00%		100.00%	100.00%	100.00%
26. prk parking services	38.75%		100.00%	100.00%		100.00%	100.00%	100.00%
27. rnp religious activities	56.25%		100.00%	100.00%		100.00%	100.00%	100.00%
28. gvt government industry	30.00%		100.00%	100.00%		100.00%	100.00%	100.00%
29. crs community food + housing +	56.25%		100.00%	100.00%		100.00%	100.00%	100.00%

* Multiply the economic impact results of the Reference Case with the adjustment factors in this table to obtain the impacts after production recapturing.

Simultaneous Resilience Case

In addition to the analysis of the effect of the resilience tactics individually, we also evaluate the simultaneous effects of all these resilience tactics implementing together. However, note that the various resilience adjustments are not additive. The LADWP Phase II Conservation and the 5% additional conservation under the Bay Delta disruptions are first considered to reduce the water constraints after storage use. Next we further reduce the water constraints by taking into consideration the diversion of replenishment water use to other uses. If there is any remaining demand shortages after conservation and replenishment water diversion, water importance factors and production recapture would be applied.

For the Reference Case, the calculation indicates that after the inclusion of storage water, conservation, and replenishment water diversion, the water constraint would be eliminated. Therefore, the only effect we simulate for the simultaneous case is the 5% water rate increase associated with the 5% incremental conservation. The utilization of all resilience tactics would be applicable to the case of extreme hydrological conditions, as specified in Table 11. In these cases, even the simultaneous use of all resilience tactics would not eliminate the water constraint.

Appendix C. Sectoral Results for the Free Market Scenario (S1A)

Table S1A2/'13/Sectoral. Impacts of Water Supply Disruptions on the LA County Economy: 4.9% Reduction Scenario (flexible price)

	Water Demand			GDP			Employment			Price
Sector	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (jobs)	Post-Disruption (jobs)	Change (%)	Change (%)
Agriculture (Annual Crops)	0.000	0.000	-6.49	0.06	0.05	-5.31	768	727	-5.31	-0.02
Agriculture (Perennial Crops)	0.000	0.000	-6.25	0.19	0.18	-5.07	2,208	2,096	-5.07	-0.02
Agriculture (Other)	0.002	0.002	-6.62	0.14	0.13	-5.43	4,004	3,786	-5.43	0.04
Metals & Minerals Processing	0.009	0.008	-6.38	4.32	4.10	-5.20	26,253	24,889	-5.20	-0.02
Electric Power	0.009	0.008	-5.59	4.09	3.91	-4.40	8,974	8,579	-4.40	-0.01
Water Utilities	0.000	0.000	0.00	1.13	1.07	-4.90	5,621	5,346	-4.90	12.39
Construction	0.010	0.009	-4.96	15.11	14.54	-3.77	207,304	199,499	-3.77	-0.01
Food, Drugs, & Chemicals	0.129	0.121	-6.00	17.08	16.26	-4.81	75,799	72,155	-4.81	-0.04
Light Industry	0.026	0.025	-6.24	13.83	13.13	-5.05	177,207	168,251	-5.05	-0.01
Heavy Industry	0.009	0.008	-6.31	7.40	7.02	-5.13	73,191	69,438	-5.13	-0.02
High Tech Industry	0.008	0.007	-6.36	24.20	22.94	-5.18	129,192	122,494	-5.18	-0.01
Wholesale Trade	0.021	0.019	-6.09	28.05	26.67	-4.91	213,337	202,872	-4.91	0.01
Retail Trade	0.129	0.123	-5.24	23.65	22.69	-4.04	444,176	426,217	-4.04	0.04
Professional & Tech. Services	0.073	0.068	-5.86	108.58	103.50	-4.68	1,132,653	1,079,645	-4.68	0.01
Motion Picture & Video	0.017	0.016	-6.57	31.23	29.55	-5.40	145,454	137,606	-5.40	0.01
Entertainment & Recreation	0.083	0.078	-5.72	30.71	29.32	-4.54	549,210	524,292	-4.54	0.02
Telecommunications	0.004	0.003	-5.43	9.42	9.02	-4.24	32,450	31,073	-4.24	0.01
Banking & Finance	0.013	0.012	-5.37	38.55	36.94	-4.18	373,243	357,630	-4.18	0.01
Real Estate	0.130	0.123	-5.43	78.79	75.45	-4.24	427,688	409,568	-4.24	0.02
Schools & Libraries	0.051	0.050	-1.97	26.55	26.35	-0.74	398,695	395,758	-0.74	0.02
Colleges & Universities	0.043	0.041	-4.98	4.07	3.91	-3.78	66,587	64,072	-3.78	0.08
Medical	0.013	0.012	-5.03	18.92	18.19	-3.84	248,660	239,116	-3.84	0.01
Hospitals	0.034	0.032	-4.98	10.64	10.24	-3.78	121,155	116,571	-3.78	0.03
Nursing Homes	0.022	0.021	-5.00	3.09	2.97	-3.80	76,838	73,921	-3.80	0.06
Personal & Repair Services	0.079	0.074	-5.47	8.94	8.55	-4.27	206,868	198,029	-4.27	0.06
Parking Services	0.016	0.015	-5.47	2.50	2.39	-4.28	54,488	52,156	-4.28	0.04
Religious Activities	0.029	0.028	-5.09	3.98	3.83	-3.89	79,928	76,815	-3.89	0.05
Government Industry	0.061	0.059	-3.43	34.72	33.95	-2.22	357,573	349,645	-2.22	0.02
Community Services	0.000	0.000	-4.94	0.64	0.61	-3.74	22,618	21,771	-3.74	0.00
Households	1.902	1.806	-5.06	-	-	-	-	-	-	0.08
Other	0.187	0.184	-1.35	-	-	-	-	-	-	
Total	3.107	2.954	-4.90	550.59	527.51	-4.19	5,662,140	5,434,015	-4.03	0.04

Table S1A5/'13/Sectoral. Impacts of Water Supply Disruptions on the LA County Economy: 1.9% Reduction Scenario (flexible price)

Sector	Water Demand			GDP			Employment			Price
	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (jobs)	Post-Disruption (jobs)	Change (%)	Change (%)
Agriculture (Annual Crops)	0.000	0.000	-2.51	0.06	0.06	-2.07	768	752	-2.07	-0.01
Agriculture (Perennial Crops)	0.000	0.000	-2.42	0.19	0.19	-1.98	2,208	2,164	-1.98	-0.01
Agriculture (Other)	0.002	0.002	-2.57	0.14	0.14	-2.12	4,004	3,919	-2.12	0.01
Metals & Minerals Processing	0.009	0.009	-2.47	4.32	4.23	-2.03	26,253	25,720	-2.03	-0.01
Electric Power	0.009	0.009	-2.17	4.09	4.02	-1.72	8,974	8,819	-1.72	0.00
Water Utilities	0.000	0.000	0.00	1.13	1.11	-1.93	5,621	5,513	-1.93	4.62
Construction	0.01	0.01	-1.92	15.11	14.89	-1.48	207,304	204,239	-1.48	0.00
Food, Drugs, & Chemicals	0.129	0.126	-2.33	17.08	16.76	-1.88	75,799	74,374	-1.88	-0.01
Light Industry	0.026	0.026	-2.42	13.83	13.56	-1.97	177,207	173,708	-1.97	0.00
Heavy Industry	0.009	0.008	-2.45	7.40	7.25	-2.00	73,191	71,725	-2.00	-0.01
High Tech Industry	0.008	0.008	-2.47	24.20	23.71	-2.02	129,192	126,576	-2.02	0.00
Wholesale Trade	0.021	0.020	-2.36	28.05	27.51	-1.92	213,337	209,246	-1.92	0.00
Retail Trade	0.129	0.127	-2.03	23.65	23.27	-1.59	444,176	437,132	-1.59	0.02
Professional & Tech. Services	0.073	0.071	-2.27	108.58	106.60	-1.83	1,132,653	1,111,918	-1.83	0.00
Motion Picture & Video	0.017	0.017	-2.55	31.23	30.58	-2.11	145,454	142,391	-2.11	0.00
Entertainment & Recreation	0.083	0.081	-2.22	30.71	30.17	-1.78	549,210	539,458	-1.78	0.01
Telecommunications	0.004	0.004	-2.11	9.42	9.27	-1.66	32,450	31,910	-1.66	0.00
Banking & Finance	0.013	0.013	-2.08	38.55	37.92	-1.64	373,243	367,123	-1.64	0.00
Real Estate	0.130	0.127	-2.10	78.79	77.48	-1.66	427,688	420,587	-1.66	0.01
Schools & Libraries	0.051	0.050	-0.76	26.55	26.47	-0.31	398,695	397,445	-0.31	0.01
Colleges & Universities	0.043	0.042	-1.93	4.07	4.01	-1.48	66,587	65,599	-1.48	0.03
Medical	0.013	0.013	-1.95	18.92	18.63	-1.51	248,660	244,913	-1.51	0.00
Hospitals	0.034	0.033	-1.93	10.64	10.48	-1.49	121,155	119,354	-1.49	0.01
Nursing Homes	0.022	0.022	-1.94	3.09	3.04	-1.49	76,838	75,693	-1.49	0.02
Personal & Repair Services	0.079	0.077	-2.12	8.94	8.79	-1.67	206,868	203,405	-1.67	0.02
Parking Services	0.016	0.015	-2.12	2.50	2.46	-1.68	54,488	53,574	-1.68	0.02
Religious Activities	0.029	0.029	-1.97	3.98	3.92	-1.53	79,928	78,706	-1.53	0.02
Government Industry	0.061	0.061	-1.33	34.72	34.42	-0.88	357,573	354,413	-0.88	0.01
Community Services	0.000	0.000	-1.92	0.64	0.63	-1.47	22,618	22,285	-1.47	0.00
Households	1.902	1.865	-1.96	-	-	-	-	-	-	0.03
Other	0.187	0.186	-0.52	-	-	-	-	-	-	
Total	3.107	3.047	-1.90	550.59	541.54	-1.64	5,662,140	5,572,663	-1.58	0.01

Table S1A6/'13/Sectoral. Impacts of Water Supply Disruptions on the LA County Economy: 2.7% Reduction Scenario (flexible price)

	Water Demand			GDP			Employment			Price
Sector	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (jobs)	Post-Disruption (jobs)	Change (%)	Change (%)
Agriculture (Annual Crops)	0.000	0.000	-3.57	0.06	0.05	-2.91	768	746	-2.91	-0.01
Agriculture (Perennial Crops)	0.000	0.000	-3.45	0.19	0.19	-2.78	2,208	2,146	-2.78	-0.01
Agriculture (Other)	0.002	0.002	-3.65	0.14	0.14	-2.98	4,004	3,884	-2.98	0.02
Metals & Minerals Processing	0.009	0.009	-3.51	4.32	4.20	-2.85	26,253	25,505	-2.85	-0.01
Electric Power	0.009	0.008	-3.08	4.09	3.99	-2.41	8,974	8,758	-2.41	0.00
Water Utilities	0.000	0.000	0.00	1.13	1.10	-2.70	5,621	5,469	-2.70	6.63
Construction	0.010	0.009	-2.73	15.11	14.80	-2.06	207,304	203,028	-2.06	-0.01
Food, Drugs, & Chemicals	0.129	0.125	-3.30	17.08	16.63	-2.63	75,799	73,803	-2.63	-0.02
Light Industry	0.026	0.025	-3.44	13.83	13.45	-2.77	177,207	172,300	-2.77	0.00
Heavy Industry	0.009	0.008	-3.48	7.40	7.19	-2.81	73,191	71,135	-2.81	-0.01
High Tech Industry	0.008	0.007	-3.51	24.20	23.51	-2.84	129,192	125,523	-2.84	0.00
Wholesale Trade	0.021	0.020	-3.35	28.05	27.29	-2.69	213,337	207,603	-2.69	0.01
Retail Trade	0.129	0.126	-2.89	23.65	23.12	-2.22	444,176	434,337	-2.22	0.02
Professional & Tech. Services	0.073	0.070	-3.23	108.58	105.80	-2.56	1,132,653	1,103,611	-2.56	0.00
Motion Picture & Video	0.017	0.017	-3.62	31.23	30.31	-2.96	145,454	141,154	-2.96	0.00
Entertainment & Recreation	0.083	0.080	-3.15	30.71	29.95	-2.49	549,210	535,558	-2.49	0.01
Telecommunications	0.004	0.004	-2.99	9.42	9.20	-2.32	32,450	31,695	-2.32	0.00
Banking & Finance	0.013	0.013	-2.96	38.55	37.67	-2.29	373,243	364,689	-2.29	0.01
Real Estate	0.130	0.126	-2.99	78.79	76.96	-2.32	427,688	417,760	-2.32	0.01
Schools & Libraries	0.051	0.050	-1.09	26.55	26.44	-0.40	398,695	397,088	-0.40	0.01
Colleges & Universities	0.043	0.042	-2.74	4.07	3.98	-2.07	66,587	65,209	-2.07	0.04
Medical	0.013	0.013	-2.77	18.92	18.52	-2.10	248,660	243,431	-2.10	0.00
Hospitals	0.034	0.033	-2.74	10.64	10.42	-2.07	121,155	118,643	-2.07	0.01
Nursing Homes	0.022	0.021	-2.75	3.09	3.02	-2.08	76,838	75,240	-2.08	0.03
Personal & Repair Services	0.079	0.076	-3.01	8.94	8.73	-2.34	206,868	202,025	-2.34	0.03
Parking Services	0.016	0.015	-3.01	2.50	2.44	-2.34	54,488	53,210	-2.34	0.02
Religious Activities	0.029	0.028	-2.81	3.98	3.90	-2.13	79,928	78,222	-2.13	0.03
Government Industry	0.061	0.060	-1.89	34.72	34.30	-1.22	357,573	353,229	-1.22	0.01
Community Services	0.000	0.000	-2.72	0.64	0.62	-2.05	22,618	22,154	-2.05	0.00
Households	1.902	1.849	-2.79	-	-	-	-	-	-	0.04
Other	0.187	0.186	-0.74	-	-	-	-	-	-	
Total	3.107	3.023	-2.70	550.59	537.95	-2.30	5,662,140	5,537,157	-2.21	0.02

Table S1A2/'14. Impacts of Water Supply Disruptions on the LA County Economy: 10.87% Reduction Scenario (flexible price)

Sector	Water Demand			GDP			Employment			Price
	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (jobs)	Post-Disruption (jobs)	Change (%)	Change (%)
Agriculture (Annual Crops)	0.000	0.000	-14.39	0.06	0.05	-11.95	768	676	-11.95	-0.05
Agriculture (Perennial Crops)	0.000	0.000	-13.88	0.19	0.17	-11.43	2,208	1,955	-11.43	-0.04
Agriculture (Other)	0.002	0.002	-14.68	0.14	0.12	-12.23	4,004	3,514	-12.23	0.09
Metals & Minerals Processing	0.009	0.008	-14.15	4.32	3.82	-11.70	26,253	23,181	-11.70	-0.05
Electric Power	0.009	0.008	-12.40	4.09	3.69	-9.90	8,974	8,085	-9.90	-0.02
Water Utilities	0.000	0.000	0.00	1.13	1.01	-10.87	5,621	5,010	-10.87	29.89
Construction	0.01	0.01	-11.01	15.11	13.83	-8.48	207,304	189,719	-8.48	-0.02
Food, Drugs, & Chemicals	0.129	0.112	-13.31	17.08	15.23	-10.83	75,799	67,590	-10.83	-0.09
Light Industry	0.026	0.023	-13.84	13.83	12.26	-11.38	177,207	157,032	-11.38	-0.02
Heavy Industry	0.009	0.007	-14.00	7.40	6.55	-11.55	73,191	64,735	-11.55	-0.05
High Tech Industry	0.008	0.007	-14.12	24.20	21.37	-11.68	129,192	114,104	-11.68	-0.01
Wholesale Trade	0.021	0.018	-13.50	28.05	24.95	-11.05	213,337	189,764	-11.05	0.02
Retail Trade	0.129	0.114	-11.62	23.65	21.49	-9.11	444,176	403,717	-9.11	0.11
Professional & Tech. Services	0.073	0.063	-13.01	108.58	97.14	-10.54	1,132,653	1,013,243	-10.54	0.01
Motion Picture & Video	0.017	0.015	-14.58	31.23	27.44	-12.15	145,454	127,775	-12.15	0.02
Entertainment & Recreation	0.083	0.072	-12.70	30.71	27.58	-10.22	549,210	493,080	-10.22	0.04
Telecommunications	0.004	0.003	-12.05	9.42	8.52	-9.56	32,450	29,348	-9.56	0.02
Banking & Finance	0.013	0.011	-11.92	38.55	34.92	-9.42	373,243	338,072	-9.42	0.03
Real Estate	0.130	0.115	-12.04	78.79	71.27	-9.54	427,688	386,868	-9.54	0.04
Schools & Libraries	0.051	0.048	-4.38	26.55	26.11	-1.67	398,695	392,050	-1.67	0.05
Colleges & Universities	0.043	0.038	-11.05	4.07	3.72	-8.51	66,587	60,920	-8.51	0.20
Medical	0.013	0.012	-11.17	18.92	17.28	-8.65	248,660	227,159	-8.65	0.02
Hospitals	0.034	0.030	-11.05	10.64	9.73	-8.52	121,155	110,828	-8.52	0.06
Nursing Homes	0.022	0.020	-11.09	3.09	2.82	-8.55	76,838	70,266	-8.55	0.15
Personal & Repair Services	0.079	0.069	-12.13	8.94	8.08	-9.62	206,868	186,959	-9.62	0.15
Parking Services	0.016	0.014	-12.14	2.50	2.26	-9.64	54,488	49,236	-9.64	0.10
Religious Activities	0.029	0.026	-11.30	3.98	3.63	-8.77	79,928	72,916	-8.77	0.12
Government Industry	0.061	0.057	-7.62	34.72	32.99	-4.99	357,573	339,720	-4.99	0.05
Community Services	0.000	0.000	-10.96	0.64	0.58	-8.44	22,618	20,710	-8.44	0.01
Households	1.902	1.689	-11.22	-	-	-	-	-	-	0.1958
Other	0.187	0.181	-3.00	-	-	-	-	-	-	
Total	3.107	2.769	-10.87	550.59	498.60	-9.44	5,662,140	5,148,230	-9.08	0.089

Table S1A2/'15. Impacts of Water Supply Disruptions on the LA County Economy: 12.08% Reduction Scenario (flexible price)

	Water Demand			GDP			Employment			Price
Sector	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (B 2013$)	Post-Disruption (B 2013$)	Change (%)	Reference Case (jobs)	Post-Disruption (jobs)	Change (%)	Change (%)
Agriculture (Annual Crops)	0.000	0.000	-15.99	0.06	0.05	-13.32	768	666	-13.32	-0.06
Agriculture (Perennial Crops)	0.000	0.000	-15.42	0.19	0.17	-12.73	2,208	1,926	-12.73	-0.05
Agriculture (Other)	0.002	0.002	-16.31	0.14	0.12	-13.63	4,004	3,458	-13.63	0.10
Metals & Minerals Processing	0.009	0.008	-15.72	4.32	3.76	-13.04	26,253	22,829	-13.04	-0.05
Electric Power	0.009	0.008	-13.78	4.09	3.64	-11.04	8,974	7,984	-11.04	-0.02
Water Utilities				1.13	0.99	-12.08	5,621	4,942	-12.08	33.80
Construction	0.01	0.01	-12.23	15.11	13.68	-9.45	207,304	187,708	-9.45	-0.03
Food, Drugs, & Chemicals	0.129	0.110	-14.78	17.08	15.02	-12.07	75,799	66,651	-12.07	-0.10
Light Industry	0.026	0.022	-15.37	13.83	12.08	-12.69	177,207	154,725	-12.69	-0.02
Heavy Industry	0.009	0.007	-15.56	7.40	6.45	-12.87	73,191	63,768	-12.87	-0.06
High Tech Industry	0.008	0.007	-15.68	24.20	21.05	-13.01	129,192	112,379	-13.01	-0.01
Wholesale Trade	0.021	0.018	-15.00	28.05	24.59	-12.31	213,337	187,069	-12.31	0.03
Retail Trade	0.129	0.113	-12.91	23.65	21.25	-10.15	444,176	399,091	-10.15	0.12
Professional & Tech. Services	0.073	0.062	-14.46	108.58	95.83	-11.75	1,132,653	999,592	-11.75	0.01
Motion Picture & Video	0.017	0.015	-16.20	31.23	27.00	-13.54	145,454	125,755	-13.54	0.02
Entertainment & Recreation	0.083	0.071	-14.11	30.71	27.22	-11.39	549,210	486,663	-11.39	0.05
Telecommunications	0.004	0.003	-13.39	9.42	8.42	-10.65	32,450	28,993	-10.65	0.02
Banking & Finance	0.013	0.011	-13.24	38.55	34.50	-10.50	373,243	334,050	-10.50	0.03
Real Estate	0.130	0.113	-13.38	78.79	70.41	-10.64	427,688	382,201	-10.64	0.05
Schools & Libraries	0.051	0.048	-4.87	26.55	26.06	-1.86	398,695	391,283	-1.86	0.06
Colleges & Universities	0.043	0.037	-12.27	4.07	3.68	-9.48	66,587	60,272	-9.48	0.23
Medical	0.013	0.011	-12.41	18.92	17.10	-9.64	248,660	224,700	-9.64	0.02
Hospitals	0.034	0.029	-12.28	10.64	9.63	-9.50	121,155	109,647	-9.50	0.07
Nursing Homes	0.022	0.019	-12.32	3.09	2.79	-9.53	76,838	69,514	-9.53	0.16
Personal & Repair Services	0.079	0.068	-13.47	8.94	7.98	-10.72	206,868	184,683	-10.72	0.17
Parking Services	0.016	0.013	-13.49	2.50	2.23	-10.74	54,488	48,635	-10.74	0.11
Religious Activities	0.029	0.025	-12.55	3.98	3.59	-9.78	79,928	72,114	-9.78	0.13
Government Industry	0.061	0.056	-8.46	34.72	32.79	-5.56	357,573	337,680	-5.56	0.05
Community Services	0.000	0.000	-12.18	0.64	0.58	-9.40	22,618	20,492	-9.40	0.01
Households	1.902	1.665	-12.46	-	-	-	-	-	-	0.22
Other	0.187	0.181	-3.34	-	-	-	-	-	-	
Total	3.107	2.731	-12.08	550.59	492.66	-10.52	5,662,140	5,089,471	-10.11	0.10