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Assessment of the Economic Impacts of California's Drought on Urban Areas

A Research Agenda

Nancy Y. Moore, Ellen M. Pint, Lloyd S. Dixon

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PREFACE

In 1991, five years of drought in California culminated in severe water supply cutbacks in both agricultural and urban areas, and the establishment of a Drought Water Bank to transfer scarce water supplies to areas of critical need, including urban areas. Water shortages are adversely affecting California's business and residential users. A number of businesses and business associations have cited an uncertain or inadequate water supply as one of the main reasons they are expanding or relocating outside California. Residential water users are unhappy at both the inconvenience and the cost of the continuing drought, including the prospect of water price increases. California's water policymakers need to better understand such urban drought costs if they are to develop a future water policy that is efficient, equitable, and environmentally sound.

This document reports some background information on the extent and severity of the California drought, evaluates existing work on the economic effects of the drought, and presents an agenda for required future research to make an overall estimate of the economic costs of the drought in urban areas. This research was funded partly by California Urban Water Agencies (CUWA), a nonprofit, nonpartisan organization of 11 urban wholesale and retail water agencies formed in 1990 to pool their expertise and devise strategies to meet their present and future water needs. It also was supported partly by RAND, using its own funds.

Additional California water policy research is ongoing at RAND. In response to the proposals in this document, CUWA and the California Department of Water Resources (DWR) are currently funding two efforts: a survey of urban water agencies to determine what drought management policies were put into effect during the period 1986-1991, and what target water cutbacks were assigned to, and actual water cutbacks were achieved by, residential, commercial, and industrial customers; and a pilot study of residential consumer-surplus losses using demand curve

analysis. DWR is also funding a study of the economic impacts on farm suppliers, processors, and employees of 1991 Drought Water Bank water purchases in agricultural areas.

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SUMMARY

California has been experiencing a drought since 1987, with varying degrees of severity over time and in different parts of the state. Water supply shortages were the greatest in 1991 for most parts of the state, and cutbacks of 15 to 30 percent were required in many urban areas. California's population and economy have been growing more quickly than the available water supply, so water shortages are becoming the rule rather than the exception. If California is to continue to prosper, one of the most important economic issues to be resolved is the allocation of water between competing environmental, agricultural, and urban uses.

Water planning and management raise important questions about the relative value of water in different uses, and expose a lack of information about the costs of cutbacks in urban uses. We have been engaged in evaluating existing studies of urban drought impacts, gathering information from user groups and water agencies, and proposing further research to determine the overall economic impact of the drought in urban areas. This document reports the findings of this preliminary research and proposes a research agenda for future work needed to estimate the dollar value of economic losses in urban areas.

Our review of existing studies of urban drought impacts revealed reports that focused on a particular year, a particular class of customers, or a particular location. As yet, there appears to be no comprehensive, statewide study of the costs of water shortages to urban users. Although existing studies provide useful information, there are many gaps in the available data that, without additional research, preclude estimation of the dollar value of economic losses. Therefore, we outline a research agenda to determine how water supply cutbacks were distributed among residential, commercial, and industrial water customers and to estimate the economic impacts of the drought on each customer class.

The process of evaluating drought impacts must consider the actions of both water agencies and their residential, commercial, and industrial

customers. Faced with water supply shortages, water agencies implement drought management policies, which may be voluntary or mandatory, and which can include public education, distribution of water-saving devices, quantity and use restrictions, and price increases. They set target water cutbacks for various customer classes, but actual water use may differ from these targets because of uncertainty about customer responses. The reaction of residential, commercial, and industrial customers to drought management policies determines actual water use, including cutbacks from normal use that result in economic losses.

Water supply shortages varied across urban areas, as did water agencies' drought management policies. A preliminary survey of the 11 members of California Urban Water Agencies indicated that some agencies targeted cutbacks equally across customer classes, but others targeted larger cutbacks at residential users than at industrial and commercial users, to avoid losses in output and jobs. However, actual cutbacks varied considerably from the targets set by water agencies.

To estimate the economic effects of water cutbacks, we must know how those cutbacks were distributed among customer classes. Therefore, the first step in understanding the urban impacts of the drought should be a survey of water agencies to determine what drought management policies were implemented, when they went into effect, and the resulting changes in residential, commercial, and industrial water deliveries.[1]

Our preliminary research also included contacts with commercial and industrial business associations and state agencies. The information collected from these groups was largely anecdotal, but it tended to confirm that residential water users faced the biggest cutbacks because commercial and industrial users were protected from cutbacks that would have resulted in lost output or jobs. However, some types of commercial

[1]In addition to helping us understand the economic impacts of the California drought, this information can help us evaluate the effectiveness of drought management policies. However, a general evaluation of the effectiveness and fairness of various drought management policies, such as price increases, quantity restrictions, restrictions on type of use, public education, conservation kit distribution, and water audits, is beyond the scope of this research agenda.

businesses, such as nurseries, gardeners, and landscape contractors, were affected by a drop in demand for their products or services.

We suggest three possible approaches to estimating residential household impacts—impacts that consist mainly of lifestyle or psychological losses rather than losses to measured gross state product. The first approach is to estimate residential willingness to pay for water, using demand analysis, based either on existing estimates of water demand curves and price elasticities or on new demand curve estimates derived from data on water consumption during the drought, obtained from agencies that used price increases as the main drought management policy. Relatively few agencies used price as their main drought management policy. Most relied on quantity or use restrictions. We need to collect data from the former agencies because they are likely to provide more accurate estimates of price elasticities.

The second approach is to conduct a valuation survey asking households to place a dollar value on the psychological or lifestyle losses they faced as a result of water cutbacks. It would provide a breakdown of the relative values of different types of household water uses,[2] as well as an overall estimate of residential drought impacts. However, a very large sample size would be required to produce accurate estimates of overall residential losses.

The third approach is a hybrid, using water demand analysis to place an overall value on household economic losses and a small residential survey to determine the relative values of different household water uses. Because the survey would not be needed to estimate overall losses, a smaller sample size would be sufficient.[3]

To assess the commercial impacts of the drought, we suggest conducting valuation surveys tailored for particular commercial sectors. Some sectors may have been affected primarily by cutbacks in the supply

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[2]Household water uses can be broken down into indoor uses, including baths, showers, toilets, laundry, cooking, and cleaning, and outdoor uses, including gardening, landscape irrigation, pools, and car washing.

[3]When a survey is used to estimate the overall value of economic losses, a large sample size is needed because the magnitude of cutbacks varied across the state's urban areas. However, we do not expect the relative values of household uses to vary as much across the state.

of water, whereas others were affected by drought-induced reductions in demand for their products or services. Therefore, a general survey of commercial businesses is unlikely to be useful. This approach would target commercial sectors that were hit hardest by the drought and would quantify their losses rather than providing an overall estimate of drought-related commercial economic losses. However, the sum of losses in the targeted sectors should cover a large share of total commercial losses and thus provide a lower bound on overall commercial impacts.

Our anecdotal evidence indicates that the industrial impacts of the drought were probably small. A valuation survey of industrial users could be used to assess the economic impacts of the drought, but the sample size would have to be large to cover many heterogeneous industrial sectors, and the outcome is likely to verify the anecdotal evidence.[4] We suggest that some follow-up work in contacting industrial associations and individual firms is likely to be adequate in this area.

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[4]Industrial users have no incentive to understate their losses, so we have no reason to disbelieve the anecdotal evidence. Water-agency representatives also indicate that one of their objectives was to avoid industrial water cutbacks that would have resulted in lost output and jobs, particularly during the 1990-1991 recession.

ACKNOWLEDGMENTS

The authors wish to thank the members of California Urban Water Agencies and representatives of user groups for providing information for this study. In particular, we thank Lyle Hoag, the Executive Director of CUWA, and the members of the CUWA Project Advisory Committee for their input. Our work also benefited from contacts with Ray Hoagland and Steve Macaulay of the California Department of Water Resources; Bill Wade and Wendy Illingworth of Spectrum Economics, Inc.; and Joy Parsons of Black & Veatch. We also thank Steven Garber for providing extensive comments on this document and Olivia Contreras for typesetting assistance.

The member agencies of CUWA and their project advisory committee representatives are Alameda County Water District (Paul Piraino), Contra Costa Water District, East Bay Municipal Utility District (Greg Ford), Los Angeles Department of Water and Power (Richard West), Metropolitan Water District of Southern California (Tim Quinn), Municipal Water District of Orange County (Art Bruington), Orange County Water District (James Van Haun), San Diego County Water Authority, San Diego Water Utilities Department, San Francisco Water Department (Chris Morioka), and Santa Clara Valley Water District (Leo Cournoyer).

Other groups that provided information are Association of California Water Agencies, Bay Area Water Users Association, California Chamber of Commerce, California Chemical Industry Council, California Department of Commerce, California Hotel and Motel Association, California Manufacturers Association, Council for a Green Environment, and Nurserymen's Association of California.

1. INTRODUCTION

The most obvious economic impacts of the California drought have occurred in agricultural areas. However, water shortages can cause losses of output and jobs in commercial and industrial sectors, and can impose lifestyle and psychological costs on residential water users in urban areas. An estimate of the statewide economic impacts of the drought on all urban activities can help to inform California decisionmakers, water managers, and the general public about the cost of water shortages in urban areas and, conversely, the value of water in urban uses. This information can be useful in such forums as the Bay-Delta hearings, where state policymakers make decisions about the allocation of water among environmental, agricultural, and urban uses.[1]

Agricultural water users have sponsored a number of studies to estimate the impacts of water shortages. The latest study by Northwest Economic Associates estimates that the 1991 drought in the San Joaquin Valley idled 25,000 acres of land, contributed to a drop in total farm revenues of $281 million, raised farm water costs by $163 million, and caused the loss of 5,000 farm jobs and 4,050 jobs in related industries. In addition, the California Department of Water Resources is currently sponsoring a study of the 1991 Drought Water Bank that will assess the indirect costs incurred by third parties when water was transferred from agricultural to urban areas. An assessment of the economic effects of the 1991 drought in urban areas is needed as a complement to these studies.

Some studies have already estimated the drought's effects in a particular year, on various urban sectors, or in particular locations. As yet, there has been no comprehensive, statewide study of the costs of water shortages to urban users. This document reports the results of a

[1]California's water supplies are currently allocated on legal, historical, and political bases rather than through a statewide price mechanism or on the basis of costs and benefits; consequently, water does not necessarily go to its highest-valued uses. However, the use of a pure price mechanism for allocation of water would be complicated by physical and environmental constraints.

preliminary research effort sponsored by California Urban Water Agencies (CUWA) with the dual purpose of surveying and assessing the adequacy of current drought impact studies, and outlining and prioritizing the additional studies that are needed to improve current drought impact estimates.

In preparation for this report, we assessed existing drought impact studies; contacted the member agencies of CUWA, user representatives, and other interested groups; and searched the academic literature for relevant studies on measuring urban drought impacts, the demand for water, and analytic techniques to estimate economic impacts. From this information, we identified the additional data that would be needed to estimate the drought's impact on residential, commercial, and industrial water users. We then developed a research agenda to obtain these missing data.

In Section 2, we provide background information on the drought and report general findings from our preliminary research. We discuss the distribution of the drought's impacts throughout California and among user classes, as well as anecdotal information obtained from user representatives, and we assess existing studies of drought impacts. In Section 3, we discuss potential research approaches to identifying the impacts of the drought in urban areas and to estimating the dollar value of the resulting economic losses to the residential, commercial, and industrial sectors. In Section 4, we give our conclusions and recommendations for further research.

2. ASSESSING DROUGHT IMPACTS IN URBAN AREAS

Figure 1 shows a schematic representation of the drought impact process. Water supply shortages, which are determined by the hydrology of the region, as well as by the availability of alternative sources of supply, drive each water agency's target cutbacks.[1] The water agencies then determine what drought management policies they will use to try to obtain the desired level of cutbacks. The agencies' drought management policies influence user behavior, which determines actual water use and economic losses.

Economic losses are the end product of the drought impact process. Residential economic losses are defined as losses in *consumer surplus*, which is the difference between a consumer's willingness to pay for water (i.e., its value in use) and the actual price he or she pays for it.[2] When water supply shortages occur, consumers lose this surplus on water they can no longer buy, and price increases create a transfer of

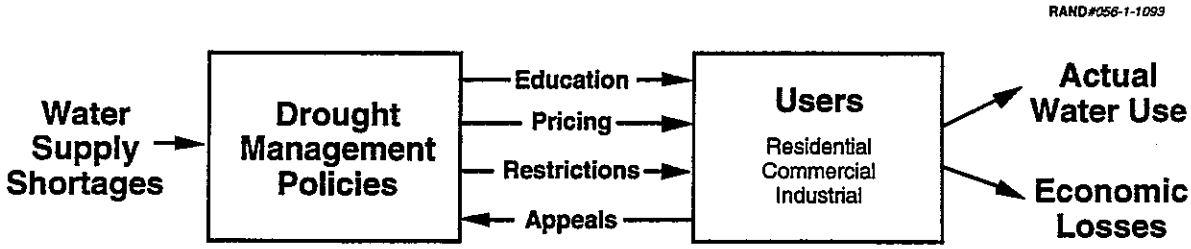


Figure 1—Drought Impact Process

[1]Retail water agencies obtain water from a variety of sources, including agency-owned surface water and groundwater; recycled or reclaimed water; local, state, and federal water projects; and wholesale water agencies. In 1991, the Drought Water Bank allowed transfers from agricultural areas to areas with "critical needs," including some urban areas. In California, most retail water agencies are city-owned or special districts with elected boards, rather than investor-owned, regulated companies. They serve populations that range from less than 100 to over 3,000,000.

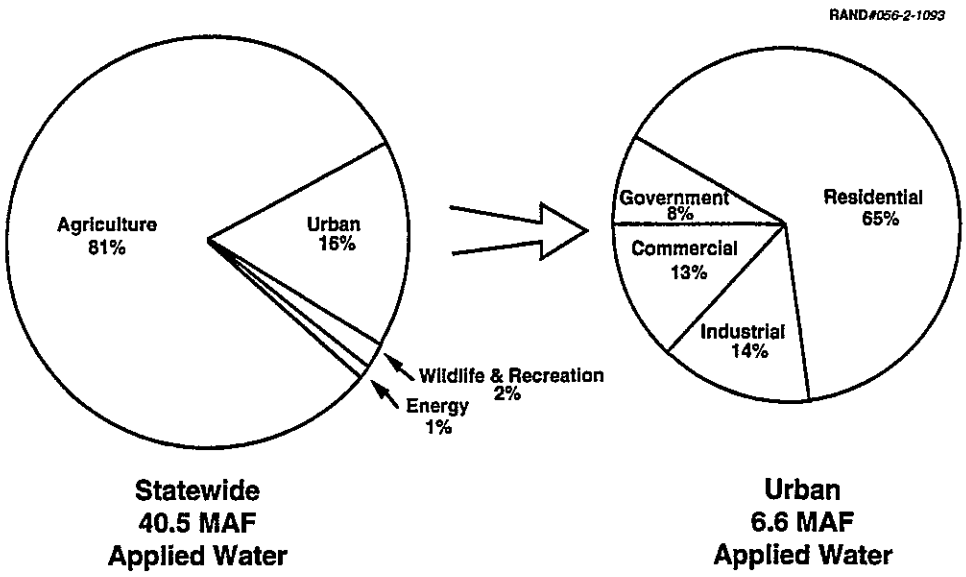
[2]See the Appendix for a discussion of the concept of consumer surplus.

income from consumers to water agencies. Commercial and industrial businesses use water as an input, or water supply may affect the demand for their products (e.g., gardeners and nurseries). Water shortages also cause losses in producer surplus, or profits. If, as a result, water shortages cause businesses to reduce levels of output, such reductions can, in turn, affect employees and other input suppliers. Employees will suffer economic losses if they remain unemployed or accept lower-paying jobs, and suppliers will be adversely affected if they cannot find alternative customers at the same price.

To estimate the economic impacts of the drought, we need to understand how the drought impact process determines water use and economic losses. As part of our preliminary research, we collected information on each stage in this process, as well as background information on water use in the state. In the subsections below, we first review some statistics on water use and water users' contributions to the gross state product. Then we describe our preliminary findings on the extent of water supply shortages, the types of drought management policies implemented, and the responses of water users.

WATER USERS AND THEIR CONTRIBUTION TO THE GROSS STATE PRODUCT

The distribution of applied water (developed sources of water rather than precipitation) use in California in 1985 (before the drought) is illustrated in Figure 2. Urban water use accounted for about 16 percent of the state total. The biggest urban use is residential, followed by industrial and commercial. However, if we look at the largest contributors to California's gross state product, we find from Table 1 that commercial businesses account for 55 percent of the total. Industrial and commercial businesses together represent all but one-eighth of the state's economy. By definition, the value of residential water use is not included in the gross state product. Nonetheless, we argue that lost consumer surplus is an important component of the economic impact of the drought, and the costs to residential users are no less real than the costs to commercial and industrial users.



SOURCE: State of California DWR, Bulletins 160-87 and 198-84.

NOTE: "Agricultural" water use includes only irrigation of crops. Residential, commercial, and industrial uses in rural areas are counted as "urban" uses.

Figure 2—Water Use in 1985 (million acre-feet [MAF])

Table 1

Contributions to California's Economy

Sector	1986 Gross State Product	
	Total ($ billions)	Percentage[a] (%)
Agricultural	11	2
Industrial	169	32
Commercial	291	55
Government	62	12
TOTAL	533	100

SOURCE: State of California, *California Statistical Abstract*, Sacramento, Calif., 1991, Table D-2, p. 47. Prepared on an industry or gross-product-originating basis.

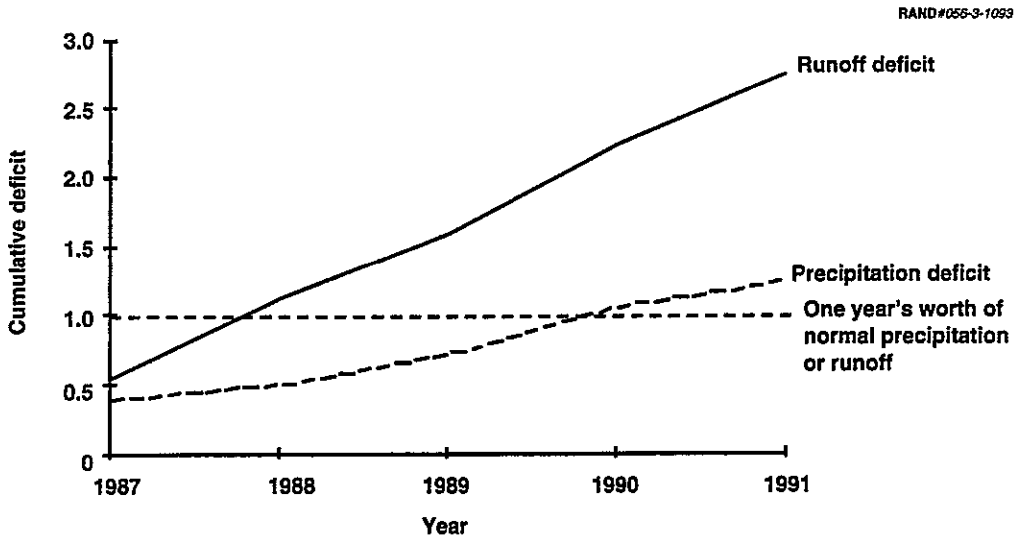
[a]Percentages have been rounded; their rounded total is 101 percent.

Ideally, water supply shortages should be distributed to minimize economic losses. However, legal and institutional constraints prevent large-scale redistribution of water between competing uses. Therefore,

water cutbacks were not necessarily distributed according to the value of water in different uses. An estimate of urban economic losses will help to indicate how the costs of water cutbacks were distributed across the state among urban, agricultural, and environmental uses, and, within urban areas, how cutbacks were distributed among residential, commercial, and industrial users.

HOW BAD WAS THE DROUGHT?

The first element in the drought impact process shown in Figure 1 is the existence of water supply shortages. Since 1987, statewide precipitation and runoff have been below normal.[3] Figure 3 shows the five-year drought's cumulative effect on average statewide precipitation and runoff. Whereas the average cumulative deficit in precipitation is a little more than one normal year's worth of rain, the average cumulative deficit in runoff, which is the primary source of California's water supply, is about three years' worth.

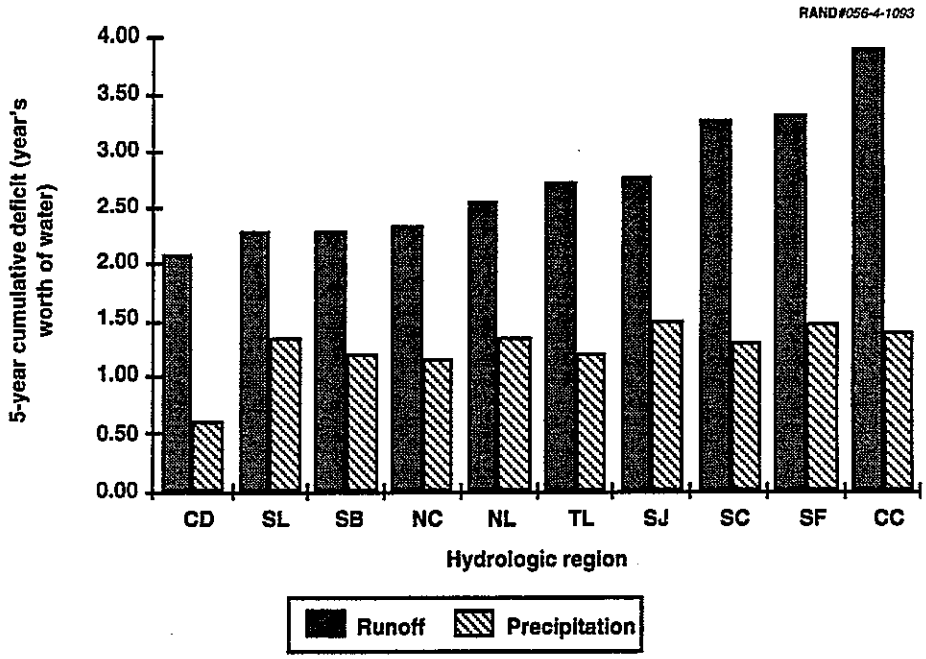


SOURCE: State of California DWR, *California's Continuing Drought 1987–1991*, Sacramento, Calif., December 1991.

Figure 3–Precipitation and Runoff Deficit

[3] *Precipitation* includes water that evaporates or is absorbed by vegetation; *runoff* represents the water that can be captured by the state's reservoir system and can be used by its population.

Water shortages were not evenly distributed across California. Figure 4 shows how the cumulative precipitation and runoff deficits were distributed among hydrologic regions. The state's large aqueducts transfer water among these regions and bring water in from regions outside the state. Water imports help to mitigate the drought's impact on specific regions. Note that the cumulative deficit was the worst—almost four years of normal runoff—in the Central Coast region (around Santa Barbara), which has little capability to import water from other regions. Because many regions of California have access to several sources of supply—local, imported, and groundwater—hydrologic data alone are insufficient to determine the extent of the drought's severity.



SOURCE: State of California DWR, *California's Continuing Drought 1987–1991*, Sacramento, Calif., December 1991.

NOTE: California's hydrologic regions are abbreviated as follows: Colorado Desert (CD), South Lahontan (SL), Sacramento (SB), North Coast (NC), North Lahontan (NL), Tulare Lake (TL), San Joaquin (SJ), South Coast (SC), San Francisco Bay (SF), and Central Coast (CC).

Figure 4—Precipitation and Runoff Deficit by Hydrologic Region

PLANNED VERSUS ACTUAL CUTBACKS

Drought management policies formulated by the water agencies are the second element in the drought impact process. Water agencies throughout the state determined how much their customers had to cut back according to the agencies' available water supplies, including imports. As part of our preliminary study, we sent a questionnaire to all CUWA members[4] asking for information about water rates, number of customers, water deliveries, water revenues, drought management policies, and target cutbacks and actual cutbacks over the periods 1986-1991 and 1975-1977. For wholesale agencies, we asked for a breakdown by member agencies (i.e., the retail agencies they supply); for retail agencies, we asked for a breakdown by residential, commercial, and industrial customers.

The responses to these questionnaires show that the degree of water shortage varied among agencies, as did their drought management policies, both in the target cutbacks expected from each customer group and in the methods used to achieve those cutbacks (e.g., voluntary versus mandatory, quantity restrictions versus higher prices). Therefore, it could be very misleading to try to determine the economic effects of the drought throughout California's urban areas by extrapolating from the experiences of a few water agencies. Accordingly, we suggest that further research to estimate the economic effects of the drought cover a broad sample of urban water-agency service areas.

Figure 5 shows how cutbacks varied among CUWA member agencies. Target cutbacks varied from a low of 15 percent to a high of 30 percent.

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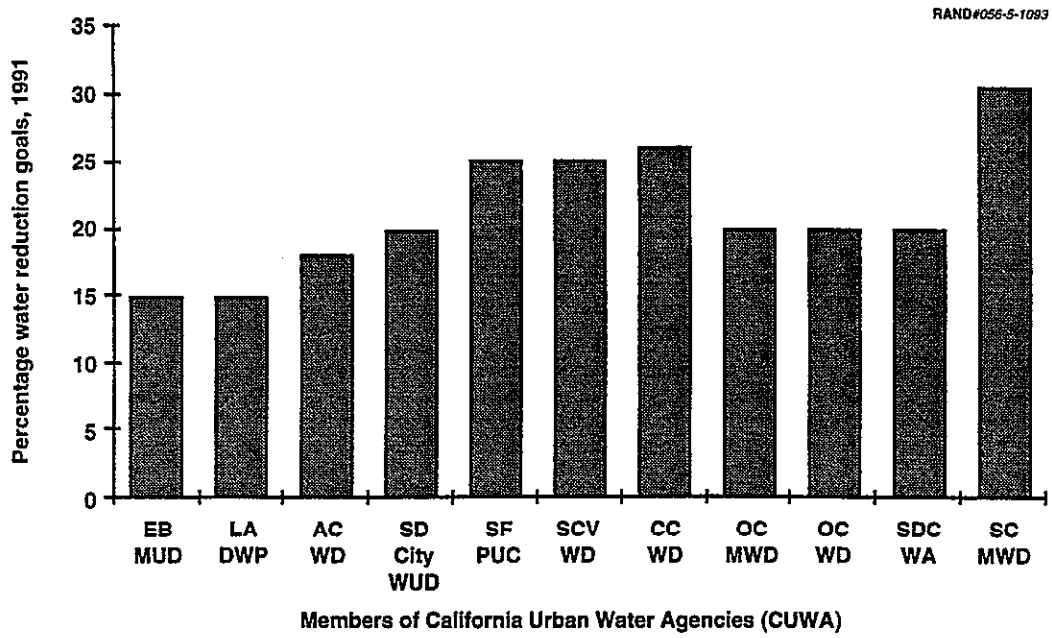
[4]The members of California Urban Water Agencies (CUWA) are Alameda County Water District (ACWD), Contra Costa Water District (CCWD), East Bay Municipal Utility District (EBMUD), Los Angeles Department of Water and Power (LADWP), Metropolitan Water District of Southern California (MWDSC), Municipal Water District of Orange County (MWDOC), Orange County Water District (OCWD), San Diego County Water Authority (SDCWA), San Diego Water Utilities Department (SDWUD), San Francisco Water Department (SFWD), and Santa Clara Valley Water District (SCVWD). CUWA members include wholesale and retail water agencies in the San Francisco Bay Area and the Los Angeles and San Diego metropolitan areas. Together they cover two-thirds of the state's population, although not all at the retail level.



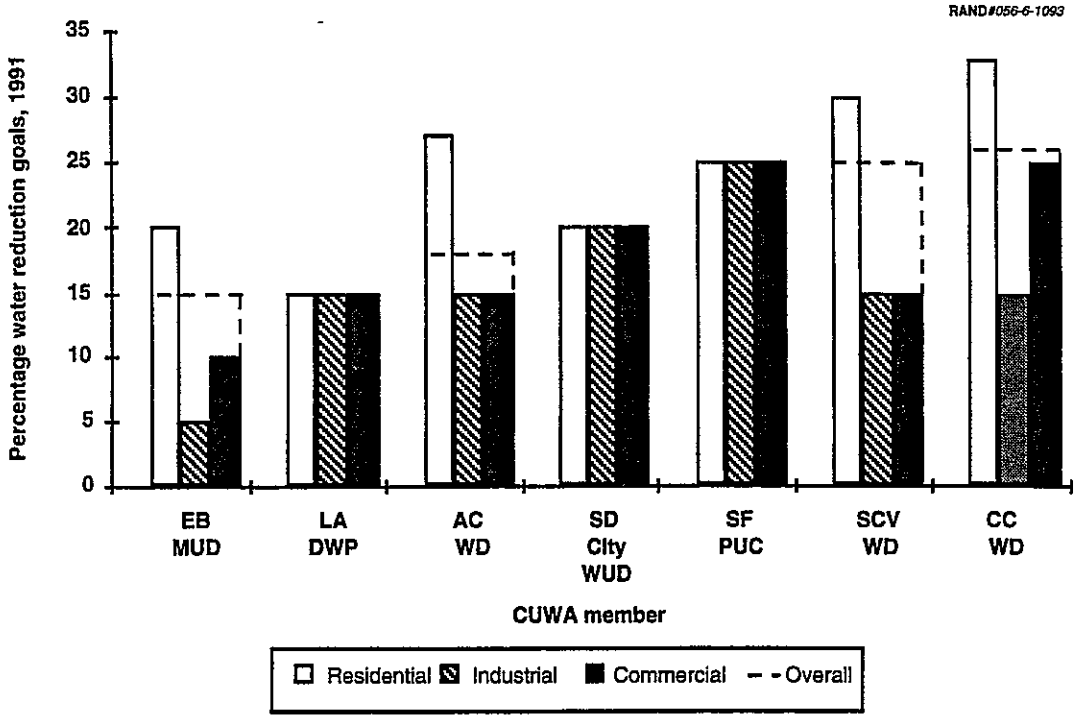
Source: CUWA , *Survey of 1991 Drought Management Measures*, Sacramento, Calif., June 1991.

Figure 5—Large Variation in Planned Overall Urban Cutbacks

These cutbacks were not always distributed evenly among the water agencies' user classes, as Figure 6 illustrates. Those agencies that varied cutbacks among users cut residential users much more than industrial or commercial users.

Throughout California there was tremendous variation in the drought management policies that water agencies used to reach water-cutback goals. The policies ranged from voluntary programs that emphasized education and the distribution of water-saving devices and literature to mandatory programs that included usage and/or quantity restrictions and price increases. Many agencies used a combination of such policies to attain their cutback goals. Customer responses, and the resulting economic impacts, depend on the drought management policies customers faced (e.g., price increases or quantity restrictions).

Note that the cutbacks in Figure 5 are *planned* cutbacks, not the *actual* cutbacks realized by their customers. Going back to Figure 1, we see that planned cutbacks (restrictions) are part of drought management policies, whereas actual cutbacks (actual water use) are one of the



Source: CUWA , *Survey of 1991 Drought Management Measures*, Sacramento, Calif., June 1991.

Figure 6—Large Variation in Planned Cutbacks Among Urban Users

outcomes of the drought impact process. Water agencies had to implement drought management policies without being certain what the customer response would be. Some customers exceeded the target cutback levels; others did not attain the target use levels. Most agencies that used quantity restrictions allowed customers to appeal their cutbacks. For example, households could make an appeal for medical reasons or if they had a large number of family members; commercial or industrial businesses could appeal if they would have had to cut employment or output.

In the responses to our preliminary survey, some CUWA retail agencies were not able to report actual cutbacks by customer category, only an overall figure for all customers. The two agencies that reported the most comprehensive breakdown of actual cutbacks by customer type were the Alameda County Water District (ACWD) and the East Bay Municipal Utility District (EBMUD). Table 2 shows their planned and actual cutbacks for 1991.

Table 2

Planned Versus Actual Cutbacks

	ACWD		EBMUD	
Customer Type	Planned	Actual	Planned	Actual
Residential	27%	15.9%		
Single-family			20%	33%
Multifamily			7%	22%
Commercial	15%	8.6%	10%	27%
Industrial	15%	0.5%	5%	36%
Public authority	15%	25.9%		
Landscape irrigation	50%	22.8%	30%	32%
Self-supplied groundwater	0%	27.5%		
OVERALL	18%	18%	15%	28%

These figures are not directly comparable: The EBMUD figures have a base year of 1987 and are adjusted for growth, whereas those for ACWD have a base year of 1990 and are not adjusted for growth. Another difficulty in comparing across water agencies is that, whereas some report water use by calendar year, others report water use by fiscal years that end in different quarters. To compare planned and actual water cutbacks across water agencies, additional data on cutbacks must be normalized to the same base year and adjusted from fiscal years to calendar years.

The difference between target and actual cutbacks reported by ACWD and EBMUD illustrates the point that, to estimate urban economic impacts of the drought, it is not sufficient to gather relatively easily available data on agencies' target water cutbacks by customer class.[5] To calculate actual cutbacks (relative to a consistent base year and adjusted for growth), it is also necessary to collect data on actual water deliveries during the drought and the resulting economic impacts.

CONTACTS WITH USER REPRESENTATIVES

The third element in the drought impact process is the water user. We contacted a number of representatives of various water user groups to

[5]California water agencies serving populations over 3,000 were required to submit drought management plans to the state Department of Water Resources, including target water cutbacks for various levels of water shortages.

obtain anecdotal or factual data they had collected on the impact of the drought on their constituents. The following summarizes what we found.

The California Department of Commerce's 1990 estimate of the drought's impacts concluded that the drought's overall economic effects were small and that agriculture suffered the largest losses.

The California Chamber of Commerce has not done any drought impact studies. However, its water policy representative believes that the biggest urban impacts were on residential users, because commercial and industrial users were protected by water agencies from large losses.

The Association of California Water Agencies'(ACWA) 1991 report on the drought, *California's Continuing Water Crisis: Lessons from Recurring Drought, 1991 Update,* stated that many water agencies shifted the burden for additional conservation to residential customers. The report observed that many water-dependent industries have maintained production levels despite cutbacks. However, ACWA noted that the horticultural sector has suffered substantially.

The Bay Area Water Users Association noted that many industrial firms in the San Francisco Bay Area exceeded water-cutback goals. However, these industrial cutbacks cannot be attributed solely to the drought and to local agency management policies without additional investigation. New regulations regarding industrial effluent and toxic waste, as well as the threat of future liability, may be contributing factors driving industry's behavior. In addition, industrial output and water use may have been reduced by the 1990-1991 recession.

The California Manufacturers Association stated that drought was not an issue for its members. We cannot conclude from this statement that manufacturers were not affected by the drought. It may be that many other factors affected their cost of doing business much more than the drought.

The California Chemical Industry Council representative said that there were no job losses among his members. However, they noted that there was not much additional capacity for conservation in the chemical industry. Reliability (i.e., the possibility of a complete cutoff of water supplies, analogous to blackouts in electricity supply) is more important to the chemical industry than the price of water. He also

noted that the threat of future mandatory regulation of technologies reduces member incentives to invest in conservation now.

The California Hotel and Motel Association stated that the impact of the drought varied by region. Ski areas and Santa Barbara were hit hard because of the publicity surrounding the drought, as well as because of the lack of snow and water.

The Council for a Green Environment, representing nurseries and landscape contractors, stated that sales were down 20 to 50 percent from 1990 levels and estimated that about 300,000 jobs were lost as a result of the drought. Contradicting these numbers are the Department of Water Resources' estimates of a 7 percent loss in sales and 5,630 jobs lost in the green industry once the effects of double-counting and the recession were taken into account.

The Nurserymen's Association of California estimated that business was off from 12 to 40 percent. However, it noted that it cannot separate the effects of the recession from the effects of the drought.

STUDIES OF DROUGHT IMPACTS

An important part of our preliminary research was an assessment of existing studies of economic losses from the drought—the end point of the drought impact process in Figure 1. These studies might help to produce an overall estimate of the urban impacts of the drought. We conducted a search of the academic literature for studies on a wide range of water issues published from 1970 to the present. Our search yielded over 300 citations, which we organized into a bibliography with the following general headings: water demand and price sensitivity, demand management, water conservation, economic theory of water pricing and allocation, water supply, legal issues, water transfers, and measuring drought impacts.

As part of our initial research effort, we concentrated on the publications that were most directly relevant to portraying the California drought and estimating its economic effects. The contributions of these studies to measuring urban drought impacts on residential, commercial, and industrial water users are summarized below. Many of the additional references, particularly those on water

demand and price sensitivity, should be useful in carrying out the suggested research agenda.

Cost of Industrial Water Shortages

The most comprehensive recent study of industrial water use and vulnerability to droughts in California is *Cost of Industrial Water Shortages* by Spectrum Economics (Wade et al., 1991). The Spectrum survey collected 1990 data; it does not include information on actual drought impacts in 1991. However, the report contains some useful information. The survey collected data on the cost per acre-foot (AF)[6] of conservation projects in 22 industrial categories, which give a lower bound on the willingness to pay for water in industrial processes.

When the cost per AF of conservation projects exceeds the avoided water intake and disposal[7] costs, firms may be "buying insurance" against future water shortages. However, water conservation projects may also be undertaken to meet environmental restrictions on the volume and levels of pollutants in effluent water or to avoid future environmental liabilities, rather than to protect against water supply shortages. To estimate drought impacts, it would be necessary to separate these two effects.

Some additional data are needed to confirm whether the cost per AF of conservation projects exceeds avoided water costs at a plant-by-plant level. The Spectrum data set contains pre-disposal water treatment costs and sewage fees for individual firms, but uses statewide averages of water-intake costs. Firm-level data on disposal costs should be matched with the water-intake costs and local drought management policies affecting each firm. Putting these elements together would give an indication of the costs firms were already undertaking to avoid water supply shortages, provided that these effects could be separated from those caused by environmental regulations.

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[6]An *acre-foot* is the volume of water needed to cover an acre to the depth of one foot. It is equal to 325,000 gallons, or approximately enough water to meet the needs of a family of five for one year.

[7]Disposal costs include sewage and effluent charges.

Further information on industrial water demand curves[8] and actual water cutbacks during the drought would be needed to assess overall economic losses to industry as a result of the drought. More direct information from firms is needed to evaluate losses to workers.

Commercial and Industrial Water Use

Another source of information is a study by Planning and Management Consultants, Ltd., *Commercial and Industrial Water Use in Southern California* (Dziegielewski et al., 1990). The purpose of this study was to estimate average water use per employee for various commercial and industrial sectors in Southern California to forecast water demand. However, because the forecasting method is based on average rather than marginal water use per employee, it cannot be used to relate water cutbacks to losses in employment. Businesses could conserve on employee sanitation and landscape irrigation and could appeal to their water supply agency rather than laying off employees or reducing production in proportion to water supply shortages. Nor does the study attempt to estimate water demand curves, which could be used to estimate drought-induced losses in profitability.

For the purpose of estimating the urban impacts of the drought, this study identifies the types of industries and commercial businesses that have the heaviest water use per employee and highest total use. The heaviest commercial user categories are restaurants; hotels and motels; hospitals and health service establishments; nursing and personal care facilities; urban construction sites; recreational facilities, such as golf courses, swimming pools, health clubs, and parks; car washes; and commercial laundries. The largest industrial users are chemicals and allied products; primary metal industries; paper and allied products; petroleum and coal products; food and kindred products; electric and electronic equipment; and transportation equipment.

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[8]*Water demand curves* show the relationship between the price of water and the amount demanded by users.

Case Study of Santa Barbara

The most informative study to date of the residential impacts of the drought is *The Costs of Water Shortages: Case Study of Santa Barbara* by Spectrum Economics and Sycamore Associates (1991). This study focuses on the effects of the drought in 1990, the worst drought year for Santa Barbara. It shows how residential water consumption and billing changed in response to drought management plans in Santa Barbara and Goleta. It also provides a direct estimate of the value of dead and damaged landscaping based on a field survey of homes and motels and hotels.

The City of Santa Barbara combined mandatory conservation directives with steeply rising block water rates as its drought management policy. Average single-family consumption fell 62 percent, while average monthly water bills increased by nearly 90 percent. However, water bills fell for very low water users because of the increasing block price structure, under which the price rose as the level of use increased.

The Goleta Water District implemented quantity restrictions, changed its rate structure to a higher flat price up to an allotment level, and set penalty rates for water use above the allotment. Average single-family water consumption fell 40 percent, and the average bill increased by 45 percent. In Goleta, households consuming smaller quantities of water faced higher percentage price increases than most households consuming larger quantities.

These findings illustrate the variation in economic effects that can arise from different drought management policies. Clearly, low water users fared very differently in Santa Barbara than they did in Goleta, and the economic effects on them were different. The levels of cutbacks achieved in the two districts were different, which also will cause changes in the residential economic impacts. However, the Spectrum study does not take the next step in the valuation process: estimating water demand curves or residential willingness to pay for water, and using price and quantity changes to obtain the dollar value of consumer-surplus losses.

The Spectrum study does assign a dollar value to one aspect of residential losses: the cost of lost landscaping. A survey was conducted to determine the percentage of dead and damaged trees, lawns, shrubs, and other plants. Trees were valued according to a legal formula developed for court cases involving tree damage or loss, and other forms of vegetation were valued according to replacement cost. Countywide losses were estimated at $234 million worth of shrubs, lawns, and groundcover, and $192 million worth of trees. However, these are likely to be overestimates, because property owners will not necessarily replace dead plants with equally mature vegetation, especially mature trees. Furthermore, the rate of plant loss cannot be extrapolated outside the Santa Barbara area, because the drought was much more severe there than in other parts of the state.

The Santa Barbara study also includes some information on economic losses suffered by two commercial sectors: the green industry (nurseries, landscape maintenance, landscape contractors, and landscape architects) and construction. For the green industry, Spectrum estimated the number of jobs lost, but it did not attempt to assign an economic value to the job losses or to assess the availability of alternative employment for the affected workers. Job losses varied in the subgroups of the green industry. Employment fell during the drought at nurseries and landscape maintenance operators, particularly among unskilled landscape maintenance workers (i.e., lawn mowing and leaf blowing). However, landscape contractors (such as those installing drip irrigation systems) and landscape architects (designing drought-tolerant landscaping) had increases in employment.

The construction industry was directly affected by drought management policies. In Santa Barbara, construction was prohibited on undeveloped land, and construction in developed areas had to demonstrate no new net water use. (If additional water use was needed on the site, the developer had to pay for other water users to install low-flow devices or take other conservation measures to reduce existing water use enough to offset the new use.) The Spectrum study measured construction losses in terms of a reduction in the number and total value of building permits. The number of residential building permits issued over 1988-

1990 fell 75 percent, and the estimated value of residential construction fell by nearly 60 percent compared with that for 1980-1987.

Some of this reduction may have been due to the recession, but the number of building permits issued in Los Angeles and Orange counties, where the drought was less severe, fell by only 29 percent and 15 percent, respectively. However, this comparison lacks an adequate control for the effects of the recession. Because Spectrum's approach ignores the costs and alternative uses for construction inputs, it is not a true estimate of profitability losses in the construction industry, nor of economic losses to suppliers and employees.

Because the severity of the drought varied geographically, it is not possible to extrapolate the Santa Barbara results to other urban areas. It will be necessary to gather information throughout California to assess the drought's statewide economic impacts on commercial businesses. The Santa Barbara study was also limited to two specific areas—the green industry and construction—whereas other commercial sectors may have also suffered economic losses from the drought.

California Water Charge Survey

Another potentially useful source of information on residential impacts is the *California Water Charge Survey* conducted by Black & Veatch (1991). The report shows typical monthly charges to residential customers for 335 California cities and water purveyors as of October 1991. Black & Veatch also has unpublished information on service charges, block water rates, and sewer rates that they may be willing to release. However, they do not have water rates for any years prior to 1991, so, to estimate consumer-surplus losses, it would still be necessary to survey retail water agencies to find out how water rates for residential customers changed during the drought, and whether other drought management policies (such as quantity restrictions) were used.

Societal and Environmental Costs of the Drought

The Pacific Institute for Studies in Development, Environment and Security produced a study entitled *The Societal and Environmental Costs of the Continuing California Drought* (Gleick and Nash, 1991). It is a collection of information on the statewide impacts of the drought,

mainly obtained from secondary sources, and includes impacts on agriculture, forestry, recreation, and the environment. Although the authors conclude that the main impacts of the drought were environmental, including declining fish and wildlife populations, tree mortality in the Sierra Nevada, and increased risk of fire, they do not attempt to place a dollar value on those impacts. The study has minimal information specifically on urban impacts, but it does provide an estimate of a $600 million loss in 1991 caused by the necessity of replacing lost hydroelectric power with power generated by other fuels. This loss would have largely been passed on to urban energy customers, since most electricity use is in urban areas.

IMPLICATIONS FOR FUTURE STUDIES OF URBAN DROUGHT IMPACTS

These studies and the anecdotal information from user representatives outlined above suggest that residential customers may have absorbed the largest economic impacts of the drought. It also appears that the drought's industrial impacts may be small. Relatively little is known about commercial impacts, except that the green industry and a few other water-dependent sectors may have been substantially affected. Information from CUWA members also indicates that most industrial and commercial customers were protected from water cutbacks that would have resulted in lost output and jobs, and that residential users were often expected to absorb a larger share of cutbacks. The major commercial impacts were felt by sectors for which demand is water-dependent (such as nurseries and pool contractors) and by sectors for which activity was explicitly curtailed (such as construction) as a drought management policy. Therefore, studies of residential impacts and selective commercial sectors are likely to identify most of the drought's adverse economic impacts. A study to estimate the drought's economic impacts on the industrial sector may not be worth the cost.

We have established that the economic impacts of the drought varied greatly by region, water agency, and customer type. Consequently, it is difficult to generalize, average, or extrapolate from a small study or sample of data to all of California. We also learned that an estimate of the impacts of the drought on urban areas requires data on drought

management policies, including price increases and quantity restrictions, and actual cutbacks by each customer type. This finding argues that any study to estimate the drought's economic impacts on urban areas must begin with a statewide survey of urban retail water agencies to obtain this information.

Next we turn to our proposals for further research.

3. AN AGENDA FOR FURTHER RESEARCH

The goal of this research agenda is to obtain good estimates of the dollar value of the drought's urban economic impacts. A necessary component of any assessment of drought impacts is a survey of water agencies to learn what drought management policies were implemented and how water users responded. Drought management policies establish the prices consumers paid and any restrictions on water quantities and/or types of use. Actual water quantities used depend on customer responses to such policies. Other drought management policies, such as public education, water audits, distribution of conservation kits, and rebates for water-saving investments, may shift the demand for water.

We describe the water-agency survey below, then outline alternative ways to estimate residential, commercial, and industrial impacts.

WATER-AGENCY SURVEY

Survey Objectives

As our preliminary research has indicated, the essential first step to estimating the economic impacts of the drought is to learn how its effects were distributed. This step involves surveying a sample of urban retail water agencies to learn the distribution of water shortages; the target and actual cutbacks for residential, commercial, and industrial customers; and the drought management policies implemented. Although each agency had to submit a drought management plan to the Department of Water Resources, we need to know which phases of the plan were put into effect and when, and the actual cutbacks that resulted.

From our survey of CUWA members, we observed that actual cutbacks achieved by customers differed from target cutbacks set by the agencies. Some customer groups exceeded their targets, whereas others may have been allowed exemptions from cutbacks for various reasons. Therefore, it is not sufficient to gather information about target cutbacks from drought management plans. To determine what the economic impacts were,

we need to know how actual water usage changed in the various customer classes.

Our preliminary survey also indicated that it may be difficult to ensure that information gathered from different agencies will be comparable: Agencies used different base years from which to compute target cutbacks; some water agencies report by calendar year; and others have fiscal years that end in various quarters. In a water-agency survey, it will be necessary to compensate for these differences in reporting by asking for monthly or quarterly data on water use, and comparing cutbacks to a consistent base year.

In addition, as the Santa Barbara study indicated, the types of drought management policies implemented influenced customer responses, and also the economic losses they incurred. In particular, quantity restrictions are more rigid than using pricing to achieve cutbacks. Quantity restrictions based on past use tend to place more of the burden on past conservers, whereas increasing block rates mean that the highest water users pay the most.

Survey Design

To collect the necessary information so that pre-drought data from 1986 can be compared with data as the drought worsened over the years 1987-1991, a water-agency survey should include questions on water rates, water deliveries, target and actual cutbacks, and drought management policies for residential, commercial, and industrial customers over the period 1986-1991. The data should be collected on at least a quarterly basis to ensure that they can be compared across water agencies with different fiscal years. Information on water deliveries should be broken down by residential, commercial, and industrial customer classes, with a further breakdown of residential use into single-family and multifamily categories, if possible.[1] The water-delivery data will then need to be adjusted for economic and population growth to assess water savings during the drought.

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[1]Multifamily residences often have a single water meter for the entire building, so incentives for residents to conserve water are different than those of single-family residences.

Data on water rates should include standby charges (fixed charges that do not depend on the level of water use) for various connection sizes and block charges for water use for various customer classes. Descriptions also are needed of the phases and components of drought management plans (mandatory or voluntary, quantity and/or use restrictions, price increases, distribution of water-saving devices, when such components were in effect, etc.). Water agencies should be asked to provide the target cutback goals and actual water savings achieved for each customer class.[2]

The sample frame for the survey consists of approximately 350 retail water agencies serving populations greater than 10,000, located throughout the state. We estimate that a sample size of 100 agencies, including those serving the largest populations, will provide adequate coverage to extrapolate overall urban water cutbacks.

In addition, it is important to obtain an accurate mailing list of water agencies and to locate the correct contact person at each agency. Because of the detailed nature of the information being requested, the survey should be conducted by mail, with telephone follow-up to obtain responses that are not forthcoming.

Data Analysis

Data collected through the survey can be analyzed to determine the severity of water shortages, the drought management policies implemented, and the resulting levels of water cutbacks achieved by residential, commercial, and industrial water users relative to a consistent base year. The levels of water savings should be adjusted for economic and population growth, and extrapolated (using an appropriate weighting mechanism) to obtain total urban water cutbacks. Such adjustments should provide a comprehensive picture of urban water cutbacks and the urban contribution to the state's drought response as an intermediate research result.

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[2]If target and actual cutbacks differ greatly, water agencies should adjust their expectations about the effectiveness of their drought management policies.

RESIDENTIAL IMPACTS

The residential impacts of the drought are measured largely in terms of lifestyle or psychological losses, rather than as the type of economic losses that are counted in the gross state product. For this reason, it is difficult to assign a dollar value to such losses. In the subsections below, we explore alternative methods for evaluating residential losses: an estimation of losses based on residential demand for water, and a survey asking households to assess the value they place on various forms of water use.

Consumer Surplus

The economic concept of "consumer surplus" can be used to assign a dollar value to lifestyle or psychological losses suffered by residential water customers. *Consumer surplus* is the difference between the value households place on water use and the price they pay for that water. (For a simple example illustrating the concept of consumer surplus, see the Appendix.) When a drought causes a shortage in the supply of water, consumers are prevented from buying as much water as they would like to use. Their willingness to pay for enough additional water to get back to their usual level of use assigns a dollar value to their economic losses from the drought.

Estimates of drought-induced changes in consumer surplus can be used to measure the economic losses from both quantity restrictions and price increases. Figure 7 shows the demand curve for a hypothetical residential household. For each price (p), the demand curve shows the amount of water (q) the household wants to buy. The demand curve is downward sloping, because the higher the price of water, the less the household wants to buy. It also shows the relationship between the quantity of water and the household's willingness to pay for an additional unit. The more water the household has, the less it is willing to pay for an additional unit. The difference between the willingness to pay and the actual price is the consumer surplus, or net benefit to the consumer. Therefore, when the household is free to buy as much water as it wants, the area to the left of the demand curve and

above the dashed line at the price p_0 in Figure 7 equals the total consumer surplus for the residential household at price p_0.

In Figure 7, the household wants to buy an amount q_0 of water when the price is p_0. During the drought, the water agency may introduce a quantity restriction that allows the household to buy only a quantity of q_1, but the price is still p_0. The difference between the willingness to pay and the price is the loss in consumer surplus on each unit of water between q_0 and q_1. Therefore, the area ABC represents the household's economic losses from the drought, as measured by its willingness to pay to get the same amount of water it would have bought in the absence of the drought. The diagram also shows how much less the household is paying to the water agency. Before the drought, they paid $p_0 \times q_0$, but now they pay only $p_0 \times q_1$, the difference being the area BCDE.

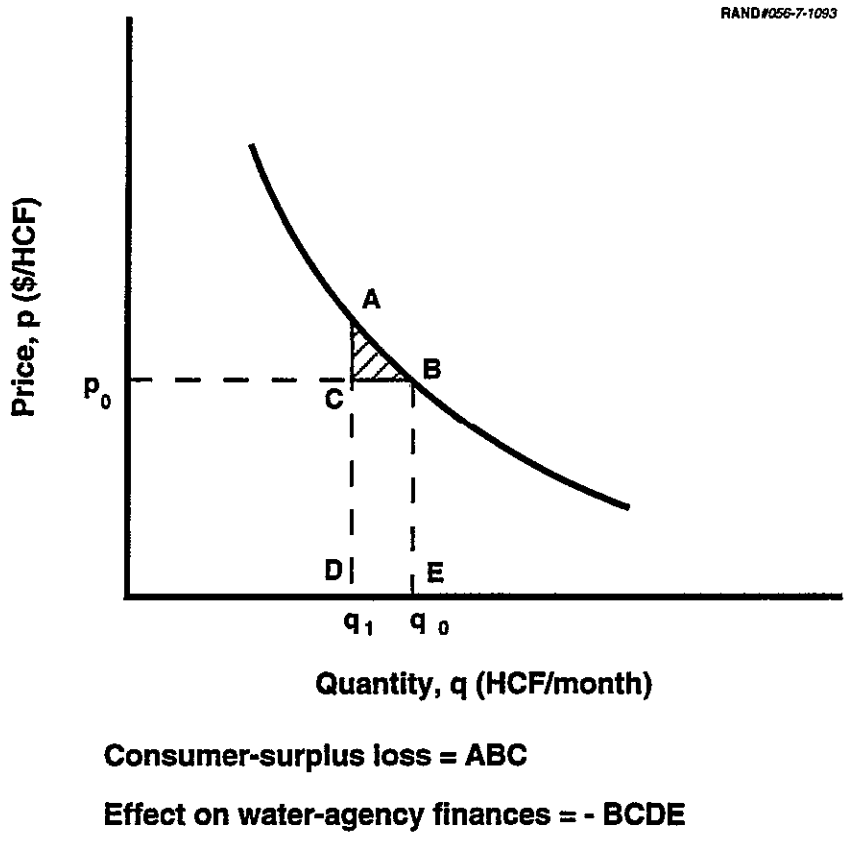

Figure 7—Quantity Restriction (in hundreds of cubic feet [HCF])

Similarly, the effect of a price increase during the drought is shown in Figure 8. If the price goes up from p_0 to p_1, the household reduces the amount of water it wants to buy from q_0 to q_1. The loss of consumer surplus from the reduction in water demand is given by the area in the triangle BCD. But the household is also paying a higher price on all the water it is still buying, so it also loses the area of the rectangle ABDE. However, that extra money goes to the water agency, so the agency is not losing as much money as it does when it implements the equivalent quantity restriction. Note that most water agencies had to raise water rates either during or after the drought to make up for losses incurred by reductions in revenue. This rate increase is a component of drought-related customer losses; however, it is transferred to water agencies, so it is not a loss for the community as a whole.

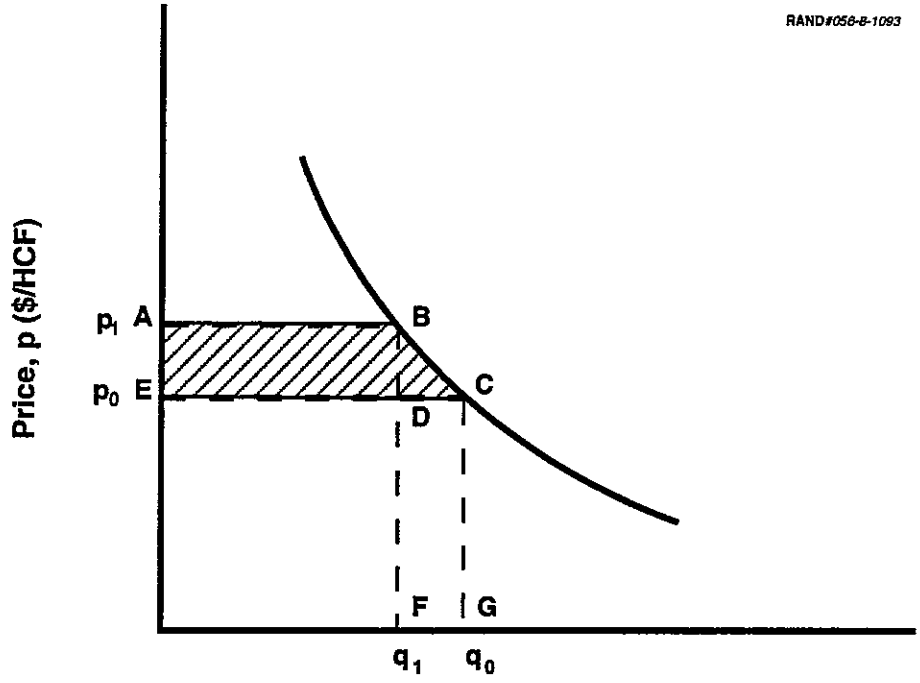

Figure 8—Price Increase

Demand Curve Analysis

One method of estimating consumer-surplus losses is to use estimated household demand curves and information from a water-agency survey on price increases, quantity restrictions, and other drought management policies. However, each household's demand curve is different. If a household is already conserving water, it may be more difficult for it to reduce water use as the price increases or as quantity restrictions based on past use are imposed. If so, the household's demand curve will be relatively steep. On the other hand, if another household is overwatering its lawn, cutting back would be easier for it. Its demand curve will be relatively flat. How steep or flat the demand curve is changes the size of the triangular area of losses, and it changes the response of the household if the price is increased. If a demand curve could be estimated for each urban household, and the quantity restrictions or price increases that were imposed on it during the drought were known, each household's losses could be measured and added to obtain the costs of the drought to the urban residential sector.

Of course, it is not possible to estimate a demand curve for each urban household. It would be necessary to divide households into fairly broad categories, based on past use, size of house or lot, etc., and either use existing estimates of demand curves to calculate consumer-surplus losses for each category or make new estimates based on data gathered while drought prices were in effect. We discuss each of these options in more detail below. Information on each water agency's drought management plan, and target and actual water cutbacks for residential customers, could be collected as part of the survey of water agencies described in Section 2. However, demand curve analysis cannot indicate which water uses are most valuable to residential households. It will give an overall dollar estimate of losses, but it does not show how those losses are divided up among browner lawns, shorter showers, etc.[3]

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[3]According to economic theory, the household should adjust its water use so that, at the margin, a gallon of water has the same value

Using Existing Demand Curve Estimates. Previous water demand studies are one potential source of estimates for residential water demand curves. This approach requires less additional research but has a number of drawbacks. First, although there are many water demand studies, they have varying degrees of applicability to water demand in California. One source of demand data for Southern California is *Water Demand of Detached Single-Family Residences: Empirical Studies for the Metropolitan Water District of Southern California* by Planning and Management Consultants, Ltd. (Boland et al., 1990). However, we have not yet located a study specific to the San Francisco Bay Area.

Second, in general, such demand studies are based on non-drought periods, when there tend to be only small variations in the prices charged and the quantities demanded by customers. Therefore, only a small range of the demand curve has been estimated. Extrapolation outside this range, to drought conditions with 20 to 30 percent quantity restrictions or large price increases, may not be very reliable.[4] One way to avoid this problem is to parameterize around existing estimates of customer sensitivity to prices: For each postulated level of sensitivity, we would be able to give the magnitude of the estimated economic losses. However, this approach could result in a wide range of possible losses.[5]

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in all uses. However, restrictions on certain types of use, such as watering of driveways and sidewalks, may prevent it from doing so.

[4]Existing household demand studies produce elasticity estimates (the ratio of the percentage change in use to the percentage change in price) ranging from -0.2 to -0.7, which indicate that a 10 percent price increase could result in a decrease in use of 2 to 7 percent and a consumer-surplus loss ranging from 9.55 to 9.90 percent of previous variable charges for water (assuming demand is linear). Similarly, a 10 percent quantity restriction could result in consumer-surplus losses ranging from 0.7 to 2.5 percent of the previous water bill, excluding fixed charges.

It is questionable whether existing point elasticity estimates (evaluated at a single point on the demand curve) are valid over wide price and/or quantity fluctuations. Billing data collected over the drought period could provide an arc elasticity estimate (evaluated over a range of the demand curve) covering wider price and quantity variations.

[5]Sensitivity analysis can be helpful in this context. But if the overall estimate of economic losses is highly sensitive to the

methodology used, although the ultimate quality of the estimates would depend on the quality of the data.

However, certain confounding factors will have to be taken into account. No water agency used price as the only drought management tool. Conservation education and media reports on the drought also influenced the behavior of residential customers. Therefore, it will be necessary to collect detailed information from the water agencies about all their drought management policies, and to try to control for non-price policies in our demand estimates. Another possible confounding factor is the recession, which may have affected water demand, so we will also need some data on the local economy. Provided that this information can be incorporated into the demand curve estimates, it should give a more reliable basis for computing overall residential losses, and greater certainty about the level of losses.

The estimated price sensitivity (for each customer category) would be used in the manner described above to obtain overall estimates of the residential impacts of the drought. However, this method should be more accurate than relying on existing demand curve estimates.

Valuation Survey

The second method of evaluating consumer-surplus losses is to survey households and ask them to estimate the dollar value of losses due to the drought. Residential users could be asked how much they would have been willing to pay at the onset of the drought to avoid the water cutbacks and price increases they faced. This approach is similar to contingent-valuation methodology, in which individuals are asked how much they would pay to avoid the expenses associated with several possible future scenarios. The difference is that, in this survey, residential users would be asked about actual losses resulting from a past event.

In a valuation survey, residential users would first be asked whether they were aware of how much water they were asked to conserve, and whether they met their conservation goals. If possible, they would be asked to report actual water use from past bills or to estimate how much water they used per month. In addition, they would be asked

In addition, public education programs, distribution of conservation kits, and other drought management policies may cause water demand to shift during droughts. If we rely on existing estimates of demand curves, it will not be possible to control for these types of policies. Finally, other questions might arise about the methodology used in existing studies, or the quality of the data.[6] Without creating new water demand and price elasticity estimates, there is no way around this problem. The best available estimates would have to be used.

When an appropriate range of price sensitivity parameters is chosen for each customer category, it will be necessary to match those parameters with population data on the number of customers of each type in each water agency's service area. The chosen range of elasticities would then be used to derive a range of dollar estimates of economic losses for each customer category. Those estimates could then be summed across all customer categories using the relevant population weights to obtain an estimated range of overall urban residential losses.

Estimating Demand Curves Using Drought Data. Collecting new data based on actual behavior during the drought would overcome some of the problems with existing demand studies. Billing data could be collected from water agencies that used price increases as their main drought management tool. Possible data sources include the City of Santa Barbara (where some data have already been collected by Spectrum), East Bay Municipal Utility District, Alameda County Water District, and the City of Long Beach. In some areas, several price changes occurred over a period of a few years. They could be used to estimate a wider range of the demand curve than was possible in previous studies during non-drought periods. There would also be greater control over the

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elasticity parameters chosen, we could not be very confident about the reliability of the estimates.

[6]In the academic literature on water demand and price elasticity estimation, one of the most important debates involves the treatment of the price variable. Because water prices typically involve a service charge plus decreasing, flat, or increasing block rates, estimating water demand is more difficult than estimating demand for products for which there is no "service charge" and whose price does not depend on the level of use. More recent water demand studies have developed more sophisticated techniques for dealing with this problem.

whether they appealed against water quantity restrictions or penalty rates and, if so, whether their appeal was granted.

The next step would be to ask what they did to conserve water during the drought—take shorter showers or water the lawn less, for example. Conservation responses could be divided into two categories: indoor uses, such as toilet flushing, showers and baths, laundry, cooking, cleaning, and dishwashing, and outdoor uses, such as irrigation for lawns, trees, and other vegetation, private swimming pools, and car washing. They might also be asked whether they noticed any reductions in community uses of water, such as irrigation in parks and golf courses, public swimming pools, and decorative fountains.

Finally, households would be asked to quantify what actual financial losses they might have suffered, such as lost vegetation or landscaping; how much they paid to install conservation devices, such as low-flush toilets or drip irrigation systems; and how much they would be willing to pay to avoid changing other aspects of their behavior that did not result in monetary losses, but in lifestyle or psychological losses for themselves or their community.

The accuracy and usefulness of this type of valuation survey are much debated in the research community. One problem is that the survey respondents do not actually have to make the payments that they report, and therefore may be over- or understating the financial value of their losses. Second, individuals have little experience valuing these types of losses, and they may be reluctant to answer hypothetical questions. As a result, their responses may not be very accurate. For these reasons, a valuation survey must be very carefully designed and fielded.

Individual responses in any given area, as well as responses in urban areas differently affected by the drought, will vary. Therefore, a good valuation survey would require a substantial number of respondents. Analysis will have to be done to determine the most cost-effective sampling approach. For example, it may make sense to categorize areas that were similarly affected and used similar drought management policies, and to sample individuals from only one city or water service area in each category.

We estimate that a broad residential valuation survey intended to yield an overall estimate of the impacts of the drought on the residential sector would require (at a minimum) a sample of 100 households from each of 30 water-agency service areas, for a total of 3,000 households. Owing to the difficulty of getting people to place values on things that do not normally have a price, it would be necessary to conduct the survey by telephone or through face-to-face interviews. The survey questions would also have to be subjected to extensive pretesting to ensure that we would get responses that are as accurate as possible.

If it were possible to obtain samples of residential households stratified by type of dwelling, socioeconomic status, and past water use from water-agency billing addresses, the results of the valuation survey could then be extrapolated to similar households based on populaton weights to obtain an overall estimate of the dollar value of urban residential losses. They would also give a breakdown of the relative values of various household water uses.

The method suggested here involves a different approach from that in previous contingent-valuation studies, most of which have been conducted on small, nonrepresentative samples. We are proposing a computer-aided telephone survey on a relatively large, representative sample. This method is expensive because of the complexity of the question design and the large sample size. However, contingent valuation is a fast-growing technique on the cutting edge of survey methodology.

Mixed Strategy

To get both an estimate of the overall economic costs of the drought to residential customers and an idea of the breakdown of losses on the basis of types of water use, the best approach may be to combine the consumer-surplus analysis described above with a small valuation survey. The consumer-surplus analysis would provide an estimate of the total dollar value of losses, whereas a small survey would indicate which water uses are most important to residential customers.

Because this approach would not be relying on the survey to establish an overall dollar value of losses, the survey would not need to be fielded to such a large sample. A sample size of approximately 300 households would probably be adequate. Although the survey would be similar in format to the one described above, the questions could be less detailed, perhaps asking households to rank which types of water use they valued most, which they found easiest to cut back on, and which water uses they would resume most quickly after the drought, rather than placing a dollar value on each type of loss. However, households should still be asked about their awareness of drought management policies and their own water use, and what specific actions they took to conserve water. To be effective, the survey would need to be carried out by telephone.

COMMERCIAL IMPACTS

Commercial impacts comprise three components: surplus losses to businesses that are analogous to consumer-surplus losses for residential users; losses resulting from changes in demand for water-related products (such as nurseries and landscape maintenance); and the consequent economic effects on employees and other input suppliers when commercial sales fall.

Demand Curve Analysis

To estimate the economic effects of the drought on the commercial sector, we would need to know how drought management policies and drought-induced changes in consumer demand affected commercial businesses. The first component of commercial losses can be measured using commercial businesses' demand curves for water before and during the drought to estimate losses in "producer surplus," or profits, in a manner analogous to that suggested for residences. However, other data sources would then be needed to estimate the effects on demand for water-related products and on employees and suppliers. Another possibility is to survey commercial firms to ask directly how the drought affected their business, employees, and suppliers. However, economic losses to employees and suppliers also depend on the availability of alternative jobs and of other buyers for supplies.

Demand curve analysis would potentially involve collecting data to estimate demand curves for various types of commercial businesses. However, it would be more difficult than for residences, because commercial businesses are less homogeneous: Some use water mainly for employee sanitation and landscape irrigation, whereas, for others, water is part of the product or service they provide. Each type of business would need its own demand curve, so a much larger amount of data would need to be collected than in the residential case. To learn more directly about the economic impacts of the drought, it would be necessary to conduct a survey of commercial businesses.

Valuation Survey

A survey of commercial businesses could be used to determine both how water cutbacks affected individual businesses and how the demand for their products was affected by the drought, if at all. In the latter case, however, it will be necessary to try to control for the effects of the recession, which is also likely to have reduced demand. Some businesses are likely to have invested in water-saving devices, which resulted in short-term costs but will have long-term value in reducing water use. Business managers can be asked to estimate what they would have been willing to pay to avoid the consequences of the drought. This information can be used to estimate the value of surplus losses in the commercial sector. The survey could also be used to gather data on the effects of water shortages on employees and suppliers. However, to the extent that other jobs were available and suppliers found other buyers, these effects would be mitigated. Information on local economic conditions could be used as a control, since it is probably not feasible to survey suppliers or employees who lost their jobs.

The most important question to be addressed in implementing the survey is, Which commercial businesses should be targeted? Broadly speaking, there are two possible lines of approach. One is to focus on the businesses that are the heaviest water users, as identified by the Planning and Management Consultants study of commercial and industrial water use described in Section 2 (Dziegielewski et al., 1990). However, these may not have been the sectors that suffered the worst economic

effects. As we have noted above, many water agencies exempted businesses from water cutbacks if employment would have been affected. Therefore, businesses that use water as part of their product or service may have been protected from drought impacts.

The other possible approach is to focus on businesses in which demand for products or services was affected by the drought, such as the green industry, construction (which may have been directly limited by drought management policies), and swimming pool contractors. These are the sectors that may have suffered the greatest economic impact. They could not be protected by water agencies, because the problem was demand for their products, not their own supply of water. However, water-related demand effects will be the most difficult to distinguish from the effects of the recession, which also reduced demand for products. Another difficulty is that, after the drought is over, business may begin to boom for these sectors, as homeowners replace lost landscaping and construction that was postponed by the drought proceeds. Thus, the drought may have delayed demand for these products but not eliminated it.

The types of question that would be included in the survey would depend on the target sector, and also on whether the sector was affected by water cutbacks or by loss of demand for its products. For those affected by water cutbacks, the focus would be on what happened to monthly water use and billing during the drought, cost and type of water conservation devices installed, whether there was any effect on the products or services sold by the business, and, if so, what losses in sales and employment resulted. The respondents should also be asked whether they appealed against water cutbacks, and, if so, what the outcome was. Finally, the survey should try to elicit, as specifically as possible, the business manager's willingness to pay to have avoided the impacts of the drought: For example, what would it be worth to a restaurant to go back to serving ice water to all customers?[7]

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[7]The business manager's willingness to pay for water is analogous to the household's willingness to pay, as represented by its demand curve for water. (See Figure 7.) The survey would therefore be asking the manager to describe his or her demand curve.

In the case of businesses affected mainly by reductions in demand for their products, the focus would be on sales and employment at the business, although questions about what happened to water supply to the business would also be applicable in such cases as nurseries that had to keep plants alive. To determine whether some of the lost demand will be restored, it will also be important to ask business managers what they expect to happen after the drought. Finally, such businesses should be asked to indicate, as specifically as possible, their willingness to pay to have avoided the impacts of the drought.

Additional data on local economies would also be needed to try to separate the effects of the recession from the effects of the drought. Local economic information might also provide a check on lost sales and employment in the surveyed sectors, if local data collection on employment is good. For example, Spectrum was able to obtain data on green industry employment from the Santa Barbara Economic Development Department.

The accuracy of this approach will depend heavily on the number of commercial sectors chosen for the survey and on the sample size for each sector. We have argued above that the drought's impacts varied geographically and also with the drought management policies chosen by the local water agency. Therefore, for the survey of a sector to give us reasonably reliable estimates of the drought's impacts that can be extrapolated to all urban areas, it would be necessary to choose samples that cover different geographical areas and different types of drought management policies.

We estimate that an in-depth, tailored survey of the green industry would require a sample size of 1,000 businesses, subdivided among the various sectors of the industry, such as nurseries, gardeners, landscape contractors, and landscape architects. Other sectors that are more homogeneous, such as construction and hotel and motel, would require a sample size of approximately 500.

The limitation of this approach is that a survey is needed for each commercial sector. The resulting estimates of economic losses could not be extrapolated to other sectors to obtain an overall estimate of drought impacts on commercial businesses. Rather, it would focus on the

hardest-hit sectors, where the greatest losses occurred. The information collected would provide a lower bound on overall economic losses in the commercial sector.

INDUSTRIAL IMPACTS

Our preliminary contacts with water agencies and manufacturing associations indicate that, although industry conserved on non-essential uses of water, it was protected, through the appeals process, from cutbacks that would have resulted in lost output and unemployment. Some follow-up is necessary to determine whether such protection was available in all urban areas. Additional effects from the drought may have been caused by changes in water quality. For example, we learned from Alameda County Water District that declining water quality during the drought was a problem for some high-technology industries, which incurred costs from installing additional pretreatment equipment for water supplies going into the production process.

The survey of water agencies will provide additional information about how much industrial users cut back during the drought, and some additional questions could be included in the survey to determine whether there were any industrial groups that had particular complaints about water availability and quality during the drought. Some additional contacts with industry representatives or individual firms may provide further anecdotal information that could be followed up.

To obtain a more comprehensive estimate of the impacts of the drought on industry, it would be necessary to conduct a survey of industrial water use during the drought similar to the Spectrum study (Wade et al., 1991).[8] The survey would include questions on monthly water use and billing during the drought; how industrial cutbacks were divided among different types of water use, such as process, boiler, cooling, sanitation, and irrigation; conservation projects undertaken

[8]We concluded that it would be necessary to field a new survey because of the gaps in Spectrum's existing data. Their survey did not match industries with water agencies, and their corresponding water rates and drought management plans; did not ask the reasons for conservation projects; and was collected before most of the major drought cutbacks were instituted.

and the reason for the project (e.g., water quality requirements); conservation devices installed in response to the drought; whether the plant was able to meet its conservation targets or had to appeal for a loosening of restrictions; and whether any output or employment was lost as a result of water shortages. We would also ask plant managers to evaluate their willingness to pay to avoid the effects of the drought.

To be meaningful, such a survey would require a relatively large sample size. In addition to the geographical variations in the drought's severity and in water agencies' drought management policies, the Spectrum study shows that there is a wide variation in the levels of water conservation technology installed in industrial plants (Wade et al., 1991). Firms that were already conserving water may have found it much more difficult to make additional cutbacks during the drought than those that had not yet installed the most current water conservation technologies. Furthermore, some industries, such as petroleum refineries, may have had their own water sources, or may have been able to pump groundwater to meet some of their needs. There is also the problem of separating the effects of the recession and of environmental water regulations from the effects of the drought.

The survey would be likely to confirm the anecdotal evidence that the direct industrial impacts of the drought were relatively small. Most water managers recognized that the economic consequences of restricting industrial process water would be much greater than the costs imposed on residential customers and commercial customers who did not use water as part of their service, and did not impose cutbacks on industry that would have resulted in lost output and employment.

The more important issue for industry is that the drought made them more aware of the risk of future water supply shortages. This is one among many factors affecting future investment decisions in California. More information on whether industry is buying insurance against future water supply shortages would be provided by a follow-on to the Spectrum study that matched water intake and disposal costs with the cost per acre-foot of conservation projects on a plant-by-plant basis, and attempted to control for the effects of environmental regulation.

4. CONCLUSIONS AND RECOMMENDATIONS

Producing reliable estimates of the economic impacts of the drought in California's urban areas will provide useful information to state policymakers as they make decisions on conservation, reclamation, supply augmentation, water marketing, Bay-Delta safeguards, and other water policy issues. However, it is not an easily achievable goal. We have suggested the research approaches that we think can best achieve this goal.

As we discussed above, it is our opinion that a water-agency survey is necessary to understand the drought impact process and to learn the actual cutbacks faced by water users. The two main options for assessing residential impacts are demand curve analysis, perhaps complemented by a small survey to learn which water uses are most valuable to households, and a contingent-valuation survey.

We believe the best approach to estimating commercial impacts is to survey the sectors that were most strongly affected, such as the green industry, construction, and hotels and motels. Our anecdotal evidence suggests that industrial impacts were relatively small, so a survey of industry is not likely to be cost-effective. A small follow-up study is probably all that is needed.

Appendix

A SIMPLE EXAMPLE ILLUSTRATING THE CONCEPT OF CONSUMER SURPLUS

Note that the demand curve for water in Figure 7 is downward sloping, which is true for almost all types of products: The higher the price is, the less of it you are likely to buy. *Consumer surplus* is the difference between willingness to pay and the actual price paid for the product. Changes in consumer surplus are easiest to illustrate for seasonal products, availability of which changes throughout the year or according to weather conditions. One example might be avocados. If avocados cost $1 each, you might buy one; if they cost 75 cents each, you might buy two; if the price falls to 50 cents each, you might buy 3; etc.

The idea of consumer surplus is that when the price of avocados is 50 cents each, the amount you actually pay for the first avocado is less than your willingness to pay. You would have been willing to pay $1 for the first avocado, but it costs only 50 cents, so your consumer surplus on the first avocado is $1 - 50 cents = 50 cents. In the same way, you would have been willing to pay 75 cents for the second avocado, so your consumer surplus on the second avocado is 75 cents - 50 cents = 25 cents. Now suppose you would be willing to buy three avocados only when the price is 60 cents or less. If they cost 61 cents, you would buy only two. Then there is a consumer surplus of 60 cents - 50 cents = 10 cents on the third avocado. Your total consumer surplus when the price of avocados is 50 cents is therefore 50 cents + 25 cents + 10 cents = 85 cents.

Now suppose there is a sudden freeze that limits the supply of avocados. Your grocer decides to keep the price of avocados at 50 cents, but you are allowed to buy only two avocados. You have lost your consumer surplus on the third avocado, which was 10 cents. If you were allowed to buy only one avocado, you would lose the consumer surplus on the second and third avocados, or 35 cents. This is the same kind of effect that happens when there is a quantity restriction on water use during the drought.

What happens if instead your grocer raises the price of avocados to 70 cents? You will no longer want to buy the third avocado, so you lose your 10 cents consumer surplus on it. You also have to pay 20 cents more for each of the other two avocados, which shrinks your consumer surplus on each of those avocados by 20 cents. Your total consumer-surplus loss would be 50 cents.

The effect in this example is similar to what occurs during the drought if water agencies raise the price of water as a drought management policy, or use financial penalties against customers who exceed quantity restrictions.

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