Sustainable Water, Unlimited Growth, Quality of Life: Can We Have it All? Tucson, AZ; August 31, 2007

RESIDENTIAL WATER DEMAND MANAGEMENT IN AURORA: LESSONS LEARNED AND REMAINING QUESTIONS

Douglas S. Kenney[1]

INTRODUCTION

Residential water demand is a function of several factors, some of which can be strategically and effectively manipulated by water utilities as part of a demand management program. This general conclusion is supported by the experience of Aurora, Colorado, which recently turned to demand management tools to withstand a severe drought period (particularly 2002-2003). In the following paragraphs, the recent drought experience of Aurora is briefly summarized, followed by a concise overview of the demand management study, and a listing of lessons, conclusions and remaining questions. A much more detailed account of this work is posted online[2] and is scheduled for publication soon in the *Journal of the American Water Resources Association*.

CASE STUDY: DROUGHT IN AURORA, COLORADO

Aurora is a rapidly growing Denver suburb of approximately 309,000 residents served exclusively by a single municipal provider: Aurora Water. Approximately 70-80 percent of deliveries in the utility's service area are to residential customers, with single-family homes accounting for the bulk of these deliveries. Similar to many other western cities, Aurora's water managers have long been challenged by several ongoing decades of rapid population growth combined with limited opportunities to expand supply. This already significant challenge was exacerbated in 2002 by severe drought, prompting the city to quickly implement (and/or accelerate) a variety of demand management efforts, including: drought restrictions (i.e., limits on outdoor water use); incentive programs; introductions of new technologies; and multiple changes in billing structures and rates, culminating in the adoption of an increasing block rate pricing structure with individualized (household-specific) water budgets adjusted annually in response to consumption levels, water storage conditions, and revenue considerations. Fortunately, these efforts were highly successful in

---

[1] Kenney is Deputy Director of the NOAA-sponsored Western Water Assessment (WWA), housed at the University of Colorado. This work was conducted with fellow WWA researchers Christopher Goemans, Roberta Klein, and Jessica Lowrey, and with the assistance of Kevin Reidy, Water Conservation Supervisor for Aurora Water. Direct comments/inquires to Doug Kenney, UCB 401, Boulder, CO 80309-0401; douglas.kenney@colorado.edu; 303-492-1296.

[2] http://wwa.colorado.edu/resources/water_demand_and_conservation/water_demand_aurora.pdf

reducing consumption: total annual deliveries declined in 2002 and 2003 by 8 and 26 percent, respectively, relative to average deliveries in the 2000-2001 period. These cutbacks came primarily from the single-family home sector and occurred during the summer irrigation season.

The success of Aurora Water's program was likely due to the rapid and aggressive adoption of several demand management tools. However, the fact that many actions were taken simultaneously, and were not done so in the context of a research protocol, meant that it was impossible to easily assess which of the tools were responsible for the observed declines in water use, and subsequently, which reductions could (and could not) be relied upon in the future. To investigate these questions, Aurora Water in the fall of 2005 entered into an ongoing research partnership with the Western Water Assessment (a NOAA-funded effort based at the University of Colorado) to explore influences and recent trends in residential water demand, with the hope of identifying lessons useful in short-term and long-term planning, including efforts to deal with climate change and variability.

THE RESEARCH PROJECT

The research project described herein has three key underpinnings. First, it is informed by a thorough review of the water demand management literature, describing factors responsible for water demand, past efforts to understand and quantify these relationships, and suggestions for research methods and questions.[3] Second, the work was conducted by a multi-disciplinary team of researchers in conjunction with water conservation and data management professionals at Aurora Water. And third, a database of monthly billing records (from 1997 to 2005) was provided by Aurora Water to support the quantitative analyses. This data was provided for every single-family account, and provides information of 2 types: consumption levels, and prices associated with each unit of consumption.

In all analyses, data was analyzed from the 2000-2005 period using a water demand equation that describes household demand primarily as a function of average price, the presence/absence of water restrictions (i.e., emergency prohibitions on lawn watering), the presence/absence of a block rate billing structure, the participation of a household in rebate programs (e.g., low-flow toilets) and/or the use of a Water Smart Reader (a device providing households with real-time data on their consumption levels), weather variables (temperature and precipitation), and a few demographic variables. Data was analyzed using a fixed effects, instrumental variables (FE-IV) technique that allowed researchers to track the behavior of each household (over 10,000 households with complete, uninterrupted billing records from 1997 to 2005) to the adoption/removal of the various demand management programs. Additionally, the effectiveness of demand management programs was also evaluated with respect to three subsets of customers: high-volume, medium-volume, and low-volume water users, defined as the top 25%, middle 50%, and lowest 25% of study

[3] http://wwa.colorado.edu/resources/water_demand_and_conservation/literature_review_version_1_12_07.pdf

households based on average consumption levels in the pre-drought period (1997-1999). The effectiveness of programs before and during drought was also compared.

MAJOR FINDINGS

The demand model used in this analysis performs well (r-squared of 0.40), leading to statistically significant (at 1%) results in the following areas.

The effectiveness of price in reducing consumption is shown below (with price elasticity of demand statistics):

Type of User	Overall Price Elasticity	Elasticity During Restrictions
All Households	-0.60	-0.37
Low-Volume Users	-0.34	-0.46
Mid-Volume Users	-0.57	-0.39
High-Volume Users	-0.75	-0.24

These statistics support the following conclusions about pricing, water restrictions, and their interactions:

- Increases in price result in reductions in consumption, although at a level that economists would label as inelastic. Overall, a 10% increase in a price results in a 6% reduction in consumption (price elasticity of -0.60) (averaged across all users and time periods).
- Price is much more effective in promoting conservation among the high-volume users than the low-volume users (7.5% versus 3.4%). (*Note*: As is traditional in this field, statistics relating consumption to price are per every 10% increase in price.) The notable exception to this occurs during periods where outdoor water-use restrictions are in effect, where the pattern is reversed (2.4% versus 4.6%) (for reasons noted below).
- During restrictions, the effectiveness of pricing tools is reduced overall (down from 6.0% to 3.7%), but especially among the high-volume users (7.5% to 2.4%), as the restrictions, rather than the price signal, become the more important (i.e., first encountered) threshold modifying customer behavior. This is a reminder that the conservation benefits from pricing tools (used individually) and restrictions policies (used individually) should not be considered additive; when both are in use, the behavior of each individual customer will be shaped by one policy or the other, determined by which policy creates the first-encountered threshold on water use. Given average prices, the observed water savings that can be attributed solely to restrictions in this case study is estimated at roughly 12%; in contrast, if no interaction between price and restrictions occurs (i.e., if water were free), the restrictions would be expected to yield savings of roughly 31%. (These statistics are not shown above.)

Other important findings include:

- Irrespective of the actual price charged for water, the mere act of switching to a increasing block rate structure reduced consumption by 5%, perhaps due to the fact that this rate structure helps to convey a conservation message.
- Customers using a Water Smart Reader displayed a net increase (16%) in consumption, which was surprising until we observed that these same customers were able to reduce the frequently at which their level of use entered the punitive 2nd and 3rd pricing tiers. Thus, use of a Water Smart Reader allowed customers to skillfully target their use at a level that took full advantage of their tier 1 allotment while avoiding the more punitive tiers, suggesting that real-time information on consumption levels is helpful to customers in achieving the consumption targets provided in their individualized water budgets.
- As expected, weather conditions affect consumption levels: for every one degree Fahrenheit increase in average daily maximum temperature over the course of the billing period, water use increases about 2 percent; similarly, for every inch of precipitation, water use decreases by roughly 4 percent.
- While the study did not specifically address the role of demographic factors in shaping demand, households in the high-volume water user category tended to be wealthier, older, and live in newer and larger homes than other customers.

CONCLUSIONS

LESSONS LEARNED AND REMAINING QUESTIONS

Demand management has proven to be a highly practical and effectiveness water management tool in Aurora. Several lessons learned can be readily identified, e.g.:

- The effectiveness of demand management policies is mostly determined by how they influence the behavior of the high-volume users, who are:
    - Highly responsive to *price* in non-drought periods
    - Highly responsive to *restrictions* during drought periods
- Increasing block rate structures work (even if the pricing tiers are only modestly punitive).
- Indoor rebate programs (e.g., for low-flow toilets) are a great long-term investment.
- Customers will hit water-use targets if you provide them with proper incentives (via rate structures) and information (via a Water Smart Reader).

A variety of remaining questions are also readily apparent, e.g.:

- How can utilities best maintain adequate revenue streams while suppressing demand?
    - What strategies are equitable?

    - How can the "conservation message" be re-configured each year to reflect different annual conditions?
- How can the culture of water agencies be amended to place demand management on a footing more commensurate with supply management?
- To what extent does long-term conservation efforts restrict the opportunities for short-term (e.g., drought period) demand reductions (i.e., the "demand hardening" question)?
- To what extent is outdoor water use a function of the types of irrigation technologies in use (e.g., hoses, sprinklers, timers), and what opportunities exist to strategically manipulate this as part of demand management programs?

THE ROLE OF DEMAND MANAGEMENT IN THE SEARCH FOR SUSTAINABILITY

While the water community is likely to always retain its supply-side emphasis, demand management has finally emerged as an important management tool, and in doing so, has quietly undermined the traditional logic of safe-yield planning—i.e., the practice of sizing water systems so large that, in the event a severe drought that significantly (and temporarily) reduces system yields, sufficient water remains to satisfy all "normal" (unmodified) demands. Due both to economic and environmental considerations, and due to the increasingly limited opportunities for new water development, the focus of the water community is now increasingly focused on both sides of the water budget equation.

This is good news as utilities work to define and achieve the latest standard for good water management: *sustainability*. In an earlier time, sustainability meant building water projects (and water yields) as fast as farms, cities, and industries could expand their legally-defined beneficial uses. But this interpretation of water system sustainability runs counter to many other notions of sustainability, particularly environmental sustainability and, increasingly, economic sustainability. Today, sustainability means finding means to perpetually balance water budgets, in good times and bad, while leaving water for environmental amenities, and while avoiding the social and economic costs associated with zero-sum water allocation disputes. Demand management can be an important strategy in this quest, although perhaps only if three key conditions are met: (1) induced changes in water-using behavior must not come at the expense of deeply-held cultural values and norms, and must balance costs among users in an equitable manner; (2) demand management must not provide shortfalls in operating revenues; and (3) water saved is used to maintain reservoirs and to ride out dry periods, rather than becoming a baseline supply serving new growth (the "demand hardening" problem). Ensuring that these conditions are met is a challenge that goes beyond the normal scope of water managers to include a broader network of municipal officials and other community leaders.