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**Urban Water Conservation:
The Last Water Hole or Mostly a Mirage?**

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**Moving the West's Water to New Uses:
Winners and Losers**

**Natural Resources Law Center
University of Colorado School of Law
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Biographical Sketch

Gary C. Woodard, J.D., M.P.P.

Gary Woodard manages the Policy Analysis Unit of the Division of Economic and Business Research in the U of A's College of Business and Public Administration. As such, he directs research into a wide array of policy issues, especially those dealing with natural resource management within Arizona.

Gary Woodard earned a B.S. with a concentration in chemistry from the University of Michigan in 1976. He then worked at the General Motors Research Center for two years, where he performed basic research on the catalysis of exhaust gas reactions by various metal and alloy surfaces used in catalytic converters.

Returning to the University of Michigan in 1978, he studied law and public policy, receiving both a Juris Doctor in law and a Masters of Public Policy studies in 1981. He joined the Division of Economic and Business Research in 1982, where he established the Policy Analysis unit. In addition to his research program in the Division, Gary has taught graduate courses and seminars in the Departments of Agricultural Economics and Hydrology and Water Resources.

Policy issues studied by Woodard include: forecasting municipal water demand and evaluating demand management strategies; analyzing utility regulation, rate structure design and consumer perceptions of price; and estimating the demand for and public support of performing arts and public broadcasting. Recent areas of research include: trends in and transactions costs of inter-basin water transfers in the West and their impacts on rural areas of origin; the cost-effectiveness of various regulatory measures to reduce carbon monoxide emissions in urban areas; and impacts of urban vegetation on heating, cooling and landscape irrigation costs.

Gary Woodard has published several dozen articles and monographs on various research topics and given numerous talks to various professional organizations. In addition to conducting and publishing research, Woodard has written numerous articles for newspapers and non-technical publications. He also has served on several state and local advisory boards and panels.

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I. Introduction

A. Summary

Continued urban growth and increasing pressures on municipal water supplies in the West are causing many water providers to seriously consider implementing major water conservation programs. However, a history of exaggerated claims, unquantified costs and benefits and inability to duplicate successful programs in other locations has created serious concerns regarding the reliability and cost effectiveness of water conservation efforts.

Most water resource managers are familiar with only a few of the wide array of water conservation measures, generally those which can be implemented rapidly to deal with sudden, temporary supply interruptions. The detailed understanding of water utility customers' usage patterns and trends necessary to select and implement targeted demand management measures generally is lacking. Water conservation options affect various components of water demand in different ways. A water resource manager may want to decrease water demand temporarily because a dam needs repairing or permanently because population growth is causing demand to exceed a finite supply. The concern may be with indoor demand, because of a desire to postpone construction of new wastewater facilities, or with peak summer demand, because of limits in the delivery system.

The set of appropriate conservation measures in any situation is a function of the component of demand that is to be reduced, how much it must be reduced, and for how long. Therefore, each demand management measure considered must be evaluated in terms of the component(s) of water demand affected.

Other relevant factors sometimes not considered are quickness of implementation, permanence of effect, adjustability of conservation magnitude, ability to undo the measure, need for community support, etc. In addition, certain conservation measures have the potential to adversely impact quality of life and efforts to manage other scarce resources.

Despite these problems and a dearth of well documented success stories or established methodologies, the potential of carefully conceived and skillfully implemented demand management programs to augment more traditional forms of urban water supply is tremendous.

B. General References

Rasmussen & Woodard, "Factors of Municipal Water Demand: An Analysis of Residential Uses," Arizona's Economy, November 1983.

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Woodard, "A Summary of Research on Municipal Water Demand and Conservation Methodologies," Water Pricing and Water Demand, Utilities Division, Arizona Corporation Commission, October 1986.

Charney & Woodard, "Utility Rate Structure: Policy by Design," Arizona's Economy, February 1984.

Woodard, "Designing Water Rate Structures to Promote Conservation," Hydrology and Water Resources in Arizona and the Southwest, vol. 14, 1984.

McPherson & Woodard, "Cooling the Urban Heat Island with Water- and Energy-Efficient Landscapes," Arizona Review, Spring 1990.

II. Water Conservation Concerns

Increasingly, municipal water providers are seriously considering devoting substantial resources to water conservation programs. However, a number of concerns exist, including:

- A. How many conservation measures are there?
- B. What are their costs?
- C. Which conservation measures really "work" and which are merely gimmicks?
- D. Which measures are most cost-effective?
- E. How long will reductions in demand persist?
- F. How accurately can the magnitude of demand reductions be predicted?
- G. How will the program affect utility costs and

revenues? Will rate increases be necessary, or will "windfall" profits accrue?

- H. How will low-income or other segments of the population be affected?
- I. What is the potential for political backlash from particular programs?
- J. How will waste water systems be impacted?
- K. Will the community's quality of life or its attractiveness to development be harmed?

Individual conservation measures raise specific concerns. How can conservation-oriented water rate structures be squared with cost of service principles? If system pressure is lowered to reduce usage and leaks, what will that do to fire protection? Do low-flow toilets increase clogging of sewer lines? Unfortunately, there are more anecdotes than facts and more theories than conclusions.

The bottom line is, can a program of water conservation measures reliably substitute for investment in traditional water supply infrastructure such as dams, wells, pumps and pipelines? The answer is a highly qualified, "Yes, but....."

III. What is water conservation?

Despite the large and growing literature on the

subject, concise definitions of the term are hard to come by. The "wise use of water resources" is a common theme that provides little guidance beyond admonishing one not to foolishly waste water. Therefore, conservation is the opposite of waste, whatever that is. Conservation is not the practice of self-denial, of eliminating activities that use water. Going long periods without bathing or replacing all landscaping with paved surfaces and crushed rock do not qualify as conservation measures.

Nor is water conservation the substitution of large quantities of other scarce resources for modest amounts of water. One can equip restrooms with handle-less faucets activated by photodetector eyes that sense when hands are placed in the sink and with one-pint toilets that operate on the principle of garbage disposals. However, these faucets and toilets are very expensive, use electricity and require maintenance. Moreover, considerable amounts of water, energy and other resources are consumed in their manufacture, making them technological marvels but dubious conservation devices.

Another definition incorporates the concept of accomplishing the same ends with less water, or stretching the supply. But even this definition cannot escape value judgements. Therefore, the term "water conservation" is dispensed with here in favor of a discussion of approaches to water demand management.

Demand management requires water resource managers or their policy-making bodies to institute measures with the intent of impacting the level or timing of water demand.

Programs undertaken in the name of demand management are best considered as a form of water supply augmentation rather than as adjustments to demand. The programs should be compared on the same terms with other expenditures made for the purpose of assuring that water demand does not exceed supply.

IV. Defining the Problem and the Goal

A. Why is there interest in water demand management? Generally, the basic problem is the perception that water demand may exceed water supply. But which supply constraint is becoming binding?

1. insufficient supply in the long term?
2. insufficient peaking delivery capacity?
3. growth overwhelming the infrastructure?
4. insufficient waste water treatment capacity?
5. threat of drought or other temporary supply disruption?

B. Each particular problem is unique. Nevertheless, they can be characterized in terms of:

1. How much reduction in demand is needed?

2. How quickly is the reduction needed?

3. For how long is it needed?

There is a natural dichotomy among conservation measures that divides those measures that can be implemented quickly but cannot be maintained for long periods of time from those that take longer to implement but provide demand reductions for indefinite periods of time. The former category consists mostly of measures aimed at influencing the behavior of water users and includes what a colleague of mine has labelled "preachments" -- urging water customers to cut back their usage because there is a shortage and saving water is the socially responsible thing to do. The latter category contains mostly hardware-based approaches, such as low-flow plumbing fixtures, and sophisticated automatic irrigation systems which save water in normal use and require no special action or sacrifice on the part of users.

Quick and temporary demand reductions necessary to cope with unanticipated supply disruptions are not the subject of this presentation. Rather, we will focus on those demand management measures which promise long-term, if not permanent, reductions in water demand.

C. What are the supply alternatives to demand management? For each of these, what are the likely:

1. economic costs?
2. environmental costs?
3. political costs?

On whom would these costs fall?

D. Given the alternatives, how much could a demand management program "cost" and still be the preferred approach? On whom can the economic costs be imposed?

1. utility customers
2. tax payers
3. new construction through fees

V. Municipal Demand Profile

An understanding of how much water is being used by whom for what purposes is a necessary prerequisite to designing water demand management programs. An oft-used measure of overall municipal water demand is gallons per capita per day (gpcd). The variability of demand for some representative western cities is apparent in the gpcd rates given below.

<u>City</u>	<u>GPCD Rate</u>
Phoenix, AZ	225
Tucson, AZ	165
Denver, CO	195
Albuquerque, NM	250
Las Vegas, NV	390

A. These differences in gpcd rates are due to differences in climate, condition of water system, water rate structures, mix of commercial/industrial activities and other factors. Designing a cost-effective demand management program requires a detailed analysis of usage patterns, based on data available from:

1. the utility billing records. Data quality depends on a number of factors, including:

- a. extent of metering;
- b. frequency of billing;
- c. number of customer classes;
- d. number of years of billing records available; and
- e. degree of computerization of records.

2. wastewater treatment plants. Usefulness of data depends on the percent of water customers are tied in to the sewerage system, how sewage flows are metered, and the overlap between water and sewer service areas.

3. local weather stations, census bureau reports, property tax records, building permit data, marketing surveys, etc.

4. Depending on the quantity and quality of

data from existing sources, it may be necessary to gather data on water use patterns through a survey. Statistical models can be constructed from the data. A survey conducted for Tucson Water six years ago not only provided detailed information on the stock of water-using fixtures, appliances and landscaping, it also gave pseudo-time series data when coupled with information on the age of structures and the length of time that occupants have lived in their current homes and in the immediate area. Analysis revealed that, all other factors being equal, relative newcomers to the Tucson area tend to use less water outdoors than do long-term residents, contrary to popular perceptions. It also was determined that the popularity of several water-using appliances, landscape types and irrigation methods are strongly affected by the age of the dwelling unit. This means that new construction differs substantially in water-using features from the existing stock of buildings.

B. Identifying components of water demand to target with specific measures requires several levels of disaggregation of total municipal demand. This can be done with simple "water demand algebra" as follows:

Municipal demand = metered uses + system losses

system losses = system leaks + unmetered uses

unmetered uses = fire protection
+ construction water
+ underrecording by meters

metered uses = residential + non-residential

residential = single family residential
+ townhouses & condos
+ duplex/triplex
+ mobile homes
+ apartments

non-residential = commercial
+ industrial
+ institutional
+ turf industries, etc.

turf industries = golf courses
+ cemeteries
+ parks
+ school yards

Each of these components involves significant quantities of water. System leaks vary from 5 to 10 percent for well-maintained systems to over 50 percent for badly deteriorated systems. Under-recorded usage by worn-out water meters easily can exceed 5 percent. Residential demand generally is the largest category of demand. However, some demand management measures are more cost-effective when larger commercial or industrial customers are targeted.

C. Water demand can be disaggregated along other dimensions, such as indoor vs. outdoor use. While demand can be divided into components along many dimensions,

the indoor/outdoor distinction is critical. Indoor demand is non-consumptive but produces effluent; outdoor demand is consumptive, but does not. Indoor demand changes gradually over time with population and other factors, while outdoor demand is highly seasonal, fluctuates with weather and is primarily responsible for peak demand. Therefore, water managers with a particular reason for undertaking demand management measures likely will be principally concerned with indoor or outdoor demand, but not both.

D. Another dimension along which water demand can be disaggregated is that associated with the existing stock of buildings, etc. vs. new construction. This facilitates determining the base line conditions of how demand patterns will shift over time in the absence of demand management efforts.

VI. Identifying trends in factors of demand

A. Demographic factors, including:

1. persons per household, which is decreasing over time;
2. broad age categories (pre-school, K-12, 19-64, 65+), which are affected by the "greying of America" and the "baby-boom echo"; and

3. income levels, which show increased variance (shrinking middle class).

B. Housing characteristics, including:

1. mix of housing types, with fewer detached homes and more apartments;
2. home values;
3. lot sizes, which are decreasing;
4. landscapable areas, which are decreasing even faster;
5. frequency of swimming pools, which is increasing; and
6. home ownership levels, which are declining.

VII. Matching demand management measures with targeted demand components

Various water demand management options affect different components of water demand in different ways, an obvious fact that sometimes is not fully appreciated. A water resource manager may want to decrease water demand temporarily because a dam needs repairing or permanently because population growth is causing demand to exceed a finite supply. The concern may be with indoor demand, because of a desire to postpone con-

struction of new wastewater facilities, or with peak summer demand, because of limits in the delivery system. The set of appropriate conservation measures in any situation is a function of the component of demand that is to be reduced, how much it must be reduced, and for how long.

Therefore, each conservation measure must be evaluated in terms of the component(s) of water demand affected. Other relevant factors that sometimes are not discussed are quickness of implementation, permanence of effect, adjustability of conservation magnitude, ability to halt or undo the measure, the need for community support, etc.

Among the demand management measures from which a program can be developed are the following:

System Related Measures

Leak detection/Water audits

Metering

all customers

individual residential units

construction water

Pressure reduction

Pricing

based on usage

increasing block rates

seasonal rates

excess demand surcharge

Wastewater flow management

Indoor and Outdoor Alternatives

Drought contingency plans

Education

public information program

teacher training program

youth programs

Positive incentives
Wastewater
 dual system plumbing
 recycling or reuse
Water audits

Indoor Alternatives

Low water use appliances
Faucets
 aerators
 metering
 self-closing
Hot water
 tankless heater
 line insulation
 recirculation
Showerhead
 air assisted
 low water use
 flow restrictor
Toilet
 Retrofits in tanks
 dams
 displacement devices
 dual flush
 adjustable flapper
 leak detection tablets
 New toilets
 low volume
 air pressure
 composting
 vacuum transport
Plumbing codes
 low-flow fixtures
 garbage disposal prohibitions
Retrofit programs

Outdoor alternatives

Prohibitions
 fountains
 decorative ponds
 large pools
 large areas of turf
Landscape irrigation
 drip systems
 ET-based weather advisory
 scheduling
 rainwater harvesting
Landscape plants
 nursery tagging, low water use plants
 xeriscape program
Swimming pools

covers
evaporation inhibitors
size restrictions

Adapted from Water Conservation Alternatives Inventory.

The list, while lengthy, is by no means complete. Often, demand management measures don't look like such. For example, a homeowners group in California greatly reduced the water used to irrigate the development's common areas by re-writing the contract with their landscape service so that the cost of irrigation water in excess of that needed to maintain the landscape was paid by the service.

VIII. Evaluating Demand Management Measures

Two major problems with water demand management programs are that: 1) they frequently are oversold; and 2) similar measures implemented in different locations often produce significantly different results.

Engineering approaches to estimating conservation potential have an aura of accuracy and precision about them that may not be warranted. A low-flow toilet might work perfectly in the lab, but when put to use in the real world, it might require frequent double-flushing in some uses. Low-flow shower heads might become high-flow shower heads at greater water pressures or provide such an insufficient stream of water in low-pressure areas

that consumers replace them. Hardness or pH of water may cause water consumption to increase as devices age. Landscaping that requires little supplemental water may be irrigated by a system that is oblivious to rain and that has been set up by a dealer who wants to make sure that no disappointed customers have wilted plants. Analytical measurement of potential water savings is only a first step in the evaluation process.

Three years ago, Glendale, Arizona implemented a rebate program for homeowners retrofitting their toilets with ultra-low flow models (≤ 1.6 gals./flush). Half the price of the toilet is refunded by the City. After 30 months of the program, they are averaging less than two rebates per month. The City of Tucson, with about 2.5 times the population, implemented a similar program in January 1990. They have averaged 150 rebates per month. Clearly, experiences may not be transferable.

There is a dearth of thorough studies on the impacts of water demand management measures. This leads not only to occurrences like that noted above, but to policy differences based on lack of understanding. Two neighboring cities in the Phoenix metropolitan area have opposing views of the effect of irrigation system timers. One city discourages their use because they believe that timers increase water demand because they are not adjusted for rain or time of year. The other city gives

partial rebates on their installation because they believe that manual irrigation uses more water due to homeowners misjudging how long irrigation systems should be run and forgetting to turn them off. A fairly simple study could settle the issue, but follow-up studies are very rarely done, in part because many conservation programs are for show and no one wants to know what, if anything they are accomplishing.

When studies are done, they may not provide useful guidance because of a failure to fully document and discuss the implications of the particular setting in which the conservation option was evaluated. There are several dimensions to this, including: site-specific socio-demographic characteristics; housing and landscape stock characteristics; climatic and other environmental characteristics; and the presence or absence of other conservation-related programs. If research done at one site is to be of value to water resource managers elsewhere, demonstration projects and program evaluations must account for all these cross-sectional variables.

Environmental conditions that must be taken into account include climate and microclimate, soil conditions, and other related factors. Demonstration projects or other studies that look at outdoor water consumption are affected not only by location but also by the particular weather fluctuations occurring at that

time. As part of a major study for the Arizona Department of Water Resources on Effects of Weather and Climate on Municipal Water Demand in Arizona, I developed models for adjusting municipal water consumption rates to a normalized weather year. The analysis showed that year-to-year weather fluctuations often affect water demand enough to swamp any measurable effects of particular conservation programs. Studies that do not adjust for weather fluctuations likely will produce misleading results.

This study also quantified climatic differences in south-central Arizona. Rainfall, temperature and humidity all were found to be strongly affected by elevation and relatively unaffected by latitude and longitude. This means that sites close to each other but with elevation differences of 1,000 feet or more have significantly different climates and outdoor water demand, while sites as much as 100 miles apart but at similar elevations have similar outdoor demand characteristics. In coastal locations, elevation might be less important than distance from the ocean, with higher temperatures and lower humidity further inland proving to be important determinants of outdoor demand. If a disproportionate percentage of new construction in a community is taking place at a different elevation or further from the ocean than the existing housing stock,

the impact on average household consumption rates over time could be substantial. Other site-specific conditions, such as soil composition, have been found to affect irrigation uses on golf courses. In addition, service areas with hillier terrain tend to have a wider range of service pressure than do flatter areas, with consequences for time-dependent water fixtures, such as irrigation sprinklers and low-flow shower heads.

The final site-specific set of conditions mentioned above is the presence or absence of other water conservation programs. There are all sorts of potential interactions between conservation options, which can be broadly characterized as either synergistic or working at cross-purposes. Most interactions among programs fall into the latter category, with the impact of a set of programs less than the sum of the impacts of the individual programs. Programs with similar intended effects can't save the same water twice. On the other hand, synergies can occur between programs that provide both "carrot" and "stick" incentives, such as price increases or conservation-oriented rate structures coupled with voluntary programs to assist with plumbing fixture or landscaping retrofits. In either event, simple algebraic models of conservation potential that assume the savings of multiple programs is the sum of the savings of individual programs can be seriously

misleading. Water demand management programs with multiple measures should address interactions with other existing or potential measures.

One of the better approaches available for estimating the potential of various conservation measures is pilot projects, if sufficient time and money are available. There is no substitute for confronting real people with the conservation measure in real-life situations. However, they contain their share of potential pitfalls as well. One of the bigger problems with pilot projects is selecting a representative group to participate in the study. Both skimming, the practice of selecting those with considerable interest in having the project, and dredging, or selecting hard-core water wasters, must be avoided. Also, the actions of people are affected if they are highly conscious of their role in a study. Random selection and blind studies with control groups is preferred, but may not be possible.

IX. Measure-specific Topics

A. Water Pricing

1. Effects of other measures

If other successful demand management programs cause the price of water to increase to cover fixed utility costs, is the effort futile? No, for a couple reasons. First, the objective is not to save

money, but rather to spend the minimum amount of money necessary to assure that demand does not outstrip supply. Second, a reduction in per household demand reduces both the water provider's revenues and its costs. The nature of water utilities is such that revenues may fall more than costs, necessitating a rate increase. Whether this occurs or not depends on costs of marginal supplies and the particular rate structure. But even assuming that rates are increased, overall utility costs still will fall, and so will typical water bills.

2. Price levels as a demand management tool frequently are touted yet often disparaged. Among the factors that must be considered are:

- a. issues of price elasticity;
- b. real vs. nominal prices and inflation;
- c. historic and future water bills in the U.S.; and
- d. effect of income and bill size.

3. Rate structure design offers the possibility of revenue-neutral shifts in pricing coupled with increased incentives to reduce water consumption. Issues that must be addressed include:

- a. possibility of "windfall" profits;

- b. problem of multiple billing goals;
- c. cost of service principles; and
- d. complex structures, frequent changes, unavailability of price information and consumer perceptions of price.

B. Emergency Response in an Efficient System

One of the oft-mentioned concerns with proposed vigorous conservation programs is that they may leave no room for further reductions in the face of sudden, temporary supply interruptions. Quite simply, you can't put a brick or toilet dam in your 1.6-gallon ultra-low flow toilet, you can't take shorter showers beneath your low-flow shower head with cut-off valve, and you can't reduce the flow rates through your timer-controlled, soil-calibrated weather adjusted irrigation system. The situation is even worse if the emergency is the result of drought conditions that can cause the reduced supply to coincide with increased water demand for outdoor uses.

C. Quality of Life Impacts are particularly associated with major reductions in outdoor water demand through vegetation removal. Two of the consequences are:

1. The "browning" of the urban landscape;
2. Urban heat island effects.

D. Impacts on Energy Consumption

Over the last couple of years, increasing conflicts among different types of resource management programs have occurred. One example is interactions between programs promoting drought-tolerant landscaping and efforts to conserve heating and cooling energy. Proposals for mass plantings of trees in urban areas to address urban heat island effects, reduce atmospheric carbon dioxide buildups and remove particulates from the air have run afoul of water conservation efforts in some Arizona communities.

A recent study by a colleague and I considered the optimal landscape configuration for dwelling units in terms of minimizing the sum of heating, cooling and irrigation costs. As one might expect, the optimal landscape ranges from turf-dominated Mesiscapes to "Zeroscapes" featuring decomposed granite, depending on relative water and energy costs. Well-designed Xeriscapes are optimal over a wide range of utility costs; however, concerns have been expressed over some water conservation programs that encourage home owners to remove turf without requiring any replacement landscaping.

These kinds of economic and quality of life conflicts involving resource conservation efforts likely

will increase in the future. Therefore, all demand management measures considered should be examined in terms of potential effects on energy use and the urban environment.

X. Summary

The history of water demand management programs to date does not instill great confidence in the ability of water resource managers to confidently design and implement programs in lieu of other supply options. However, the level of activity in the field is precipitating attempts to make water demand management less of a black art and more of a science. The potential for significant permanent reductions in per capita demand exists, but the costs of successful program implementation, particularly planning and evaluation, should not be underestimated.