

# Water Loss Control in North America: More Cost Effective Than Customer Side Conservation – Why Wouldn't You Do It?!

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## Abstract

Times are changing rapidly in North America; the old reactive loss control measures are giving way to a more proactive control. Many states and regulators are starting to require their agencies to prepare standard AWWA (IWA) water balances and in many cases a more detailed component based analysis of losses. The authors have worked on several of these comprehensive projects throughout North America and will present key findings from small, medium and large sized utilities with a variety of resource constraints and loss components. One of the most important findings over the last few years is the relative low cost of distribution side water conservation (loss control) over demand side water conservation. Examples from Metro Nashville TN, LADWP CA and SFPUC CA show that the range of cost, including the initial high cost transitional intervention and repair costs, still leaves comprehensive real loss management as an option that compares very favourably with traditional demand side conservation methods.

## Introduction:

Distribution side conservation programs, also known as water loss control programs, are ready for new innovation in North America while, on the other hand, creative demand side conservation programs are a common practise, especially in the western states of the United States.

Whilst it is difficult to generalize the reasons for not employing more thorough distribution side conservation, the most common reasons are mentioned by Dickinson as: political infeasibility of admitting system leakage; falsifying water accounting records; lack of recognition that recapturing non-revenue water with an upfront investment is a still great business case with fast payback; and inherent mistrust of anyone outside the utility examining their system (Dickinson, 2005).

Demand side conservation is already widely practised in the U.S. and is seen as a state of the art and cost effective conservation measure. This paper provides the reader with a general comparison of distribution and demand side conservation and their cost effectiveness, keeping a special focus on the U.S..

## Background:

In North America, comprehensive water loss control programs are not pervasive, even though leakage (water loss) can be reduced with some simple starting points, resulting in multiple benefits to the drinking water utility and the environment.

Currently, the U.S. water industry has no uniform regulatory structure for water loss control in place. Existing U.S. regulations are simple and typically of poor precision. Validation of the water loss performance of drinking water utilities is rarely conducted and the most commonly used water loss performance indicator (percentage ratio of water losses in relation to the total system supply) is highly unreliable and, therefore, inappropriate. As a result the majority of U.S. water utilities only apply reactive leakage management practices. Similar to the absence of standard reporting and accounting methods and regulations, no national strategy exists to control and reduce these noteworthy losses (Fanner et al., 2007). Another likely reason for the lack of widespread distribution side conservation might be the fact that system losses and the monetary losses they are causing can be incorporated in the water rates paid by the customers.

Due to the current lack of standard reporting methods, it is difficult to quantify the amount of water lost in U.S. distribution systems. One of the few sources available estimating the current level of water losses in the U.S. is the U.S. Geological Survey (United States Geological Survey, 1998). This survey identifies 6 billion gallons per day as “public use and loss”, an amount of water sufficient to supply the ten largest cities in the U.S.

The past 20 years have seen major improvements on demand side conservation. Recent water utilities’ promotions of water conservation and efficiency resulted in major advances in research, public education and water use practices, particularly increased installation of water efficient fixtures, better irrigation practices, and more climate appropriate landscaping. However, water conservation in North America has largely focused on reducing customer demand conservation (Fanner et al., 2007). It appears that more precise regulatory structures in form of federal and state standards plus government incentives for demand side conservation have helped to make demand side water conservation a standard practice for water utilities.

Nevertheless, it is a main responsibility of the water utility to manage both the demand and supply of water responsibly and efficiently. Distribution side conservation through reduction and efficient management of system water losses provides real benefits to a water utility. These benefits include:

- Most effective and economic way of reducing level of losses from distribution system
- Improves public health protection
- Increases the level of service provided to customers through increased reliability of water supplies
- Leakage recovery often stands as the best source for new water resources for systems facing water supply shortage
- Reduced pressure on water resources and therefore environmental improvement
- Deferment of capital expenditure on water resources and supply schemes
- Improved public perception of water companies
- Applying best leakage management practice reduces liability to water supplier

Governments in North America are expressing interest in this area of water conservation, by mandating water audits and other initiatives to improve long-term water sustainability via better water supply efficiency. Some of the most important recent initiatives are:

- The Water Loss Control Committee (WLCC) of the American Water Works Association (AWWA) recommended both the IWA Water Balance and the IWA Performance Indicators in their Committee Report (Kunkel, 2003) as the current industry best practice for assessing water losses.
- In 2003, the Texas State Legislature passed house bill 3338, which includes in its language a requirement for drinking water utilities to submit a standardized IWA/AWWA water audit every five years.
- Other water oversight agencies also want to improve water supply efficiency and long term sustainability. The following organizations are reviewing state regulations, statutes, and water plans: Delaware River Basin Commission (DRBC), and the states California, Washington, Maryland, Massachusetts, Pennsylvania, Florida and New Mexico.
- The AWWA WLCC is rewriting the AWWA M36 Manual of Water Supply Practices, Water Audits and Leak Detection, to reflect the developments in the use of water audits, as well as leakage management and assessment.
- In early 2006, a free introductory software developed by the AWWA WLCC became available. The software includes a Water Balance and Performance Indicators, based on the AWWA approved standard water audit methodology and performance indicators. The software can be downloaded from the AWWA web page.
- California Urban Water Conservation Council (CUWCC) is currently revising its Best Management Practice 3 (BMP 3) to adopt the water loss management best practise recommended by the WLCC. Water losses will be assessed using standard water balance methodology and component analysis of real losses. Utilities will be required to achieve their economic optimum level of leakage within a set time frame.
- California Public Utilities Commission (CPUC) is in the process of ordering its member agencies to undertake distribution side water conservation measures. These measures will include regular standard water audits and component analysis and cost effective intervention against system losses.

Clearly, the awareness about the importance of distribution side conservation has increased over the past several years and with growing population and static water supplies it is paramount to accurately quantify system losses and to reduce system losses to an economic optimal point.

## **Water Conservation Goals:**

According to the Pacific Institute (2003) “the largest, least expensive, and most environmentally sound source of water to meet California’s future need is the water currently being wasted in every sector of our economy”. Key benefits of global water conservation and efficiency are quoted as:

- No need for further water reservoir and dam construction
- Saving water saves money! Both for Water providers and consumers as well as for the State
- Ecological and esthetic benefits to the environment

- Energy efficiency

## **Defining water “conservation” and “efficiency”**

The concept of conservation and improved management of water use goes back many decades. In 1950, the Presidents Water Resources Policy Commission published “A water for the American people” which noted:

*“We can no longer be wasteful and careless in our attitude towards our water resources. Not only in the West where the crucial value of water has long been recognized, but in every part of the country, we must manage and conserve water if we are to make the best use of it for future development”.*

The Pacific Institute (2003), goes on to say that there are many different and sometimes contradictory definitions of conservation. Bauman et al. (1980) defined water conservation as using the benefit cost approach for the socially beneficial reduction of water use or water loss. In this context water conservation includes trade offs between benefits and costs of water management options. The advantage of this definition is that it focuses on comprehensive demand management strategies with a goal of increasing overall well being – not curtailing water use.

Another term “technical efficiency” is sometimes used to refer to the ratio of outputs to inputs such as dollars per gallon of water used. Improving technical efficiency can be achieved by either increasing output or reducing water inputs. This is not dissimilar to the concepts used in water loss management where either billed volumes can be increased by reduction of apparent losses or water input can be reduced by reduction of real losses.

## **The Principle of Cost Effectiveness:**

Cost effectiveness analysis is the comparison of costs of a conservation device or activity, measured in dollars, with its benefits expressed in physical units for example \$ per acre foot of savings or \$ per MG of savings. Cost benefit analysis is the comparison of costs of a conservation device or activity measured in dollars with its benefits expressed in dollar terms for example \$ net benefits = \$ benefits - \$ costs. The most meaningful measure for purposes of cost benefit analysis is net present value NPV. NPV compares costs and benefits that occur at different times by discounting to determine their present value (CUWCC, 2000).

### ***BMP and the Importance of Cost Effectiveness***

In California many stakeholder groups including water utilities, regulators, environmental groups and consultants and contractors recognize the need for conservation of the State water resources. To this effect a memorandum of understanding (MOU) regarding urban water conservation was adopted in 1991. The signatories of this MOU pledge to uphold 14 different Best Management Practices (BMPs) covering various customer side and distribution side conservation activities. However, a signatory water utility is deemed to be exempt from the implementation of a specific BMP if that supplier can substantiate that after a full cost benefit analysis has been undertaken the conservation measure in question was deemed was not cost effective.

The exemption clause therefore serves to bring a certain business view point to environmental custodianship.

### **Importance of Cost Effectiveness in Distribution Side Conservation**

The core of efficiency analysis often takes the form of applied cost analysis comparing the costs and benefits of management alternatives. The first step is to identify the costs and benefits of the alternatives under consideration. The cost of the intervention tools is often relatively simple to identify however the benefit is often more difficult to define. It can be understood using avoided cost methods as identified in the AWWARF project *“Water Efficiency Programs for Integrated Water Management”*. Variable costs for water supply have grown over the years; specifically chemicals, treatment processes, energy for pumping as well as capital costs to develop new supplies. All of these costs should be applied to the benefit portion of the calculation for distribution side conservation (Chestnut T et al., 2007).

### **Components of a Comprehensive Water Loss Control Program:**

Water loss control programs vary from utility to utility, since they are tailored to the needs and specific characteristics of the utility. However, in general there are three major components in each comprehensive water loss control program. First the water audit phase, which is complemented by a component analysis of real losses, the assessment of the economic optimum volume of real losses, and the design of an appropriate intervention strategy. The next step is the intervention phase, and finally the result evaluation phase. It is paramount for the success of any intervention program or any investment in leak detection equipment, no matter how expensive and sophisticated the equipment might be, that the utility has undertaken a detailed water audit in order to gain the necessary understanding of their water losses.

### **Water Audit and Component Analysis of Real Losses**

The Water Audit itself is the process of identification and validation of the volumes which go into the Water Balance (see Figure 35).

System Input (Corrected)	Authorized Consumption	Billed Authorized Consumption	Billed Water Exported	Revenue Water
			Billed Metered Authorized Consumption	
			Billed Un-metered Authorized Consumption	
		Un-billed Authorized Consumption	Un-billed Metered Authorized Consumption	Non-Revenue Water
	Un-billed Un-metered Authorized Consumption			
	Water Losses	Apparent Losses	Unauthorized Use (including theft of water)	
Consumption Meter Error				
Real Losses				

**Figure 35** AWWA Standard Water Balance

First the corrected System Input Volume (corrected for any system input meter inaccuracies) is identified and then all of the Authorized Consumption volume is subtracted. The remaining volume is classified as Water Losses. Water Losses are defined as the difference between the volume of water put into the distribution system and the volume taken out for billed and unbilled Authorized Consumption.

Next, Water Losses are broken down through a series of analyses into two components; Apparent Losses and Real Losses.

Revenue Water represents the total amount of Billed Authorized Consumption. Non-Revenue Water is composed of Unbilled Authorized Consumption and Water Losses.

The Water Balance calculates the total volume of Real Losses for the audit year. However, it does not provide the information on what portion of these Real Losses is due to Hidden Losses (losses from leaks that have not been capture by the utilities current leakage management policy). Hence, an additional methodology (component analysis of real losses) is used to assess the level of Hidden Losses so that specific cost-effective Real Loss management activities can be identified. By assessing the volume of Real Losses through component based analysis, it is possible to determine the volume of Real Losses that have been captured through the current leakage control policy. Therefore, by deducting the Real Losses assessed through the component based analysis from the Real Losses assessed through the top down Water Balance, it is possible to determine the volume of Hidden Losses. Appendix A (Figure 38) provides a general flow chart on the process that is involved in calculating the amount of Hidden Losses. Hidden Losses are made up of detectable leaks that are not being identified because of insufficient or incorrectly targeted leak detection activities. In effect, Hidden Losses are a backlog of leaks and breaks waiting to be detected and repaired. Individually, each hidden leak may not be causing a customer service problem and may not be visible at the ground surface. Collectively, however, Hidden Losses can account for a considerable volume of Real Loss each year. Based on the volume and nature of the Hidden Losses an appropriate and cost effective intervention program is designed.

### ***Intervention Program***

Based on the results of the water balance and component analysis the economically most feasible intervention program is designed for the water utility. There is a variety of intervention measures available and according to the needs of a utility they will be used as found appropriate to design the intervention program. The most common intervention measures to reduce hidden losses are:

#### ***Active Leak Detection Campaign***

Active leak detection involves sounding parts of or the entire distribution network in set intervals for hidden leaks. The technologies used for detecting the sound generated by hidden leaks may vary from utility to utility. In most cases a combination of technologies is used in order to achieve the maximum results.

#### ***District Metered Area (DMA)***

Hydraulically discrete zones (DMA) are created on temporary or permanent bases and supply into the DMA is metered and recorded. By deducting the legitimate consumption from the total inflow to the DMA the volume of real losses existent in the DMA can be calculated. DMAs allow prioritizing leak detection efforts to those areas with the highest volume of real losses and therefore guarantee the most efficient use of leak detection resources. DMAs also allow, when used on a permanent bases, to identify the rise of leakage volumes in DMAs in order to determine when it is cost effective to go back into the DMA and find and fix the newly occurred leaks. DMA measurements provide the utility with information necessary to reduce the runtime of hidden leaks to an economic

optimum. However, DMAs are also the most expensive form of intervention against real losses.

### ***Pressure Management***

Pressure management for leakage control, in its widest sense, can be defined as “The practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and customers, while reducing unnecessary or excess pressures, eliminating transients and faulty level controls all of which cause the distribution system leak unnecessarily” (Thornton, 2005). Pressure management has the effect of reducing the frequency of new breaks and it reduces the flow rates of all breaks and background losses.

Based on the volume and nature of system losses and their monetary value the most feasible intervention program is designed using all, a combination or only one of the intervention measures outlined above.

### ***Result Evaluation***

If the intervention program was designed for the entire distribution system then a second water balance should be established after completion of the intervention program. If the intervention took place on a DMA level then it is best to repeat the DMA measurements after completion of the intervention.

## **Typical Demand Side Conservation Programs:**

A great variety of demand side conservation programs exist and this section tries to outline the most common ones.

### ***High Efficiency Washing Machines Rebate Programs***

High efficiency washing machines are designed to save water and energy. Water utilities provide customers using high efficiency washing machines with rebates in various forms.

### ***Metering Programs***

Meters are installed at existing customer sites where currently no meter exists. These programs also require installation of water meters at all new construction sites. Such programs can also add meters to individual units in a multi-family building where there was previously only a master meter (BMP cost and Savings Study, 2003).

### ***Residential Plumbing Retrofits Programs***

Low flow shower heads and other water efficient plumbing devices are provided to the customer through various types of incentive programs.

### ***Residential Surveys/Audits***

Residential home surveys target both indoor and outdoor water use. In practice, home surveys usually imply a site visit by trained staff who solicit information on current water use practices and make recommendations for improvements in those practices. Sometimes indoor plumbing retrofit devices are directly installed when appropriate. The outdoor portion of the survey can vary widely, ranging from an intensive outdoor

efficiency study to provision of a brochure on outdoor watering practices (BMP cost and Savings Study, 2003).

### ***Ultra Low Flush and High-Efficiency Toilet Programs***

Ultra-low-flush (ULF) toilets are low water using toilets using no more than 1.6 gallons a flush, and High Efficiency Toilets (HETs) are high efficiency toilets using no more than 1.3 gallons per flush. HETs include dual-flush fixtures. Various incentive programs are used by water utilities to promote the installation of ULF toilets and HETs.

### ***Commercial – Institutional and Industrial Surveys/Audits***

Such surveys can range from short “walkthroughs” to sophisticated water efficiency studies. Customers are targeted with a marketing strategy and incentives. Recommendations are made to reduce the water consumption at the facility (BMP cost and Savings Study, 2003).

### **Cost and Savings of water loss control programs:**

In order to evaluate the cost of distribution side conservation programs, eight systems and their water loss control programs were analysed. The cost for the programs includes the cost for detailed audits and assessment of economic optimum volume of losses, the cost for the leak detection program and the repair of the leaks.

### ***San Francisco Public Utilities Commission (SFPUC)***

SFPUC has a relatively low volume of real losses due to a very efficient leak repair policy and good infrastructure. However, analyses of the economic optimum for real losses have shown that it is economically feasible for SFPUC to reduce the volume of real losses through proactive leak detection and repair if real losses are valued at the retail cost of water. SFPUC is a very proactive utility already applying numerous conservation programs and a policy decision was taken to value real losses at the retail cost since the volume gained from real loss reduction will form part of SFPUC water conservation portfolio. Since, the intervention part of the project has not started yet it was necessary to estimate the cost for the leak detection and repair program based on average industry cost data. The average cost for the entire program including the cost for the detailed water audits that formed the bases for the intervention program and the cost to detect and repair the leaks was calculated to be \$439 per acre foot of water saved.

### ***Nashville Water Works***

Nashville Water Works is in the third year (of a five year program) of an intensive leak detection and repair program. The detailed water audits and related economic analysis have shown that it is economically feasible for Nashville Water Works to increase their water loss control efforts in actively detecting and repairing hidden leaks. Water Systems Optimization was contracted to carry out this five year leak detection program. DMAs are set up on a temporary basis to evaluate the volume of losses in each DMA. Following the DMA measurements leak detection teams from WSO are sent into the DMA to find all leaks and mark their location. Once all leaks are identified the information is handed over to Nashville Water Works for the repair of the leaks. After all leaks have been repaired a second DMA measurement is carried out to calculate the savings in real losses. The average cost for the entire program including the cost for

the detailed audits and the cost to detect and repair the leaks was calculated to be \$318 per acre foot of water saved.

### ***Los Angeles Department of Water & Power (LADWP)***

LADWP has a relatively low level of real losses. However, economic analyses have shown that a more aggressive active leak detection and repair policy is economically feasible. Since this part of the project has not started yet it was necessary to estimate the cost for the leak detection and repair program based on average industry cost data. The average cost for the entire program including the cost for a detailed water audit that forms the bases for the intervention program and the cost to detect and repair the leaks was calculated to be \$347 per acre foot of water saved.

### ***California Department of Water Resources- Water Audit and Leak Detection Program 1988***

In 1988, the California Department of Water Resources carried out a Water Audit and Leak Detection Grant Program with 47 participating utilities from California. All utilities conducted a detailed water audit prior to the leak detection program to assess the cost effectiveness of such a program. Utilities showing a cost/benefit ratio greater than 1.0 continued into the leak detection and repair phase. The average cost for an entire water loss control program was \$658/acre foot of water saved.

### ***Las Vegas Valley Water District (LVVWD)***

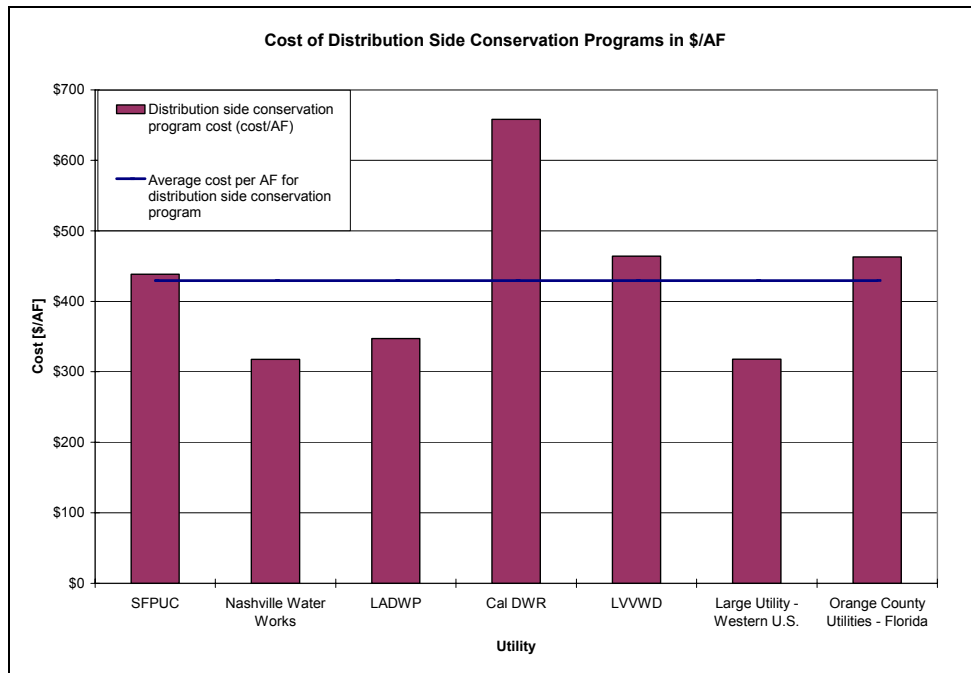
An article by Marcellus Jones Jr. from LVVWD published in the AWWA journal in February 2006, was used to estimate the cost for the water loss reduction program in LVVWD. The article did not include any cost for a detailed water audit. In order to be able to compare the program cost with the other cases presented an average audit cost based on the utilities size was assumed. The cost for the noise loggers purchased by LVVWD for this program was not included in the analysis since their investment cost has to be spread out over several years. The total cost for the water loss control program including audit cost, the cost to run an active leak detection program and the cost to repair the leaks was estimated to be \$464/acre foot of water saved.

### ***Large Utility – Western United States***

A large utility in the western U.S. that wishes to remain anonymous conducted a detailed water audit. The findings showed that it was economically feasible to conduct an aggressive leak detection and repair program covering the entire network once a year. Since the intervention program has not started yet average industry cost data were used to assess the cost for the leak detection and repair program. The total cost for the water loss control program was estimated to be \$318/acre foot of water saved.

### ***Orange County Utilities (OCU) Florida***

A detailed water audit has shown that reducing real losses through an active leak detection and repair program is economically feasible for OCU. The leak detection program is planned to commence in summer 2007. In order to be able to compare the program cost to the other utilities the cost for the leak detection and repair program was estimated based on average industry cost data. The total cost for the water loss control program was estimated to be \$463/acre foot of water saved.



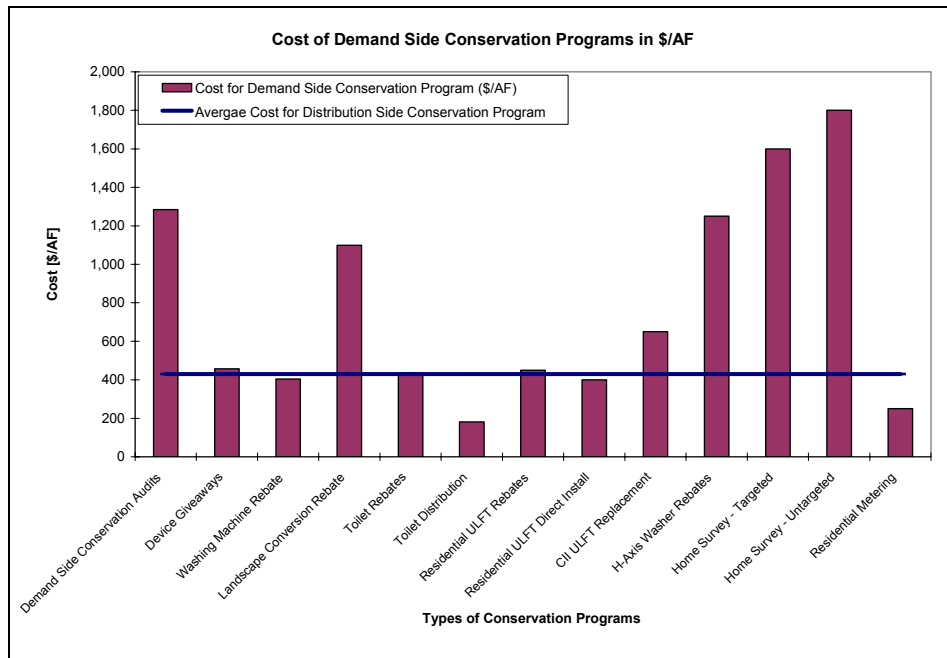
**Figure 36** Cost for distribution side conservation programs

This analysis shows that the program cost might vary from utility to utility. A general guideline is that distribution side conservation programs are cheaper when the volume of real losses is high. The lower the volume of real losses the more effort is required to reduce them and therefore the overall cost for the distribution side conservation program increases. Since it is recommended by the CUWCC to calculate the cost effectiveness of demand side conservation programs against the avoided cost of water (basically the retail cost of water) the average avoided cost for an acre foot of water was calculated for the six utilities shown in Figure 36. The average avoided cost (retail cost) of an acre foot of water was \$1,030/acre foot. This clearly shows the cost effectiveness of the distribution side conservation programs evaluated for this paper.

### **Typical costs per AF for demand side conservation:**

Two documents form the basis for the demand side conservation program costs outlined in this paper. The first source was the CALFED Bay Delta Program – “Water Use Efficiency Program Plan July 2000”. The unit cost estimates in this report were constructed using methods outlined in the California Urban Water Conservation Councils (CUWCC) “Guidelines for Preparing Cost-Effectiveness Analyses of Urban Water Conservation Best Management Practices”. Water supplier BMP implementation reports provided most of the program cost data used for these estimates. The second source was the “Evaluation and Cost Benefit Analysis of Municipal Water Conservation Programs” prepared by the Water Conservation Alliance of Southern Arizona.

The typical costs per acre foot saved water were assessed for 13 demand side conservation programs and are depicted in Figure 37.



**Figure 37** Typical cost for demand side conservation programs compared to average cost for distribution side conservation programs

The cost for demand side conservation programs varies considerably. The average cost for demand side conservation programs employed in California averages between \$250 and \$600/AF water saved based on discussions with the CUWCC. Reality is that utilities will start by employing the cheapest demand side conservation programs first, which can be very cost effective – less than \$200/AF. However, with time the utility will have to move on to more expensive demand side conservation programs with some of them costing as much as \$1,000/AF of water saved. . Figure 37 also shows for the purpose of comparison the average cost for distribution side conservation programs (\$429/AF) as a blue line.

## Conclusions:

Demand side conservation programs are now becoming an integral part of a water utilities operation. An important factor in promoting demand side conservation programs is that over the past 15 to 20 years meaningful and unambiguous federal and state water conservation standards and policies were introduced. So far distribution side conservation is not seen as a complementing component of a comprehensive water conservation port folio. However, when comparing demand side conservation program cost with distribution side conservation program cost it becomes clear that the cost effectiveness of distribution side conservation programs is equal or in many cases better than the cost effectiveness of demand side conservation programs. The water saved through reduction of real losses makes available new sources that can be used for additional supply which will help to avoid or reduce the need for demand restrictions during periods of droughts, and will ease the pressure on the environment and water resources. The authors therefore conclude that based on the cost effectiveness and benefits related to distribution side conservation programs water utilities should include distribution side conservation programs in their water conservation port folio.

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## Appendix A

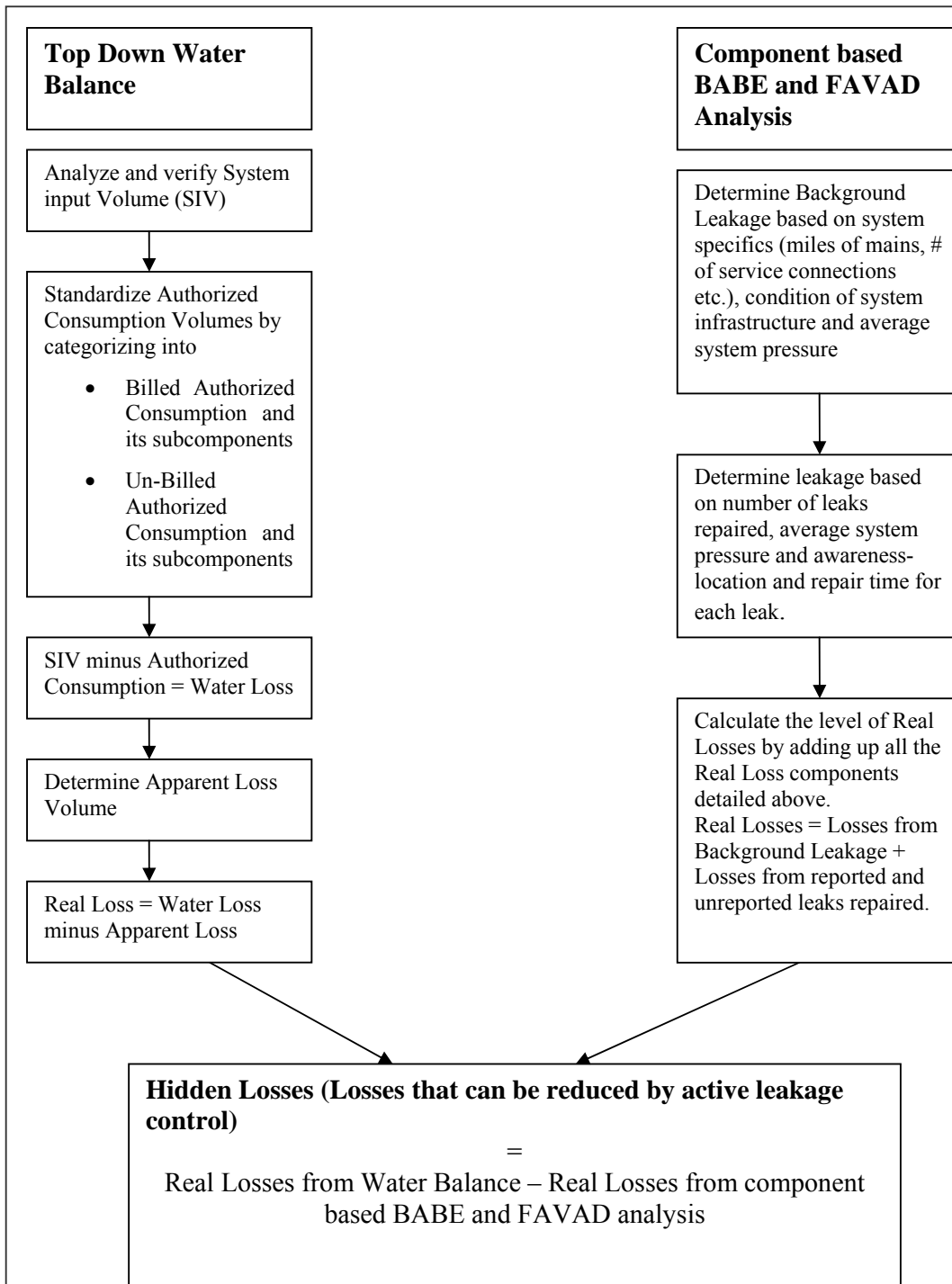


Figure 38 Flow Chart How to Determine Hidden Losses