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Water Conservation Manual

For Development of a Water Conservation Plan

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PREFACE

This "*Water Conservation Manual for Development of a Water Conservation Plan*" has been printed and distributed by the New York State Department of Environmental Conservation (NYSDEC), Division of Water. It is intended to help local water supply systems to comply with state legislation that requires a water conservation program as a part of any new application to NYSDEC for a Public Water Supply Permit.

The manual is a "how to" guide that addresses a large number of water conservation measures such as water metering, the conduct of a system water audit, the detailed study of water demand, reduction in system water loss, and reduction in system water demands.

If you have any questions or comments please call the Division of Water's Bureau of Water Resource Management in NYSDEC at (518) 402-8086. You may also email your questions or comments to the attention of "Public Water Supply Program" at dowinfo@gw.dec.state.ny.us

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Acknowledgments

This manual was conceived and written in 1989 by William Nechamen of the Bureau of Water Resources (now the Bureau of Water Permits) in the New York State Department of Environmental Conservation.

The appendix on public information and education, published for the first time in the 1998 re-printing, was written in 1993 by William Nechamen of NYSDEC and Jeff Featherstone of the Delaware River Basin Commission.

The 1998 re-printing was composed in WordPerfect (Version 6.1 for Windows) by G. Gordon Behn of the Bureau of Water Permits in NYSDEC.

I. Introduction

In July of 1988, the Governor of New York State signed legislation requiring a water conservation program as a condition of a water supply permit.

To assist local governments in complying with this new requirement, the law directed the New York State Department of Environmental Conservation (DEC) to develop a model water conservation plan which includes beneficial short- and long-range water conservation procedures reflecting local water resource needs and conditions. This manual serves as a model to help advise local officials regarding water conservation techniques which individual suppliers may use to conserve water.

In addition, the Statewide Water Resources Management Strategy, approved in January 1989, recognizes the importance of water conservation and directs DEC to assist local water suppliers with water conservation programs. The strategy cites the delicate balance between water supply and demand. Also, the strategy also notes that, in many areas of the state, demand is catching up with available supplies. Increased water demand and contamination of supplies have placed more stress on existing water resources.

Why Should Municipalities Conserve Water?

Other than maintaining a supply-demand balance, municipalities conserving water will realize the following benefits[1]:

- increased ability to handle emergencies such as drought mechanical failures, or water contamination;
- variable cost savings in energy and chemicals from reduced production, treatment, and consumption water;
- deferment of expenditures for expansion of water supplies or wastewater treatment facilities by allowing an existing water supplies and/or wastewater treatment systems to serve increasing populations;
- greater efficiency and increased capacity in wastewater treatment facilities;
- improved in-stream flows in source water and related water resources and higher quality in wastewater receiving bodies; and
- alleviation of competing demands for water resources.

How Do Users Benefit from Conservation?

Water heating costs can be cut by nearly one-third, and water and sewer bills will decrease under conservation programs. Where conservation can postpone or reduce the size of expanding existing facilities or developing new supply sources, water conservation is often the most cost-effective alternative. Even where conservation programs necessitate water rate increases, the average consumer will likely pay less than if the program had not been undertaken

What is Water Conservation?

Conservation is simply a protection from loss of waste. Therefore, water conservation activities reduce the demand for water, improve the efficiency in use and reduce losses and waste of water. Short-term conservation measures (such as those for emergency or drought conditions) differ from long-term measures in terms of implementation time, degree of public cooperation, long term effectiveness and influence on water supply planning.[2] In a nutshell, long term measures are substitutes for new water supplies while emergency measures are applied to quickly fix temporary emergency water problems. Short-term and long-term measures can influence each other. For example, a long-term measure such as a landscape design change may require increased watering at first, thereby reducing short-term savings available through outdoor irrigation restrictions. When designing a conservation program, it is necessary to have an accurate picture of water demands in order to estimate potential savings. For this reason, a water supply audit, which breaks supplies and demands into all components, followed by a demand projection, is key to an achievable plan. An accurate water audit cannot be accomplished without customer water meters and meter records.

Water meter information can also be used to bill customers for their water usage, providing strong incentive for the user to conserve.

Water Conservation Methods

Every community has special circumstances affecting its water supply and demands. The appropriate plan for one community might differ from that of its neighbor. Careful consideration should be given to methods benefiting a particular system. For example, older housing might benefit most from a conservation program that replaces plumbing fixtures in existing housing, while a developing region might better concentrate on using low-flow plumbing fixtures in new housing and conservation through landscaping.

Education and information are essential components of any conservation plan. Water users must receive information about the reasons for, benefits of and methods of conservation. It is important to involve the public in developing a water conservation plan.

Furthermore, water users should understand that conservation is important to them even during normal hydrologic cycles. Water conservation approaches considered in this manual are:[3]

- Metering
- Pressure reductions
  - Services
  - System
- Pricing
  - Uniform commodity rates
  - Inclining commodity rates
  - Seasonal rates
- Outdoor Use
  - Restrictions
  - Efficient landscape design
  - Scheduled irrigation
  - Efficient irrigation systems
  - Tensiometers
- Industrial reuse/recycling
- Leak detection and repair
  - Within water supply system
  - Within customers' premises
- Plumbing retrofit
  - Low-flow showerheads
  - Toilet-tankdisplacement (insertion of bottles or dams)
  - Pipe insulation
  - Faucet aerators
- Moderate plumbing code
  - Enforcementof existing state code
- Advanced plumbing code
- Public education/information

This manual describes methods and provides examples for devising a beneficial local water conservation plan that considers various demand sectors, dimensions and coverages and recognizes the interaction of related conservation programs. For each water conservation measure, a coverage factor is applied to a particular demand sector and dimension. The coverage factor is the fraction of a particular demand sector covered by a particular conservation approach. The demand sector includes various components of a system's water demand, as identified in a system water audit. Sectors include interior residential, exterior residential, commercial, industrial, public and unaccounted-for water uses. A dimension is a flow rate corresponding to a specific condition, such as average daily flow, peak daily flow, and peak hourly flow.

Some conservation benefits decrease over time, and the effectiveness of a conservation approach might eventually diminish if additional actions are not taken. In addition, a particular method might achieve significant benefits by itself while adding only marginal additional benefit to those achieved by a method already underway.

II. Information Requirements

Before the components of a conservation program can be determined, it is necessary to compile a water supply audit and water demand evaluation for an individual water system.

A. Water Metering

1. Metering for Information

Meters are prerequisite for other conservation methods, such as water pricing, education and leak detection. Meters provide information about water consumption necessary to identify users with leakage problems, and carry out repair programs that cannot be efficiently carried out without the consumption information only meters can provide. Meters provide water accountability, without which it is not possible to know the results of a conservation effort. The American Water Works Association officially advocates 100 percent metering of water customers.[4]

Without meters, customer bills cannot be based on volumes of water used. Once meters are in place, they allow for various water rate structures which can help influence water use. Metered water rates, with timely and understandable billing, provide proven incentives in reducing unnecessary water uses, repairing leaky plumbing, and installing more efficient water-using fixtures. In addition, meters are necessary for efficiently maintaining water systems, accurately assessing demand, and determining appropriate capital expenditures.

2. Metering for Incentive

Metered water rates provide a direct incentive for user based water conservation, because meters allow water utilities to charge for water based on actual usage. Savings are greatest during warm weather months when water is used for landscape irrigation. However, even indoor use during winter months tends to decrease after meter installation and unit billing because building owners are encouraged to fix leaks and use more efficient plumbing and appliances.

Using metered rates as an incentive to conserve requires frequent meter reading and billing to show a clear pattern to the consumer. A quarterly meter reading and billing schedule based on actual water consumption is the minimum recommended.[5] Timely billing is particularly important where seasonal water use is a concern. Large water users should be billed more frequently. Some water utilities around the country have begun more frequent billing of residential accounts.

Experience in New York State has shown a total demand reduction of over 20 percent after first time metering. In Kingston, a universal metering program resulted in reduced peak daily and hourly loads, from 8 MGD in 1957 to 4.3 MGD in 1962 (both years were dry). Average water use went from 5.5 MGD in 1957 to 4.0 MGD between 1960 and 1963. The program resulted in postponement of a water treatment plant expansion and allowed the city to determine unaccounted-for water and to evaluate production costs. In New York City, the Jamaica Water Supply Company recently completed metering 90,000 residential accounts in its Queens service area, and has seen a 20 percent average usage reduction. In both the Kingston and New York City cases, the new meters were accompanied by regular billing with rates based on water used.

A comprehensive metering program includes source or master meters and service meters, and it considers maintenance and record-keeping needs.

3. Types of Meters

a. Master Meters

Master or source meters measure the water supplied from sources, storage facilities and treatment plants. They are designed for accountability, rather than sale, of water. Obtaining data from master meters is the first step in determining if a system has unaccounted-for water.

All water meters tend to under-register. Master meters, however, can also over-register by as much as 25 percent[6] due to improper setting, sizing or gearing, poor water quality, reading errors, or air or jetting action.

Master meters should be tested for accuracy at least once a year.[7] Tests can be conducted in place with a Pitometer or comparative flow meter. A pitot tube measures The flow rate by comparing differential pressures and converting the square root of the pressure difference to flow units. Under good conditions, accuracy is within 3 percent. Because turbulence decreases accuracy, pitot installations should be made with 10 to 20 pipe diameters of straight pipe from any obstruction.[8]

b. Service Meters

Service meters include residential and commercia meters. An efficient water supply system should have a service meter at every service connection, including public facilities which may not directly pay for service. As with master meters, it is important that meters be properly sized and installed, that they be maintained, and that records be kept assisting meter and system maintenance and system planning decisions.

4. Costs and Benefits to the Utility

For a water system not fully metered, a metering program is admittedly costly. Installing, maintaining, and reading meters can represent a significant portion of a utility's costs.[9] Furthermore, switching to full metering causes revenues to become more uneven as income reflects the ebbs and peaks of annual demand. Depending on the size and type of meters used, and installation conditions and requirements, the cost of metering can range from $50 to over $300 a service, with even higher costs for very large service connections.

In most instances, however, the benefits derived from meters far outweigh their cost. In terms of the water conservation message alone, metering costs of up to $500 per service are likely to be cost effective in the long term due to reductions in peak and average demands.[10] Meters also engender equity in customer charges and the ability to use various pricing policies.

Utilities can find ways to bring the cost of metering down. One way is to use less expensive residential meters made with plastic and periodically replaced rather than repaired and returned to service. Another way is to contract out meter installation to a private firm, rather than the utility installing its own meters.

5. Meter Size

The size and type of meter should be appropriate for the range and rate of water use. Residential meters of the 3/4 inch or 5/8 inch size are fairly standard, but commercial meters show considerable variation. (Commercial meters in this case include those one inch or larger, regardless of the type of user.) These meters may represent a small portion of a system's total number of meters while accounting for a large amount of water use. There is a tendency to oversize a large meter because of concern with meeting the customer's maximum demand. However, oversized meters can under-register low flows, resulting in loss of revenue. A meter which is too small, however, can produce an excessive drop in pressure causing rapid wearing.

The type and size of meter depends on flow rates, allowable pressure loss and possible safety requirements, such as fire service regulations. Types of meters include turbines, positive displacement, and compound meters. Compound meters are particularly useful where water usage is predominately at the lower and intermediate range of flows. A compound meter is a combination displacement and turbine meter with a changeover valve which shifts water flow from one measuring element to the other depending on the velocity of the water. Higher flows are diverted to the turbine side. Meters can also be manifolded using two or more meters installed as a battery with weighted check valves to regulate usage and flow rates of each meter.

The American Water Works Association recommends that utilities consider maximum-, average- and minimum-flow rates when determining meter type and size. Table 1 has some recommended applications.

Table 1: Meter Type and Recommended Applications.

Meter Type and Size	Demand Flow Rate	Maximum Continuous Demand
Positive Displacement Meters		
5/8 inch	1/4 to 20 gpm	10 gpm
3/4 inch	½ to 30 gpm	15 gpm
1 inch	3/4 to 50 gpm	25 gpm
1.5 inch	1.5 to 100 gpm	80 gpm
Class II Turbine Meters		
2 inches	4 to 200 gpm	160 gpm
3 inches	8 to 350 gpm	300 gpm
4 inches	15 to 630 gpm	500 gpm
6 inches	30 to 1400 gpm	1100 gpm
8 inches	50 to 2500 gpm	2000 gpm
10 inches	75 to 3800 gpm	3000 gpm
Compound Meters (New Styles)		
2 inches	1/4 to 160 gpm	
3 inches	½ to 350 gpm	
4 inches	3/4 to 630 gpm	
6 inches	1.5 to 1400 gpm	

For more detailed information on appropriate meter type and sizing, the reader is advised to consult American Water Works Association manual M6: "Water Meters—Selection, Installation, Testing, and Maintenance."

6. Meter Maintenance

Water meters cannot perform their required function if not properly maintained. All meters slip to varying degrees with passing time. Sand, debris and minerals passing through the measuring element increase the tolerances in the chamber, allowing more water to pass through than is recorded. As meters begin to slip, low flows fail to register, and under-registration continues to increase as the wearing process continues. Up to 23 percent of all water flows in domestic meters can fail to register. Tables 2 and 3 show the average flow rates of domestic services and average under-registration of meters by age.[11]

Table 2.
Percentage of Total Flow Through Domestic Meters at Various Rates.

Range of Flow Rates (In GPM)	Water used in this range of flow rates (As percentage of total water used)
0.00 - 0.25	13.0
0.25 - 0.50	3.4
0.50 - 1.00	6.8
1.00 - 2.00	13.3
2.00 - 4.00	43.0
More than 4	20.5

Table 3.
Under-Registration of Meters According to Age.

Age of Meters (years)	Inaccurate Meters (per cent)	Minimum Registrable Flow (gpm)
0-9	5	0.75
9-19	20	0.75
19-29	50	1.25
More than 29	84	1.50

A regular program of meter testing and maintenance will minimize under-registration, resulting in less unaccounted-for water, more stable water revenues to the supplier, and more appropriate price signals for the customer. Master meters and large commercial meters should be tested annually. A program of sample testing of residential meters could help determine an optimal repair or replacement schedule.

The American Water Works Association recommends that meters remain in service until they fail to register within accepted accuracy limits. A residential meter should register between 98.5 percent and 101.5 percent of actual flow at flows between 2 and 15 gallons per minute. At a flow rate of 1/4 gpm, 95 percent to 101 percent accuracy is considered appropriate. It may be necessary to remove and test a representative sample of residential meters which includes the range of types, makes and ages and includes meters that may serve regions with different water sources. An initial sample of 5 percent of each group of meters will yield approximate accuracy rates for all residential meters.

Meter testing should be done for at least three flow rates: 1/4, 2, and 15 gallons per minute. A rough estimate of total meter accuracy can be made by multiplying the meter accuracy at each of the three test flow rates by a percentage of use at that flow by .13, .72 and .15 respectively, then adding the products. The average under-registration should also be used in determining metered water sales for a water system audit.

Based on sample findings, a priority schedule should be developed for calibrating, and repairing or replacing as needed all residential meters over a 10-year rotating schedule.

7. Meter Records

An appropriate meter program must include accurate record-keeping. Meter history cards could be kept, or data could be maintained on computers, providing information on meter size, make, type, date of purchase, location, and tests and repairs. A sample form follows on page 8 as Worksheet 1.

8. Advanced Meter Technologies

A common impediment to an appropriate meter reading schedule is the difficulty of gaining access to private residences to read the meters. Estimated readings are often the rule rather than the exception. Once the meter is read, consumers often are hit with a very high water bill to make up for past, unbilled use. At the very least, this causes bad public relations. It also eliminates the price-related feedback on which conservation programs depend.

Remote reading registers can circumvent the access problem by allowing meter readers unlimited access to meter information. Remote read systems are attached to indoor meters either through an electric pulse or a flexible cable. The electric systems require no external power source. They typically require a meter reader to visually read and copy information.

There are also hand-held computer systems which electronically read meters through a plug in the remote register and are later loaded down to an office computer. This computer maintains meter records and processes water bills. Such a system can record the time and date of the reading, can flag information based on certain conditions (such as a reading over a certain percentage more than the average reading), and can even print out a bill right on demand.

New technologies currently under development will eliminate the need for meter readers while providing added flexibility in the schedule and frequency of meter reading. These remote registration systems will obtain readings through telephone data hookup or by radio signal. Telephone systems can be designed as a "call out" in which a central computer calls out to meter locations and logs data at the rate of about 8 to 10 reads per minute. A "call in" system relies on each meter using the building phone line to automatically call readings out to a central computer on a scheduled basis. Radio read systems use radio signals from a mobile unit that drives down the street. Currently, the Spring Valley Water Company in Rockland County is developing a call-out system, and the New York City Bureau of Water Register has plans to conduct a pilot study of all three systems. With any remote meter reading system, it is necessary to periodically calibrate the remote device with the actual meter. An annual check of the actual meter will assure system operators and customers that the remote system represents actual water use.

9. Water Metering in the Conservation Program

Worksheet 2, on pages 9 and 10 below, can help you to define the water metering element of your conservation program. By completing the worksheet, you can determine the degree to which your present metering efforts meet the stated goal and objectives. You can then identify future efforts that can bring about the needed improvements to your metering program.

Worksheet 1: Sample Meter History Record Form

A: METER INFORMATION

Mfr. No.	Co. No.	Make	Size
Date Purchased	Cost	Style	

B. INSTALLATION RECORD

Installed		Name	Address	Tap No.	Removed		
Date	Reading				Reason	Date	Reading

C. TEST AND REPAIR RECORD

Date	Rate of Test			% Accuracy		Repair Cost		Tested by	Remarks	
	Min Flow	Inter Flow	Max Flow	Before Repair	After Repair	Materials	Labor			

Worksheet 2: Water Metering.

The following information would aid in development and assessment of your water conservation plan.

GOAL: To provide an accurate measurement and record of water use, and promote water conservation

Recommended Actions:

- 100 percent metering of all water system connections, including public buildings.
- Ongoing metering program with regular program of testing, recalibrating, repairing or replacing meters as needed. Residential meters will be tested at least every ten years. Large meters should be tested annually.
- Quarterly meter reading and prompt billing with water rates reflecting amount of water used. Large services to be read more frequently.

A. Past and Present Efforts:

1. What percent of your system is metered? ________________%
2. Number of operable meters in system: __________________

    List percentage of users metered by category:

    Residential ______% Industrial _____% Commercial______%
    Public ______% Other _____%

3. How often are master (or source) meters calibrated? ___________________________
4. How often are the master meters read? ______________________________________
5. How often are customer meters read? _______________________________________
6. What is the general condition of your meters?

    Master ______________________ Customer _______________________

7. Do you use externally read meters? ____ YES ___ NO. If yes, _______%
8. Do you have an ongoing program to monitor, check, repair, and replace meters?
    ____YES ____ NO

    If YES, briefly explain your program:
    ____
    ____
    ____
    ____
    ____

(Worksheet continues on next page)

9. Has your metering repair and calibration program been effective in reducing the amount of unaccounted-for water, increasing revenues, or decreasing demand?

   Briefly explain:
   ____
   ____
   ____
   ____

10. What problems, if any, prevent the accomplishment of an optimal metering program? Include, if applicable, cost and labor and institutional impediments.
    ____
    ____
    ____
    ____

11. Estimate how much is spent on the metering program per year

Meter installation:	$__________
Meter repair and calibration	$__________
Meter reading	$__________

B. Future Efforts:

12. What long range goals exist for improving your metering program?
    ____
    ____
    ____
    ____

13. What measures are planned to implement these goals?

14. What is the timetable for achieving these goals?
    ____
    ____
    ____
    ____
    ____

15. What is the approximate cost and funding source for these efforts?

____
____
____
____

B. Water Supply Audit

A water system having well-maintained meters and meter records, is in a position to undertake and periodically update a system water audit. The information gained from the audit can help determine how much unaccounted-for water is leakage, what portion is due to meter under-registration, and other needed areas of improvement. The audit is also a preliminary element of a detailed water demand summary. That, in turn, is a necessary component of a comprehensive water conservation plan.

Utilities often strive for an unaccounted-for water figure of 10 percent to 15 percent and a per capita residential demand of 70 gallons per capita per day (gpcd), although these figures may vary. What is most important is not whether a particular system meets certain arbitrary rules of thumb, but whether that system is utilizing reasonable, cost effective methods to reduce waste, minimize unaccounted-for water and decrease system demand. The water supply audit is an indispensable step in making those determinations and setting priorities.

The steps of a water audit include:

- identifying and quantifying all water sources and all metered uses,
- identifying and estimating authorized unmetered uses,
- identifying and estimating water losses by types, and
- analyzing audit results.

All elements of the water audit should be consistent in terms of period studied (a 12-month period is recommended) and water units measured. Units could be in thousands or millions of gallons or cubic feet, as long as the unit is clearly identified and is consistent.

The audit results will help in forecasting water demand and conducting a leak detection and repair program. Sections B.1 through B.4 describe the basic steps in a system water audit and offer sample worksheets to help complete the audit.[12]

1. Quantify the Water Supply

The utility should have a current list of all water sources supplying the distribution system, including interconnections with other systems and intermittent or emergency supplies. Ideally, source locations or connections should be illustrated on a system map. Each source or interconnection should have a way of measuring quantities supplied to the distribution system. For each source, the following should be recorded:

- Name of source
- Type of source (well, reservoir, natural surface water body, purchased)
- Type of measuring device
- Date of installation
- Identification number of measuring device
- Frequency of reading
- Type of recording register (e.g., dial, builder type)
- Units register indicates
- Multiplier (if any)
- Size of conduit
- Frequency of testing Date of latest calibration

A one year record of supply should be totaled using Worksheet 3 (on page 12 below) and the result entered in the main audit worksheet (See Worksheet 4 on pages 15 and 16).

Supply figures should be adjusted for changes in system storage. Each storage tank or storage reservoir should be measured at the beginning and the end of the audit period. If total storage has increased, that difference should be subtracted from the annual supply total. Conversely, decreases in total storage should be added to the supply total. These figures represent the difference between water delivered from sources and water entering the distribution system. Use the following formula to determine the total storage adjustment:

For each storage tank or reservoir:

Beginning Volume - Ending Volume = Change in Volume

The sum of the Changes in Volume = the Total Storage Adjustment
(Add to Worksheet 4, Line 2a)

Any other known additions or losses to the total supply should also be added to the Worksheet 4 on Line 2b.

Worksheet 3: Total Supply to the system for Calendar Year _______				
MONTH	SOURCE A (Units)	SOURCE B (Units)	SOURCE C (Units)	MONTHLY TOTAL
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
SOURCE TOTALS				
TOTAL ANNUAL SUPPLY TO THE SYSTEM (Add to Worksheet 4, Line 1):				

2. Quantify Authorized Metered Water Use

All authorized uses of water, including unbilled public uses, should be metered and quantified by category in the same time period as the water source audit. The first step in quantifying metered watered use is to identify all metered accounts. Metered accounts should then be sorted by type of use, including industrial, institutional, commercial, residential, public purpose, wholesale sales to other jurisdictions, and other possible breakdowns, such as categories of residential use. Uses should also be broken down by meter size.

The uncorrected, total, metered water use must then be adjusted for meter reading lags, since most meters are probably not read on the beginning and ending dates of the audit period. To correct for meter lag, figures must be prorated for the first and last billing period of the audit period. It is best if the audit period begin and end during the winter months so outside watering does not create a variation in water use.

To correct for meter lag, for each meter route, take the total amount of water sold for the earliest billing period ending after the start of the audit period. Adjust the total by multiplying it by the average percentage of days of the billing period which fall between the first day of the audit period and the meter reading date. For example, if meters for a particular route are read in December and in March, and the audit period begins on January 1, determine the average number of days between January 1 and the March reading, divide that by the average number of days between the December reading and the March reading to determine the portion used during the audit period, and multiply that ratio by the total water use for the route during the meter reading period. For the end of the audit period, take the earliest meter reading period ending after the audit period and determine the portion which falls before the end of the audit period.

To make the adjustments more meaningful, it would be useful to separate large water-using accounts from the average readings and prorate them separately. The adjusted metered water use for the audit period should be added to Line 5 of the Worksheet 4 (on page 15 below).

If meter records are not maintained in a manner which allows for metered use quantification, a plan should be undertaken to maintain appropriate records. Many water systems now use computers for billing purposes. Computerized billing records can easily be maintained so that accounts are organized by type, meter size and geographic area. Account data can also include meter maintenance histories as well as water consumption data. With well maintained records, not only are system audits easily undertaken, but accounts can be screened to show unusually high or low demand, which can in turn indicate leakage or a malfunctioning meter.

3. Quantify Authorized Unmetered Uses

Authorized unmetered water uses are often called "authorized unaccounted-for water." Such uses include public buildings and parks, fire fighting, and street cleaning. While all public services should be metered, it is obviously impossible to precisely quantify water running through fire hydrants. Such uses can, however, be estimated as part of the system water audit. Authorized unmetered uses may include:

- Firefighting
- Landscaping in large public areas
- Firefighting training
- Decorative water facilities
- Flushing of mains
- Swimming pools
- Storm drain flushing
- Construction sites
- Sewer flushing
- Water quality and other testing
- Street cleaning
- Process water at treatment plants
- Schools

Where water is used in tanks, (i.e., street cleaning), volumes can be estimated by multiplying the volume of the tank by the number of times it is filled. Where water is applied directly from a pipe, (i.e., fire fighting), the average discharge rate can be multiplied by the total time during which it flows. In the absence of records, volumes will have to be estimated. Fire fighting and training use might be more easily estimated if a fire department requires a "run report" any time a unit responds to a call. Run reports can be culled for instances where hydrant water was used, with an average rate per use as a multiplier.

Main flushing use can be easily estimated if the utility maintains logs of flushing activities, including the location of the main or blowoff and the length of time of flow. Again, an absence of records would require an estimate of the number of flushing activities and average volumes of flow. Stormdrain and sewer flushingcan be estimated by the same method of main flushing if the water is supplied directly from water mains. If water is transported by truck, multiply the trucks' capacities by the number of times tanks are filled to determine water use. The responsible maintenance department should be urged to maintain records of hydrant use or tank filling. Sewage treatment plants which take additional water for treatment purposes should likewise be urged to maintain records of water use. Such uses should be metered.

Landscape use in public areas (parks, golf courses, cemeteries, playgrounds, highway median strips, etc.) can be estimated by comparing use with metered landscaped areas having similar uses and watering schedules. Frequency and duration of watering can be obtained from the persons responsible for landscape maintenance. Use from time-controlled irrigation systems can be calculated easily from the average flow and time of operation. Water uses from decorative fountains and pools should also be estimated. Information on draining and refilling, and also on average daily evaporation can be obtained from facility operators.

Schools and other institutional uses can be estimated by comparing them to similar metered uses. A per student or per resident use can be applied to the facility population. In the absence of comparative data, a per employee figure of 55.6 gallons per employee per day can be used for schools and universities, 72.0 gallons per employee per day for vocational schools, and 101.6 gallons per employee per day for boarding houses[13].

Construction contractors should be required to use portable meters and to report readings for temporary on site water use. In the absence of portable meters, a rule of thumb would be to estimate construction site water use as 19 gallons per employee per day.[14] Water utilities use system water for quality testing to meet public health standards and for process water at treatment plants. Volumes used should be estimated by the water utility.

All authorized unmetered uses should be added to Lines 7a through 7n of Worksheet 4 (On pages 15 and 16 below) and then totaled. Where records are insufficient to adequately determine usage in the respective categories, plans should be made to improve record keeping to the extent possible.

4. Quantify Water Losses

All water that is not either metered use or authorized unmetered use is considered to be water lost from the distribution system. To determine total losses, subtract authorized unmetered water from total unmetered water. The categories of losses are as follows:

- Source meter error
- Customer meter under-registration
- Accounting procedure errors
- Illegal connections
- Malfunctioning distribution system controls
- Storage tank overflow
- Theft
- Underground leaks

Each source meter should be reviewed for accuracy, either by reviewing available meter test results or retesting the meter. American Water Works Association standards should be utilized to determine if the meter is properly sized and installed. If a meter is found to be inaccurate, the data for that meter should be adjusted accordingly by dividing the recorded flow by the meter accuracy. The meter error adjustment should be determined using the following equation and copied to the audit work sheet.

For each source meter: $(UMV/(0.01*MA)) - UMV = ME$

Where:

UMV	=	Uncorrected Meter Volume
MA	=	Meter Accuracy Percent
ME	=	Meter Error

(Add to Worksheet 4, Line 11a)

The quantity of water lost due to customer meter under-registration can also be estimated as previously discussed in Section A (on page 6 above). If meters are tested and calibrated by a method other than the one described in Section A, then a sample of meters should be tested to determine an average percentage of meter under-registration. Separate testing is necessary for residential and large meters. In each meter category, adjusted metered water use should then be further adjusted by multiplying by the percent of accuracy.

Accounting procedure errors include misread meters, improper calculation methods, computer programming errors or other discrepancies. These are mistakes on paper which can be found and corrected, often by reviewing the billing and accounting procedure. A random sample of meter book accounts might discover whether registers are being read and recorded properly. Comparison with billing records can then indicate whether discrepancies exist in the computer or billing system.

Illegal connections are difficult to discover. Meter readers should be alert to possible water line connections which are not in the meter book. Inactive accounts should be periodically checked to make certain that water is not being used. Electric utility records or assessor's listings might be used for comparison. Illegal taps to unmetered fire lines might be identified through checks of metered accounts which record smaller than expected water use. Often, persons using illegal connections are unaware that their use is unauthorized. Water might be taken illegally or stolen from hydrants by water tank trucks or vandals. A program of meter locking or use of spray caps in areas where hydrants are opened during hot weather could help minimize such losses.

System valves should be checked periodically for malfunction. For instance, altitude control valves on storage tanks might be broken or set improperly, allowing the tank to overflow. Pressure relief valves which are set too low might cause spill when pressures reach the high range. Improperly set pressure-reducing, pressure-sustaining and pressure-maintaining valves can cause spills at altitude control valves, pressure relief valves or surge control valves. Surge relief valves, if set too low, can cause unnecessary blowoff to the atmosphere. A failed pump discharge valve may allow water to discharge from the distribution system back down the well. When problems are discovered during routine inspections, possible water losses should be estimated.

Leakage represents the largest share of unauthorized water use. Section III.A.1 of this manual provides guidance in leak repair record keeping and leak detection.

Worksheet 4, following, should be filled out to estimate categories of water use and waste, using the preceding sections for guidance. By analyzing the results, it is possible to estimate and forecast water uses and prioritize conservation programs.

Worksheet 4: System Water Audit

LINE	ITEM	WATER VOLUME		UNITS
		Subtotal	Cumulative Total	
1	UNCORRECTED TOTAL WATER SUPPLY to the distribution system (Total of master meters)			
2	ADJUSTMENTS TO TOTAL WATER SUPPLY:			
2a	Change in System Storage (+ or -)			
2b	Other Contributions or Losses (+ or -)			
3	TOTAL OF ADJUSTMENTS (+ or -)			
4	ADJUSTED TOTAL WATER SUPPLIED to the distribution system (Add Line 1 and Line 3)			
5	METERED WATER DELIVERIES, corrected for meter lag			
6	CORRECTED TOTAL UNMETERED WATER (Subtract Line 5 from Line 4)			
7	AUTHORIZED UNMETERED WATER USES:			
7a	Unmetered Public Buildings			
7b	Firefighting and Firefighting Training			
7c	Main Flushing			
7d	Storm Drain Flushing			
7e	Sewer Cleaning			

Worksheet 4: System Water Audit				
LINE	ITEM	WATER VOLUME		UNITS
		Subtotal	Cumulative Total	
7f	Street Cleaning			
7g	Landscaping in Public Areas			
7h	Schools			
7i	Decorative Water Facilities			
7j	Swimming Pools			
7k	Construction Sites			
7l	Water Quality and Other Testing			
7m	Process Water at Treatment Plants			
7n	Other Authorized Unmetered Use			
8	TOTAL AUTHORIZED UNMETERED WATER (Add Lines 7a through 7n)			
9	WATER LOST TO LEAKS SINCE REPAIRED			
10	**TOTAL UNACCOUNTED-FOR WATER** (Subtract Lines 8 and 9 from Line 6)			
11	IDENTIFIED WATER LOSSES:			
11a	Source Meter Error (+ or -)			
11b	Customer Meter Under-registration			
11c	Accounting Procedure Errors			
11d	Illegal Connections			
11e	Malfunctioning Distribution System Controls			
11f	Theft			
12	TOTAL IDENTIFIED WATER LOSSES (Add Lines 11a through 11f)			
13	UNIDENTIFIED LOSSES (POTENTIAL LEAKAGE) (Subtract Line 12 from Line 10)			

5. Analyze Audit Results

Conducting a water audit is one way to discover evidence of insufficient record-keeping, faulty metering, illegal taps, leaking storage tanks, or leaking mains.

6. Estimate Variable Utility Costs

Once key problem areas are identified, you can determine variable utility costs (costs per unit of water production; costs vary with changes in production) and variable wastewater system costs. Wastewater costs include energy costs for operating pumps and chemical costs for the treatment of water, and are assumed to be directly related to the volume of water produced.[15] Another variable cost is for water purchased from another supplier.

Once variable utility costs have been determined, it is possible to measure the cost-effectiveness of alternative ways to reduce unaccounted-for water and achieve water conservation. Cost-effectiveness is primarily based on the value of recoverable water. For example, correcting problems may be more cost-effective than expanding facilities to eliminate a supply shortage.

Fixed capital costs are large part of the cost of supplying water and treating wastewater. But once physical facilities are constructed, a change in water use will not affect that part of the cost of service. For that reason, this part of the analysis does not consider fixed capital expenses. However, when evaluating a complete water conservation program, it is necessary to consider the long term future savings of deferred, eliminated, or downsized capital expansions, both in the water and wastewater system. These savings will be evaluated during the plan selection and implementation section.

Worksheets 5 and 6 on pages 18 and 19 will help the user to calculate the variable production costs for water and wastewater. Information from the most recent five-year period should be used.

If the water system is supplied entirely by its own sources of supply, only Part 1 of Worksheet 5 need be completed. The most recent year for which data are available should be entered as year "y" in the fifth row of Part 1. Data for the preceding years ("y-1", "y-2", etc.) should be entered in the appropriate rows. The potential variable cost savings are computed in Column I.

If part of the water supply is purchased from another system, Part 2 of Worksheet 5 should also be completed and the following additional steps taken:

- If the purchased portion of the water supply is physically separated from self-produced supply within the distribution system, then potential variable cost savings are the cost of purchased water (Column P) until savings have exhausted the amount of purchased water. Additional savings will be for the variable coat of self-supplied water (Column I).

- If the purchased portion of the water supply is completely mixed with self-produced supply within the distribution system, then potential variable cost savings are the average variable cost of supply from Column Q.

Potential variable cost savings resulting from the impact of water conservation on sewer costs (See Worksheet 6) should be considered regardless of whether rate payers are directly billed for sewage service. If variable sewer expenses are unavailable, a rule of thumb figure is $12.00 per million gallons of system demand.[16]

Worksheet 5: Water Utility Average Variable Costs of Production

Part 1: For Self-produced Supply								
A	B	C	D	E	F	G	H	I
Year	Water Produced (Million Gallons)	Constant Dollar Multiplier *	Energy Cost		Chemical Cost		Energy plus Chemical Cost (E+G)	Total Cost per Million Gallons (H/B)
			Actual Cost in Dollars	Constant Dollars (C*D)	Actual Cost in Dollars	Constant Dollars (C*F)		
y-4:		1.216						
y-3:		1.158						
y-2:		1.102						
y-1:		1.050						
y:		1.000						
5-year Average								

Part 2: For Purchased Supply							
J	K	L	M	N	O	P	Q
Year	Total System Water Demand (Million Gallons)	Amount of Water Purchased (Million Gallons)	Constant Dollar Multiplier *	Cost of Purchased Water		Cost of Purchased Water per Million Gallons (O/L)	Average Variable Cost in Dollars per Million Gallons {(B*I)+(L*P)}/K
				Actual Cost in Dollars	Constant Dollars (M*N)		
y-4:			1.216				
y-3:			1.158				
y-2:			1.102				
y-1:			1.050				
y:			1.000				
5-year Average							

*Assumes 5% annual inflation. For any other assumed interest rate i, determine constant dollar multiplier from the formula CDM = $(1+i)^n$ where n = number of years back from the base year.

Worksheet 6: Wastewater Utility Average Variable Costs of Treatment							
Part 1: Variable Expense of Treatment							
A	B	C	D	E	F	G	H
Year	Constant Dollar Multiplier*	Electric Costs			Chemical Costs		
		Actual Cost in Dollars	Constant Dollars (B*C)	Variable Portion (D)*(0.333)	Actual Cost in Dollars	Constant Dollars (B*F)	Variable Portion (G)*(0.5)
y-4:	1.216						
y-3:	1.158						
y-2:	1.102						
y-1:	1.050						
y:	1.000						
Part 2: Variable Cost Savings							
I	J	K	L	M	N	O	P
Year	Total Variable Sewer Costs (E+H)	Total Sewer Flows in Million Gallons	Total Cost per Million Gallons (J/K)	Total Water System Demand in Million Gallons	Ratio of Sewer Flows to Water Demand (K/M)	Average Variable Cost in Dollars per Million Gallons of Water Demand (L*N)	
y-4:							
y-3:							
y-2:							
y-1:							
y:							
5-year Average							

*Assumes 5% annual inflation. For any other assumed interest rate I, determine constant dollar multiplier from the formula CDM = $(1+i)^n$ where n = number of years back from the base year.

C. Water Demand Forecast

Developing a water demand analysis and forecast is the next step in gathering information for a water conservation plan. The conventional forecast approach is inadequate under most conditions, because it relies on population and per capita demand projections which merely carry historic trends into the future. Where the design, size and timing of additional facilities depends on forecasted demand, errors can lead to construction of inadequate facilities and excessive economic and environmental cost.[17] Even if population assumptions prove correct, errors will result if the forecast ignores changes in the mix of household types, housing size, water price, changes in the local economy or if existing conservation efforts are ignored.

A more detailed, disaggregated water demand forecast is an important prerequisite for estimating the effectiveness of water conservation measures.[18] Disaggregation refers to separation by major water use sectors. Because different water use sectors respond at different rates to individual conservation measures, sectoral disaggregation is the only way to evaluate the effectiveness of a conservation measure to the entire water system. The disaggregation can vary from a general breakdown (for example, residential, commercial, industrial, public and unaccounted-for water) to very detailed breakdowns within more general user categories. The greater the number of sectors in the disaggregation, the more flexible, detailed and accurate the forecast will be. Disaggregation should also include dimensions of water use. Dimensions refer to water flow rates corresponding to a specific time condition. Common dimensions important in water supply planning and demand projections are average daily flow, winter seasonal daily flow (this represents indoor use), summer seasonal use (used to determine outdoor use), and peak daily use.[19] Dimensional disaggregation is important when determining reduction factors for conservation methods on different use dimensions. For example, one method might impact only residential outdoor water use, which is determined by the difference between summer and winter average use in the residential sector.

Some water utilities, especially those with pending facility expansions, might wish to hire outside consultants to perform detailed disaggregated demand analyses. Table 4 lists some data types and information sources for demand studies.[20] A simple disaggregation facilitated by the water supply audit, can be accomplished internally with less detailed information, and will considerably assist the preparation of a conservation plan.

Table 4: Information Sources for Water Demand Studies

A: Historic Data.

1. Water use data (municipal and industrial)
   - Water Utility
2. Population data
   - DEC Substate Water Management Strategies
   - County or regional planning agency
   - U.S. Census of Population
3. Number of households or dwelling units
   - County or regional planning agency
   - U.S. Census of Population, Housing
4. Number of connections
   - Water utility
5. Climatic data
   - National Weather Service
   - State University Department of Atmospheric Sciences, Meteorology or Climatology
   - Utility records
6. Water and Wastewater rate structures
   - Utilities
7. Other economic variables
   - County or regional planning agencies
   - U.S. Census of Population, Housing, Business, Manufacturers
8. Existing water resource policies
   - State plumbing code
   - Local government
   - Utility
9. Manufacturing employment, output, processes
   - Local or regional economic development agency
   - Regional office, N Y State Department of Labor
   - U.S. Census of Manufacturers
   - U.S. Bureau of Labor Statistics
   - Individual firms

B: Projected Data

10. Population, Household size, Number of households, etc.
    - DEC Substate Water Management Strategies
    - Local or regional economic development agency
11. Economic variables
    - County or regional planning agency
    - Regional office, N Y State Department of Labor
12. Manufacturing employment
    - County or regional planning agency
    - Local economic development agency
    - Individual firms

Water Demand Worksheets

If your utility has recently completed a disaggregated water demand analysis, that analysis should be used. Likewise, if major capital expansions are being considered, a detailed disaggregated water demand analysis should be undertaken. At the very least, however, in order to determine the approximate demand reductions from various conservation approaches, the following sequence of worksheets (Worksheets 7 through 10) should be completed.

Worksheet 7: Historic Water Demand

Name of water supplier: ______________________________

Address: ______________________________

Contact person: ______________ Title: ______________ Phone: ______________

Use at least two years of records, including the most recent complete year of record. Information from the Water Audit Work Sheet can be used where applicable. A previous year of record should, if possible, be a census year, such as 1980. Additional years of record will help improve demand forecasts.

Include average daily demands in MGD for base year and chosen historic years for each category. Years should be evenly spaced: e.g.., every 3 years, every 5 years, etc. If demand breakdowns are not possible, include as detailed breakdown as is possible, and note combined categories in "notes."

For each entered year of record, "MGD" is the average millions of gallons per day in that user category for the given season. Winter use is usage from November through April. Summer use is usage from May through October. "GPSD" is the average number of gallons per service connection per day in that user category for the given season. The percent columns should indicate the percent of total services or water use for the entire water system.

BASE YEAR: _______ TOTAL POPULATION SERVED: __________

USER CATEGORY	No. services	%	WINTER MGD	WINTER GPSD	WINTER %	SUMMER MGD	SUMMER GPSD	SUMMER %
Residential								
Single family	____	____	____	____	____	____	____	____
2-4 family	____	____	____	____	____	____	____	____
Apartment	____	____	____	____	____	____	____	____
TOTAL Residential	____	____	____	____	____	____	____	____
Commercial	____	____	____	____	____	____	____	____
Industrial	____	____	____	____	____	____	____	____
Metered public	____	____	____	____	____	____	____	____
TOTAL Authorized Unmetered			____		____	____		____
Unaccounted-for water			____		____	____		____
TOTAL WATER USE	____	100%	____	____	100%	____	____	100%

NOTES ______________________________

____

Worksheet 7: Historic Water Demand (Continued)

FIRST PREVIOUS YEAR:______ TOTAL POPULATION SERVED:__________

USER CATEGORY	No. services	%	WINTER MGD	WINTER GPSD	WINTER %	SUMMER MGD	SUMMER GPSD	SUMMER %
Residential								
Single family								
2-4 family								
Apartment								
TOTAL Residential								
Commercial								
Industrial								
Metered public								
TOTAL Authorized Unmetered								
Unaccounted-for water								
TOTAL WATER USE		100%			100%			100%

NOTES ____

SECOND PREVIOUS YEAR:______ TOTAL POPULATION SERVED:__________

USER CATEGORY	No. services	%	WINTER MGD	WINTER GPSD	WINTER %	SUMMER MGD	SUMMER GPSD	SUMMER %
Residential								
Single family								
2-4 family								
Apartment								
TOTAL Residential								
Commercial								
Industrial								
Metered public								
TOTAL Authorized Unmetered								
Unaccounted-for water								
TOTAL WATER USE		100%			100%			100%

NOTES ____

Worksheet 7: Historic Water Demand (Continued)

THIRD PREVIOUS YEAR:______ TOTAL POPULATION SERVED:__________

USER CATEGORY	No. services	%	WINTER MGD	WINTER GPSD	WINTER %	SUMMER MGD	SUMMER GPSD	SUMMER %
Residential								
Single family	____	____	____	____	____	____	____	____
2-4 family	____	____	____	____	____	____	____	____
Apartment	____	____	____	____	____	____	____	____
TOTAL Residential	____	____	____	____	____	____	____	____
Commercial	____	____	____	____	____	____	____	____
Industrial	____	____	____	____	____	____	____	____
Metered public	____	____	____	____	____	____	____	____
TOTAL Authorized Unmetered			____		____	____		____
Unaccounted-for water			____		____	____		____
TOTAL WATER USE	____	100%	____	____	100%	____	____	100%

NOTES ____

____

FOURTH PREVIOUS YEAR:______ TOTAL POPULATION SERVED:__________

USER CATEGORY	No. services	%	WINTER MGD	WINTER GPSD	WINTER %	SUMMER MGD	SUMMER GPSD	SUMMER %
Residential								
Single family	____	____	____	____	____	____	____	____
2-4 family	____	____	____	____	____	____	____	____
Apartment	____	____	____	____	____	____	____	____
TOTAL Residential	____	____	____	____	____	____	____	____
Commercial	____	____	____	____	____	____	____	____
Industrial	____	____	____	____	____	____	____	____
Metered public	____	____	____	____	____	____	____	____
TOTAL Authorized Unmetered			____		____	____		____
Unaccounted-for water			____		____	____		____
TOTAL WATER USE	____	100%	____	____	100%	____	____	100%

NOTES ____

____

Worksheet 8: Percentage Trends in Water Demand

Using the data from Worksheet 7, compute the percent change between historic years in each demand category.

CATEGORY	PERCENT CHANGE BETWEEN YEARS: 4th Previous and 3rd Previous	3rd Previous and 2nd Previous	2nd Previous and 1st Previous	1st Previous and Base Year
Service Population	______	______	______	______
Residential				
Single family				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
2-4 family				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
Apartment				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
TOTAL Residential				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
Commercial				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
Industrial				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
Metered public				
# Services	______	______	______	______
Winter use (gpsd)	______	______	______	______
Summer use (gpsd)	______	______	______	______
TOTAL Authorized Unmetered				
Winter use (MGD)	______	______	______	______
Summer use (MGD)	______	______	______	______
Unaccounted-for water				
Winter use (MGD)	______	______	______	______
Summer use (MGD)	______	______	______	______
TOTAL WATER USE				
# Services	______	______	______	______
Winter use (MGD)	______	______	______	______
Summer use (MGD)	______	______	______	______

Worksheet 9: Projection Year Percent Change

For projection years, use the trend in percentage change or other information to estimate demand figures. For instance, if the trend for a particular category indicates increasing use, but at a declining percentage of increase, use a continually declining percent of increase in the future. Judgement may indicate a leveling of the trend or a counter trend due to some new circumstance.

From Year:	Base Year	______	______
To Year	______	______	______
Service Population	______	______	______
Residential			
Single family # Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
2-4 family			
# Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
Apartment			
# Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
TOTAL Residential			
# Services	______	______	______
Winter use (gpsd	______	______	______
Summer use (gpsd)	______	______	______
Commercial			
# Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
Industrial			
# Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
Metered public			
# Services	______	______	______
Winter use (gpsd)	______	______	______
Summer use (gpsd)	______	______	______
TOTAL Authorized Unmetered			
Winter use (MGD)	______	______	______
Summer use (MGD)	______	______	______
Unaccounted-for water			
Winter use (MGD)	______	______	______
Summer use (MGD)	______	______	______

Worksheet 10: Future Year Projections of Water Demand

Except for unmetered and unaccounted-for use, projected water use should be based on projections of number of connections and usage per connection rather than on total water use. For residential categories, look also at projected population figures from the Substate Water Management Strategy for your area and consider how future population is likely to be allocated to various housing categories. For unmetered and unaccounted-for use, volume projections can be made. However, if the water supply audit provides for further usage breakdowns, projected use can be similarly broken down.

Use this worksheet to convert projected percent changes into "MGD" (the average millions of gallons per day in a user category for a given season) and "gpsd" (the average number of gallons per service connection per day in a user category for a given season).

YEAR			
Service Population			
Residential			
Single family			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
2-4 family			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
Apartment			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
TOTAL Residential			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
Commercial			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
Industrial			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
Metered public			
# Services			
Winter use (gpsd),(MGD)	,	,	,
Summer use (gpsd),(MGD)	,	,	,
Tot Authorized Unmetered			
Winter use (MGD)			
Summer use (MGD)			
Unaccounted-for water			
Winter use (MGD)			
Summer use (MGD)			
TOTAL WATER USE			
# Services			
Winter use (MGD)			
Summer use (MGD)			

III. Water Conservation Methods

Water audits, demand studies, and projections allow for detailed consideration of water conservation techniques to reduce system water loss and/or reduce water demand.

A. Reducing System Water Loss

1. Leak Detection and Repair

Distribution system leakage causes significant water-waste in some water supply systems. Even small leaks, if uncorrected, can waste hundreds of gallons a day. Waste may include pumped, treated water, and therefore paid for by system users. Leakage may also represent water which, if saved, can cancel or postpone the need for system facility or supply expansions.

All water supply systems leak. The amount of “acceptable” leakage is not a firm figure, although it is agreed that beyond a certain point it is uneconomic to further reduce leakage. Most water supply systems in the U.S. probably leak 5 percent to 15 percent of their water, but many exceed 15 percent[21], and some leakage estimates have been as low as 2 percent.[22]

Acceptable leakage varies from system to system. It would be greater for a gravity-flow system with a large excess capacity than for a system with a limited available supply or a high variable water production expense. One source claims that depending on the age and condition of the system, up to 5% water loss through leakage could be considered reasonable.[23] More specific attempts have been made to estimate acceptable leakage based on the length of mains between joints, number of service connections, or age of pipe. One rule-of thumb estimate is based on losses of one drop per second from each joint, five drops per second from each hydrant and stop valve, and three drops from each service pipe. This result of this calculation is roughly 2500 to 3000 gallons per day per mile in older systems, and 1500 to 2500 gallons per day per mile in newer systems having longer lengths of pipe.[24]

Most water utilities routinely repair visible leaks which result in structural flooding. Hidden leaks can continue to waste hundreds or thousands of gallons a day of pumped, treated water.

When repairing leaks, it is important to record factors contributing to the leak. This record may make leak detection, repair, and replacement decisions easier.

Causes of leaks and factors affecting leakage rates include[25]

- Poor construction methods
- Poor leak pouring in joints
- Poor material or old material (leadite)
- Electrical currents causing pitting
- Ground movement, sometimes from moisture content, temperature, frost and subsidence
- Soil characteristics: permeability
- Traffic loading, especially where bedding and pipe zone materials are substandard or pipes are shallow; vibrations are a major contributor of traffic loading
- Cinder fill
- Internal corrosion - sulphur pitting
- Internal electrical transfer
- External corrosion from a variety of causes
- Pressure, either fluctuating or surging
- Age; many other contributors are time-dependent, although age by itself is not necessarily the most significant factor

A pre-survey review will help guide a leak detection survey. The review should include:[26]

- Results of the water audit — how much water is lost from the system?

- Mains and services — types of pipe, ages, diameters, joints, installation methods, inspections, leak histories, and operating pressures. Where information is incomplete, plans would be made to improve records.

- Valves — locations, types, left or right handed, number of turns to exercise valves, how often exercised.

- Hydrants — types, sizes, locations, flushing frequencies, unmetered usage.

- Pressure reducing and air release valves and blowoffs — locations, how often they are exercised.

- Distribution system maps — what is shown, how current is the information, how often is the information updated?

Equipment for a detailed leak detection survey should include an electronic sonic detector and a correlator. Electronic leak detectors use a microphone, amplifier and frequency filters to amplify the sounds that leaks make and filter out many other sounds. An indicating meter can provide a more sensitive method of determining the position of maximum intensity of the sound.[27]

Correlators use micro-processor chips and computers to pinpoint a leak between two listening points. Although new model correlators have eliminated shortcomings such as missing leaks, time consuming setup, and erroneous pinpointing,[28] error still results from mistakes in distance measurement, changes in pipe material, and improper contact with transducers (valves, hydrants, etc.).

Sonic leak detection equipment without a correlator costs from $500 to $2600. A correlator ranges in cost from $18,000 to $45,000. A water supplier may wish to contract out the leak detection survey. Costs for contract work range between about $130 and $300 per mile of main surveyed.[29]

Expert sonic leak detection comes with experience. Different kinds of leaks make different sounds and pipe materials absorb different amounts of sound. The sounds in the pipe actually travel through the water rather then through the pipe wall. Softer pipe materials absorb greater amounts of sound. Other changes in leak sounds are caused by groundwater, air in pipes, soil, and surface materials.

Thorough record-keeping will help determine the effectiveness of the total leak-detection and repair effort. Such record-keeping will help system operators determine specific conditions in their water system. This will, in turn, aid decision-making on priority segments for more detailed leak detection.

Worksheets 11 through 15 on the following pages can help the system operator manage leak detection and repair, and also help determine costs and benefits of correcting the leaks. Worksheets 11 (pages 30 and 31) is a sample leak repair report form. Worksheet 12 (pages 32 and 33) is a preliminary work sheet to plan the survey effort. Worksheet 13 (page 34) is a sample leak detection survey daily log. Daily logs can be combined to complete the leak detection survey and repair summary in Worksheet 14 (page 35). Finally, a step-by-step guide to calculating project cost effectiveness is found in Worksheet 15 (page 36).

Tables 5 and 6 (on page 29) can be used to estimate the amount of leakage from holes, joints and cracks in water mains and joints.

Table 5: Leak Losses for Circular Holes Under Different Pressures

Water Lost (in gallons per minute) = (30.394)(A)(square root of P)
Where A = Area of hole in square inches
P = Pressure in pounds per square inch

Diameter (inches)	Area of hole (sq.in.)	WATER PRESSURE IN POUNDS PER SQUARE INCH							
		20	40	60	80	100	120	140	160
0.1	0.008	1.1	1.5	1.8	2.1	2.4	2.6	2.8	3.0
0.2	0.031	4.3	6.0	7.4	8.5	9.5	10.5	11.3	12.1
0.3	0.071	9.6	13.6	16.6	19.2	21.5	23.5	25.4	27.2
0.4	0.126	17.1	24.2	29.6	34.2	38.2	41.8	45.2	48.3
0.5	0.196	26.7	37.7	46.2	53.4	59.7	65.4	70.6	75.5
0.6	0.283	38.4	54.4	66.6	76.9	85.9	94.1	101.7	108.7
0.7	0.385	52.3	74.0	90.6	104.6	117.0	128.1	138.4	148.0
0.8	0.503	68.3	96.6	118.3	136.6	152.8	167.4	180.8	193.2
0.9	0.636	86.5	122.3	149.8	172.9	193.4	211.8	228.8	244.6
1.0	0.785	106.8	151.0	184.9	213.5	238.7	261.5	282.5	302.0
1.1	0.950	129.2	182.7	223.7	258.3	288.8	316.4	341.8	365.4
1.2	1.131	153.7	217.4	266.3	307.5	343.7	376.6	406.7	434.8
1.3	1.327	180.4	255.1	312.5	360.8	403.4	441.9	477.3	510.3
1.4	1.539	209.2	295.9	362.4	418.5	467.9	512.5	553.6	591.8
1.5	1.767	240.2	339.7	416.0	480.4	537.1	588.4	635.5	679.4
1.6	2.011	273.3	386.5	473.4	546.6	611.1	669.4	723.1	773.0
1.7	2.270	308.5	436.3	534.4	617.1	689.9	755.7	816.3	872.6
1.8	2.545	345.9	489.2	599.1	691.8	773.4	847.3	915.1	978.3
1.9	2.835	385.4	545.0	667.5	770.8	861.8	944.0	1019.6	1090.0
2.0	3.142	427.0	603.9	739.6	854.0	954.9	1046.0	1129.8	1207.8

Table 6: Leak Losses for Joints and Cracks Under Different Pressures

Water Lost (in gallons per minute) = (22.796)(L)(W)(square root of P)
Where L = Length of crack in inches
W = Width of crack in inches
P = Pressure in pounds per square inch

Dimensions of Crack		WATER PRESSURE IN POUNDS PER SQUARE INCH							
Length (inches)	Width (inches)	20	40	60	80	100	120	140	160
1.0	1/32	3.2	4.5	5.5	6.4	7.1	7.8	8.4	9.0
1.0	1/16	6.4	9.0	11.0	12.7	14.2	15.6	16.9	18.0
1.0	1/8	12.7	18.0	22.1	25.5	28.5	31.2	33.7	36.0
1.0	1/4	25.5	36.0	44.1	51.0	57.0	62.4	67.4	72.1

Worksheet 11: Leak Repair Report

Agency______________________________ Date of Repair:______/______/______
month day year

W.O. No.________________ Foreman______________________________

Leak Identification

Discovery Date _____/_____/______ Leak No.____________ Map Reference______________________

Location: (include street name and number)______________________________

For Main and Service Lateral Leaks Only

Attach a map of the site including:

1. Street name; north arrow
2. Meter Number (if applicable)
3. Mains and hydrants in shutdown area
4. All valves, valve numbers and show which were closed during repair.
5. Locate leak to nearest intersection or house with address. Show distances to property lines or street centerlines.

Attach Three Photos:

1. Straight down over leak or damage
2. Close-up of leak and damage
3. Any other photo which you feel will help.

Type of Leak

Leak Found:____________(yes/no)

Meter Leak	____________	Main Line Leak	____________	Joint Leak	____________
Meter Spud Leak	____________	Service Lateral Leak	____________	Other Leak	____________
Meter Yoke Leak	____________	Fire Hydrant Leak	____________	Describe	____________
Curb Stop Leak	____________	Valve Leak	____________		____________

Description of Repair

Damaged part was: ______Repaired ______Replaced

If repaired, what repairs were made?
______Leak Clamp ______Repacked Valve
______Welded ______Recaulked Joint
______Other (describe)______________
____
____

If replaced, what material was used?
____
____

Equipment used for repair:
______ Backhoe
______ Dumptruck

Crew Size _______ (persons)
Crew members:___________
____
____
____
____

Repair Costs

Materials	$____________
Labor	$____________
Equipment	$____________
Other	$____________
Total	$____________

Size of Leak:

Measured______________________________GPM
Estimated______________________________GPM
Method Used:______________________________
____

(Worksheet 11 continues on next page)

Description of Damage for Mains and Services

What part was damaged?
_____ Pipe barrel _____Flange nuts, bolts, tie rods
_____ Joint _____Other (describe)______________________
_____ Valve ____

In your opinion, what caused the damage?___________________________
____
____
____
Estimated age of leak in months____________________
How determined? ____
Diameter of main or lateral in inches____
Depth to top of pipe in inches_______________________

Type of Break
_____Split
_____Hole
_____Circumferential split
_____Broken coupling
______Cracked at corp. stop
_____Service pulled
_____Gasket blown
_____Crushed pipe
_____Cracked bell
_____Other (describe)

Pipe Material:
____Galv. Iron ____Ductile Iron ____A.C.P. System Pressure ______________________
____Black Iron ____Steel ____P.V.C. How Determined _____________________
____Cast Iron ____Copper ____Polybutylene ____R.C.P.

Examine broken edge of cast or ductile iron pipe:

Original thickness:______inches

Min. thickness of good grey metal remaining______inches

Deterioration is on:
_____ Outside
_____ Inside

Is there evidence of previous leak or repairs in same general area? _____Yes _____No

Number of previous leak repair clamps present____________

Last repair date (if known)___________________ Cause of Leak _____________________________
____

In your opinion, should pipe be replaced? ____Yes ____No ____Do not know
If yes, explain extent and nature of replacement needed:
____
____

For Excavations Indicate Ground Conditions

Type of Soil:
_____Rocky _____Sandy
_____Clay _____Hard Pan
_____Loam _____Other_________________

Existing Bedding:
_____Gravel/Sand
_____Native Soil
_____Pea Gravel
_____Other______________________

Type of Cover:
_____Concrete
_____Asphalt
_____Soil
Other_________

(page 31 does not exist)

Worksheet 12: Preliminary Planning for Leak Repair Program

Name of Agency:____

Date:_____________

A. Area to be Surveyed:

1 Using the results of the water audit, show on a map which areas in the distribution system sill be surveyed. Indicate which areas have the higher potential for recoverable leakage. (Items to consider include records of previous leaks, type of pipe, age of pipe, soil conditions, high pressures, ground settlement, and improper installation procedures.)

2 Total miles of main to be surveyed: _________. If less than the total system is being surveyed, the calculations for the benefit:cost ratio must reflect the reduction. (When calculating the miles of main, include the total length of pipe and exclude service lines.)

3. Average number of miles of main surveyed per day: ________. Explain if more than 3 miles per day are surveyed. (The average survey crew can survey about two miles of main per day. Items to consider include distances between services, traffic and safety conditions, and number of listening contact points.)

____

____

4. Number of working days needed to complete the survey: ____________________.
(Divide Line 2 by Line 3)

B. Procedures and Equipment

1. Describe the equipment and procedure you will use to detect leaks. (Best results can be obtained by listening for leaks at all system contact points, such as meters, valves, hydrants and blowoffs.)

____

____

2. Describe why the areas noted on the map (A-1) have the greatest potential for recovering leakage.

____

____

3. If you will not be listening for leaks at all system contact points, describe your plan for effectively detecting leaks.

____

____

____

4. Describe the equipment and procedure you will use to pinpoint the exact location of the detected leaks.

____

____

____

5 Describe how the leak detection team and the leak repair crew will work together. How will they resolve the problem of dry holes?

____

____

(Worksheet 12 continues on nest page)

Worksheet 12: Preliminary Planning for Leak Repair Program (Continued)

6. Describe the methods you will use to determine the flow rates for excavated leaks of various sizes. (e.g..: bucket and stopwatch, diameter of hole and pressure)

___

___

___

C Staffing Computations

1. How many agency staff will be used? _______

Staff costs including wages and benefits:

Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
TOTAL		$________/hour,	$/day=	$________

2.How many consultant staff will be used? _______

Cost of consultant staff:

Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
Persons at	$________/hour=	$________/hour,	$/day=	$________
TOTAL		$________/hour,	$/day=	$________

D. Leak Detection Survey Costs

Leak Detection Surveys	$/day	# days	Cost
1. Agency Crew Costs	________	________	________
2. Consultant crew costs	________	________	________
3. Vehicle Costs	________	________	________
4. Other	________	________	________
5. **TOTAL** Survey Costs			________

E. Leak Detection Budget

1. Cost of Leak Detection Equipment $____________
2. Leak Detection Team Training $____________
3. Leak Detection Survey Costs $____________
4. **TOTAL** Leak Detection Costs $____________

F. Leak Detection and Repair Schedule

Beginning Survey date: _______________
Approximate ending Survey date: _______________
Beginning leak repair date: _______________
Approximate ending leak repair date: _______________

Prepared By:

Name: ____ Date: _______________

Title: ____

Worksheet 13: Leak Detection Survey Daily Log

Agency ____________________________________ Date _____ _____ _____
(month day year)

Leak Detection Team Members ________________________, ________________________

________________________, ________________________

Area Surveyed____________________________________ Map Reference
____

Street and Block Nos:______________________________ Pages &
Coordinates__________________________

Leak No.	Location or Address Of Suspected Leak	Utility or Custome r (U or C)	Leak Pin-pointed (Y or N)	Leak to be Recheck ed (Y or N)	Leak Re-paired (Y or N)	Not a Leak/Date

Indicate Number of Listening Points Used — Meters ______ Hydrants ______ Valves ______ Test Rods ______ Other ______

Miles of Main Surveyed _________ Survey Time _________ hours

Number of Leaks Suspected _________ To be rechecked _________ (Number)

Number of Leaks Pinpointed _________ Pinpointing Time _________ hours

Remarks:
____
Remarks:
____

____

Worksheet 14: Leak Detection and Repair Project Summary

Agency:____

Report Prepared by: ________________________________
Date:_________________

Leak Detection Survey

Total number of days leak surveys were conducted: _____________

First survey date:_____/_____/_____ Last survey date_____/_____/_____

Number of Listening Points Used:	Meters	Hydrants	Valves	Test Rods	Other
	______	______	______	_______	_____

Number of Agency Leaks:	Suspected	Pinpointed
	_________	___________

Survey Time: ______hours

Miles of Main Surveyed: _____

Pinpointing Time: ___________ Hours

Average survey rate = $\frac{\text{Miles of main surveyed} * 8}{\text{Total survey and pinpointing hours}}$ = _______miles per day

TOTAL number of visible leaks reported since survey started, from other sources (not discovered during leak detection surveys.) _____________

Leak Repair Summary

Date first leak Repair Made:_____/_____/_____

Date last leak Repair Made:_____/_____/_____

TOTAL Water Losses from Excavated Leaks:_______gpm

TOTAL Water Losses from Non-excavated Leaks: _______gpm

TOTAL amount of Losses:_______gpm

Excavated Leak Repair Costs		Nonexcavated Leak Repair Costs		TOTAL Repair Costs	
Materials	$________	Materials	$________	Materials	$________
Labor	$________	Labor	$________	Labor	$________
Equipment	$________	Equipment	$________	Equipment	$________
Other	$________	Other	$________	Other	$________
Subtotal	$________	Subtotal	$________	TOTAL	$________

Worksheet 15: Leak Detection Project Cost Effectiveness

Step 1. Calculate variable cost of water in dollars per million gallons.

Total treatment chemical expense: most recent year of record: $__________________
Total pumpage energy expense in most recent year of record: $__________________
Total price of water purchased from other water systems: $__________________

(tve)=TOTAL VARIABLE EXPENSE: .... $__________________

(mgy)=Millions of gallons produced: most recent year of record: __________________

(vwc)=Variable cost of water per mil gals produced=(tve)/(mgy)= $__________________ /mg

Step 2. Calculate the value of water recovered from all repair leaks.

(tlr)=Total leakage recovered in gpm /.5256 = ... _____________ mgals/year

(tvl)=Total value of leakage recovered = (tlr)*(vwc) = $ ..... ______________ /yr

(Note: This does not include value of deferred capital expansions.)

Step 3. Determine the total cost of leak detection survey and repairs.

Leak detection survey costs:
Leak Detection Equipment .... $ ____________
Leak Detection Training .... $ ____________
Leak Detection Survey Costs .... $ ____________
Total Repair Costs.. $ ____________

(tcst)=TOTAL cost of leak detection survey and repairs $ ____________

Step 4. Determine the benefit cost ratio.

(B:C)=Benefit:Cost Ratio (per year) = (tvl)/(tcst) = ... __________

Note: If (B:C) < 1.0, program will still be beneficial if value of leakage recovered exceeds the cost of the leak detection and repairs during the time period between surveys. For example, if a portion of the system is covered by a leak detection program once every three years, multiply (B:C) by three to determine total benefit-cost ratio.

Step 5. Determine the average survey costs per mile of main surveyed.

C/M)=Cost per Mile = (tcst)/number of miles surveyed.

(tcst).. $____________
Miles of Main Surveyed .... ____________ miles
(tcst)/Miles of Main Surveyed = $____________

(Use this figure to plan future leak detection efforts.)

2. System Pressure Controls

Reducing excessive pressures in the distribution system can save a significant quantity of water. In general, excessive pressures are those above 80 pounds per square inch (psi). Pressures below 80 psi can also be reduced, as long as pressure in any part of the system does not fall below 20 psi and fire flow pressures are maintained. In residential areas, 50 psi is probably sufficient pressure.

Reducing pressures decreases leakage, amount of flow through open faucets, and leak-causing stresses on pipes and joints. System stress reduction in turn decreases system deterioration, saving long-term repair costs and reducing breakage incidents. Pressure reductions also reduce wear on consumers' water-using appliances.

In areas where pressure exceeds 80 psi, pressure-reducing valves should be installed in street mains or individual buildings. Flow rate is related to the square root of the pressure drop, so reducing pressure from 100 psi to 50 psi would result in about a one-third drop in water flow. Because many water-using appliances depend on total volume rather than flow rate, and most people throttle back shower and faucet use from maximum capacity, total savings would be less. Outdoor water use would probably be most greatly affected, as would system and house-hold leakage. A 30 percent to 40 percent pressure reduction (from 90 to 100 psi down to 50 to 60 psi) reduces overall demand by about 6 percent[30] in areas with excessive pressure. Pressure reduction is a generally reliable and cost-effective way to reduce water demand. Pressure-reducing valves range in price from $50 to $600, depending on the size of the main. Once installed, however, pressure reducing valves require little maintenance.

B. Reducing Water Demand

Water demand can be reduced directly or indirectly. Direct methods are those which physically suppress demand. They include changes in plumbing fixtures, pipe insulation to reduce waiting time for hot water to reach the tap, customer pressure reductions, customer leak repairs and changes in the landscape to make it less water-demanding. Indirect methods are those which offer an inducement to reduce water use. These methods primarily include water use pricing and billing, public education about water supply, use and conservation, and legal restrictions or limits on use.

In this section, the various methods to reduce water demand will be discussed. Chosen methods can be combined with system water loss reductions, emergency plans and supporting information to complete a water conservation plan.

1. Pricing: Simple Economics

Pricing policy can be an important component of water conservation, although it is difficult to assess. Traditionally, water rates have been set at a level sufficient to provide necessary revenue for the utility, but without regard to the impact of rates on demand. This tradition is changing as utilities are faced with rising costs to provide sufficient water of acceptable quality.

Researchers in the 1950's and 1960's found that residential water demand is influenced by personal income, family size, housing characteristics, size of the urban area, weather conditions and water price.[31] Among these variables, only price is within the ability of the water utility to control.

Water price influences demand because water has a diminishing market value; the first units of water used are valued more highly than later units. The most valued water is used for drinking, cooking and hygiene. Less valued uses include lawn sprinkling and car washing. Based on the cost of using water, each user chooses to decrease use of less valuable units.[32] In other words, as price increases, the user will be more discretionary in his water use.

a. Price Elasticities

The price elasticity of water demand is the percent change in quantity consumed resulting from a one percent change in price. Elasticities are negative; a percent increase in price results in a percent decrease in demand. High elasticities are those less than-1.0, meaning that a one percent increase in price results in a greater than one percent decrease in demand. Low elasticities are those between zero and one, meaning that a one percent increase in price results in a less than one percent decrease in demand. The price/demand curve may not be linear; there may be different elasticity values at different price/demand relationships. There are also different elasticity values for different sectors and dimensions of water use. And, there are likely to be different long-run and short-run elasticities. For example, consumers may invest in long-run, water-conserving products only because other, short-run adjustments are not possible. Conversely, long-run adjustments may diminish as consumers become accustomed to higher prices.

A wide assortment of studies have been designed to determine price elasticities of water, with nearly as wide an assortment of conclusions. The most frequently referenced study was done by Howe and Linaweaver who concluded in 1967 that average indoor water demand is relatively inelastic, but that outdoor water use is elastic. The study also found that maximum daily demand was more elastic in the Eastern United States than in the West, because residential landscaping is less dependent on sprinkling in the East than in the more arid West. The relative insensitivity of demand to price is attributed to the small budget share which water demands, and the lack of substitute commodities.[33] A detailed literature survey of elasticity studies, including the Howe and Linaweaver study, was conducted for the Army Corps of Engineers in 1984.[34] The study assessed the statistical adequacy of each of the studies and reached the following conclusions about likely price elasticities for residential water demand in the Eastern United States.

Most Likely Elasticity Range

	Short run	Long run
Average Winter (Indoor) Use	n/a	0.0 to -0.1
Average Summer Use	n/a	0.5 to -0.6
Seasonal (Sprinkling) Use		n/a 1.3 to -1.6
Total Average Use	0.0 to -0.3	0.2 to -0.4

Although these figures may result from the best available research, they should be used only in the context of the variables other than price which influence demand and vary from community to community.

Relatively little is known about price elasticities in non-residential sectors. A few studies of elasticity have been conducted for specific industrial categories, with findings ranging from -0.3 to -6.71. Aggregate industrial elasticities have been estimated to be between - 0.5 and - 0.8. However, because wastewater disposal can represent a significant cost to industries, the combination of water and wastewater expenses can provide a significant conservation incentive. There have been few studies of elasticity in the commercial sector, with long range estimates in individual categories ranging from -0.2 to -1.4. Both industrial and commercial estimates of price elasticity were reported to be marred by statistical inadequacies.[35]

While available research does not present precise elasticity figures, estimates based on percent increases in water rates can be made from Table 7 (on page 39 below). The computation should be based on a percent increase in the combined water and sewer rate for the last unit of water consumed by the average customer.

Table 7: Reduction Factors: Water Rate Increase
(include water and sewer rates).

Percent Rate Increase	Residential Use Winter	Residential Use Summer	Maximum day residential	Industrial	Commercial
	Fractional Water Use Reduction				
5%	0.003	0.027	0.049	0.031	0.038
10%	0.006	0.053	0.095	0.060	0.073
15%	0.008	0.077	0.138	0.087	0.106
20%	0.011	0.099	0.178	0.112	0.136
25%	0.013	0.119	0.215	0.135	0.163
30%	0.016	0.139	0.250	0.157	0.189
35%	0.018	0.157	0.283	0.177	0.213
40%	0.020	0.175	0.314	0.196	0.236
45%	0.022	0.191	0.344	0.215	0.257
50%	0.024	0.206	0.371	0.232	0.277
55%	0.026	0.221	0.398	0.248	0.296
60%	0.028	0.235	0.423	0.263	0.313
65%	0.030	0.248	0.447	0.278	0.330
70%	0.031	0.261	0.470	0.292	0.346
75%	0.033	0.273	0.492	0.305	0.361
80%	0.035	0.285	0.512	0.318	0.375
85%	0.036	0.296	0.532	0.330	0.389
90%	0.038	0.306	0.552	0.341	0.402
95%	0.039	0.317	0.570	0.352	0.414
100%	0.041	0.326	0.587	0.363	0.426
Elasticities	-0.06	-0.57	Residential Summer times 1.8	-0.80	-0.65

Formulae derived from Boland, John J., Benedykt Dziegielewski, Duane D.Baumann, Eva M. Opitz "Influence of Price and Rate Structures on Municipal and Industrial Water Use," 12/84 US Army Corps of Engineers, Institute for Water Resources, Ft. Belvoir, VA.

b. Water Rate Structure

The structure of rates is as important as the rate itself in sending appropriate signals to consumers. There are about 20 different types of rate structures, some of which can be used in combination. Some rate structures encourage conservation; others discourage it. The major types are discussed in the following paragraphs.

Water systems not using water meters generally use a fixed charge. This system uses the same rate structure for all user categories or are based on building types, sizes, values, frontages, or other measure. Rates may be collected as a separate bill, or may be merely included in property taxes. Fixed charges do not promote water conservation or economic efficiency, and they result in small users subsidizing large users.

Another typical rate structure is a declining block rate design. With this structure, unit charges decrease as usage increases. Justification of declining block rates is based on economies of scale; as water use increases, it may cost less per unit to provide the water. However, perceived economies of scale may be a fallacy for large users if their water demand results in a need for expanded supply or facilities. Declining block rates enhance revenue stability since the more variable components of demand are located in the tail blocks. But the declining block structure often results in prices which exceed cost of service in the initial blocks and which are less than the cost of service in the tail blocks. Declining block rates encourage wasteful water use and result in small users subsidizing large users.

A uniform commodity rate charges the same unit rate for all units consumed. Water bills go up and down proportionately with water use. The rate design provides some incentive to conserve average water use and is simple and equitable.

There are two major forms of peak load pricing: seasonal pricing and peak demand pricing. Peak load pricing is used to reduce summer or peak demand. This structure is useful if there is a high peak or summer seasonal demand and if capacity investment or resource adequacy is determined by the peak demand. Peak load pricing helps to reduce the most "elastic" demands, such as watering outdoor plants. Peak load pricing helps to reduce demand during critical water supply periods.

Seasonal rates are set higher every summer. They serve as an annual reminder to customers that rates will increase every year before the water short season. They also make it less likely that a customer will become accustomed to a permanently higher rate.

Peak demand pricing, sometimes called excess use pricing, is the charging of a significantly higher price for all water used above an average use. The average use may be an average for an entire user sector, or may be based on an individual user's average winter use. Peak demand pricing may be structured differently for different user sectors in order to maintain equity.

Peak load pricing depends on frequent meter reading and prompt billing. Customers may not perceive the indirect message to conserve in their outdoor use if their summer water bill arrives in December. New remote meter reading technologies can be particularly useful if using peak load pricing.

Inverted block rates are designed so that as consumption increases, unit prices increase. This structure usually reduces average as well as peak demand, with residential use reductions of up to 10 percent.[36] This structure sends consumers price signals to decrease incremental demands. It is particularly useful for utilities that expect a system expansion to drive up unit costs. There is a potential problem with cross-sectional equity, however, especially if large water users do not influence demand peaks. There are also concerns about large users potentially subsidizing small users. A utility contemplating inverted block rates might wish to set different block structures or different minimum fees for different water-using sectors.

Mixed or combined rate structures are frequently used. The most common mixed rate structure combines a flat or minimum charge with some sort of block rate structure. This type of rate structure is justified on grounds that a portion of the cost of service is fixed; once the capital structures are in place, the supplier has a fixed expense regardless of water consumption. The block rate portion would be set to cover the more variable cost components. Incentive to conserve with this mix of rate structures depends on how much of typical water demand is reflected in the variable portion of the water bill and what type of variable structure is used. When all or most of consumption lies within the minimum charge block, the rate essentially becomes a flat rate, with no incentive to conserve.

Another common mixed rate structure combines some form of peak demand rate with the regular rate structure. This can be done as a seasonal rate or as an excess consumption surcharge.

Other rate structures may apply to specific conditions:

- Lifeline pricing is sometimes used to maintain low rates for low-income residents or very low-volume water users to maintain affordable water for those least able to pay higher costs.

- Scarcity pricing is a form of an increasing block rate which adds the price for a depleting supply to the existing price. This may be effective if increased demand endangers a sole source of water supply or requires potential construction of an expensive additional supply.

- Sliding scale pricing is a modified form of increasing block rates where charging is higher for discrete block use, rather than using the unit price for all water consumed.

- In developing areas, a spatial pricing system might be used to recoup the cost of expanding the system to serve a remote location or the higher expense of serving higher elevations.

- Hook-up fees or added service charges are other ways to recoup the cost of additional services.

c. Marginal Cost Pricing

As supply expansion becomes more and more expensive, interest is growing about an economic concept known a "marginal cost pricing." The marginal price equals either the reduction in the total water bill resulting from saving one unit of water, or the increase in the total bill resulting from the last unit of water consumed. The marginal cost of supply equals the cost of providing the last unit of water. Average water rates are determined by the total costs of supplying all system users. Generally, the marginal water rate will not equal the marginal cost of supply.

To the supplier, the least expensive available water supply is the first used, and the actual cost of providing the last unit of supply may exceed the average cost. Because the actual cost of supplying the last unit is likely to be greater than the rate charged for that unit, economic signals lead to over-consumption. To the consumer, however, the most valuable units consumed are the first ones, and the last units consumed are the least valuable. Therefore, if the prices for the last units increase with the cost of supply, consumption will decrease.

Use of marginal cost pricing is particularly useful for water systems near demand capacity. The cost of expanding the system or the supply to meet additional demand should be reflected in the price as capacity is approached. Where expansion is actually needed, marginal cost pricing would result in a smaller capacity expansion than if average pricing is used.

For a system with excess capacity, the marginal cost of supply may actually be lower than the average cost due to economies of scale. The use of marginal cost pricing, then, will vary depending on how close system demand is to capacity. The varied nature of marginal cost pricing may make it impractical as an exact pricing method. However, the actual cost of various units of supply should be considered as a part of rate-setting decisions, especially where demand approaches capacity.

d. Price setting

Prices should be set to reflect the actual cost of service, including all costs associated with property, hardware, operations, maintenance and personnel. These costs should include depreciation of capital assets and needed planning expenses. Prices should not be hidden in property taxes, as this eliminates direct incentive for conservation.

There is little consensus regarding what pricing structures are most effective in encouraging conservation. However, the following are known about consumer behavior. If a new pricing structure results in an unchanged total bill, there will be no response by the users. When prices do go up, response is delayed until bills are received. The initial response to higher rates may exceed the long term response if the perceived price impact is greater than the ultimate reality.[37] If prices are too low in the first place, a price increase may have little impact on demand.

Equity among water use segments is an issue to consider when weighing pricing alternatives. Careful analysis should be made of the allocation of the total cost of supplying water to a community. Public participation in rate changing decisions is necessary to achieve political acceptability of the resulting rate.

A final point about rate hikes and revenues: Higher rates will result in increased net revenues, because elasticities are generally between zero and -1, and percent water use reductions will be less than percent price increases.

2. Residential Use Reductions: Plumbing Fixtures

Using water-saving plumbing fixtures is the most effective way to minimize water use within residential, commercial, and institutional buildings.

a. State Plumbing Code

A typical non-conserving resident in a pre-1980 housing unit uses 77.5 gallons per day for all indoor purposes. Under 1980 standards, that figure should decrease by about 10.5 gallons per person per day. New York State implemented a state water conserving plumbing fixtures law in 1980 which mandated that all plumbing fixtures distributed, imported, sold or installed in the state should not exceed maximum flow standards. The standards specify 3.5 gallons per flush for water closets, 1.0 gallon per flush for urinals, and 3.0 gallons per minute for showers and faucets. An amendment added requirements for self-closing water fountains and self closing lavatory faucets in public places. Savings are steadily increasing as plumbing fixtures are replaced and housing stock is renewed.

A 1989 amendment to the State Plumbing Code requires that, as of January 1, 1992, all water closets meet a standard of 1.6 gallons per flush and, effective January 1, 1991, all lavatory faucets meet a flow standard of 2.0 gallons per minute. The amendment also requires the Department of Environmental Conservation to develop product testing and labeling regulations. Under the new law, per person residential water use should decline by about 18.5 gallons per day compared to pre-1980 units, and by about by about 8 gallons compared to units installed according to the 1980 law.

The New York State Building Code empowers local building inspectors to enforce the plumbing fixtures law during inspections of new or rehabilitated buildings. Compliance would improve if local governments included the state plumbing fixtures law as a local ordinance, requiring local wholesale and retail plumbing fixture outlets to sell only approved fixtures. Cities and villages should consider direct enforcement of the plumbing fixtures law as part of their water conservation plans. Water supply districts, authorities and companies should negotiate enforcement measures with local governments in their service areas.

b. Retrofit of Existing Fixtures

To “retrofit” existing plumbing fixtures is to add or replace them with water-saving fixtures. For example, retrofitting includes installing new, water-conserving showerheads as well as installing shower insert disks or faucet aerators into existing showerheads. Retrofitting also includes repairing toilet tank leaks and placing water displacement devices, such as dams or water-filled plastic bags, inside toilet tanks. Retrofit programs around the nation save an average of 16 gallons per person per day.

Quality retrofit kits can be purchased in bulk for as little as $4.00 each. The kits may be distributed via direct mail, depot pick ups, door-to-door, or contract installation. Kits may include water-saving or low-flow showerheads that decrease a showerhead opening and restrict the passage of water. These showerheads have been found to save 7.2 gallons of water per person per day. Kits may also include shower insert disks, which are inexpensive washer-like devices inserted behind the showerhead to reduce flow.

Distribute shower insert disks with caution: A federal Department of Housing and Urban Development study in 1984 found that although disks saved an average of 3.7 gallons per person per day, the average person spent an extra 1.2 minutes in the shower.[38] Many people find the disks provide unsatisfactory showers and remove them. Many of these people will then be unresponsive to further, better quality, household water conservation efforts.

Reducing shower water use saves energy as well as water. Depending on the fuel used for water heating and its price, energy savings can be quite dramatic.

The following formulas can be used to estimate water heating savings as a result of shower use reductions:[39]

<u>Electric Water Heaters:</u>
(Gals of hot Water * 8.34 * Change in Water Temperature)/3413 = kwh electricity

<u>Gas-fired Water Heaters:</u>
(Gals of hot Water * 8.34 * Change in Water Temperature)/(100,000 * 0.60) = therms of gas

<u>Oil-fired Water Heater:</u>
(Gals of hot Water * 8.34 * Change in Water Temperature)/(132,000 * 0.60) = gallons of oil

These formulas assume 100% efficiency for electric water heaters, and 60% efficiency for gas and oil water heaters. To compute shower savings, assume 50% of total shower use is hot water. The change in water temperature is the difference between raw water temperature out of the cold water tap and the setting of the water heater. For instance, if average cold water temperature is 60^{o}F and the water heater is set at 145^{o}F, the change in water temperature is 85^{o}F. Multiply the results by the cost per unit of fuel to determine total costs. Compute the cost with and without water-conserving showers. Table 8 illustrates potential savings.

TABLE 8: Potential Energy Savings

	Normal	**Conserving**	**Savings**
Shower use (gals/person/day)	16.3	9.1	7.2
Hot Water Use (50% tot use)	8.2	4.6	3.6

A. Electricity

	Price/PersonDay		Price/Person/Year		Savings/
Cost/KWH	Normal	Conserving	Normal	Conserving	Person/Year
$0.06	$0.11	$0.06	$38.33	$21.40	$16.93
0.08	0.14	0.08	51.11	28.54	22.58
0.10	0.18	0.10	63.89	35.67	28.22
0.12	0.21	0.12	76.67	42.80	33.87
0.14	0.25	0.14	89.45	49.94	39.51
0.16	0.28	0.16	102.23	57.07	45.16

(Table continues on next page)

Table 8: Potential Energy Savings (Continued)

B. Gas

Cost/Therm	Price/Person/Day Normal	Price/Person/Day Conserving	Price/Person/Year Normal	Price/Person/Year Conserving	Savings/ Person/Year
$0.50	$0.05	$0.03	$18.17	$10.14	$8.03
0.60	0.06	0.03	21.81	12.17	9.63
0.70	0.07	0.04	25.44	14.20	11.24
0.80	0.08	0.04	29.07	16.23	12.84
0.90	0.09	0.05	32.71	8.26	14.45
1.00	0.10	0.06	36.34	20.29	16.05
1.10	0.11	0.06	39.98	22.32	17.66
1.20	0.12	0.07	43.61	24.35	$19.26

C. Oil

Cost/Gal	Price/Person/Day Normal	Price/Person/Day Conserving	Price/Person/Year Normal	Price/Person/Year Conserving	Savings/ Person/Year
$0.60	$0.05	$0.03	$16.52	$9.22	$7.30
0.70	0.05	0.03	19.27	10.76	8.51
0.80	0.06	0.03	22.03	12.30	9.73
0.90	0.07	0.04	24.78	13.83	10.95
1.00	0.08	0.04	27.53	15.37	12.16
1.10	0.08	0.05	30.29	16.91	13.38
1.20	0.09	0.05	33.04	18.45	14.59
1.30	0.10	0.05	35.79	19.98	15.81

Assumptions: Change in water temperature = 88°F., normal shower use is 16.3 gals/person/day and conserving shower use is 9.1 gals/person/day.

The most comprehensive study of the effectiveness of retrofit programs for saving water was performed by Brown and Caldwell of Walnut Creek, California for the federal Department of Housing and Urban Development.[40] That study compared actual water use in households around the country using non-conserving fixtures, retrofit fixtures and new conserving fixtures. Test areas for the project included North Marin, North Tahoe, Dublin, East Bay and Los Angeles, California, Denver, Atlanta, Washington, D.C., and Hoboken, New Jersey. Over 200 households were sampled.

An average of 16 gallons per person per day was saved through programs which included replacing showerheads with water-efficient showerheads, inserting toilet tank dams, installing faucet aerators, and fixing toilet tank leaks. Those savings break down as follows:

- Low-flow showerheads saved about 7.2 gallons per person per day.
- Toilet tank dams saved an average of one gallon per flush, or 4 gallons per person per day. Toilet tank bags saved .5 gallons per flush, or 2 gallons per person per day.
- Faucet aerators saved an estimated .5 gallons per person per day.

About 20 percent of toilet tanks leaked. Fixing those leaks would save an average of 4.3 gallons per capita per day. (Leaking toilets waste an average of 24 gallons per day, and there are about 1.1 persons per toilet.) Within individual apartment buildings, the leakage rate may have been even higher. (A survey of three Washington, D.C. apartment buildings found that most toilets leaked, with an average of 48 gpd of leakage per unit, or 24 gpd per toilet. A 1981-82 Howard County, Maryland, study of apartment complexes and condominium associations found that 66% of all housing units had at least one leaking toilet.[41])

A variety of methods can be used to distribute retrofit devices:

- A **kit request program** involves mailing request cards to customers followed by mailing retrofit kits to those who respond to the cards by telephone or by mail. This is a low-cost distribution method and results in a high percentage of distributed kits being used. This method allows kit contents to be adjusted for individual needs. Generally, only a small percentage of the public responds to the cards.

- A **depot distribution method** allows residents to pick up kits at depots established at convenient locations. This is a low-cost approach in which few kits are wasted. One advantage of depot distribution over a mail method is that the depot method allows bulkier and heavier but more efficient kit components such as toilet tank dams and replacement showerheads to be included in the kits. Another advantage is that trained staff can help householders choose the best devices for their homes and explain benefits and installation methods. Special thought must be given to locating depots, as well as timing hours of operation. For instance, fire houses or water utility offices may have less response but high motivation by those responding. High traffic areas, such as shopping centers, may increase visibility and device distribution, but may result in many casual pickups which are not actually installed. It might work well to have a highly publicized campaign with several depots followed by a reduced number of depots as activity tapers off.

- A **mass mailing method** can be used to send inexpensive kits to every customer. Typical mass-mailed kits include plastic water displacement bags for toilet tanks, plastic shower flow restrictors, a set of toilet tank leak detection tablets and printed information. Program costs are relatively low, but many kits are not used. A mass-mailed kit can not include the best possible devices because of their bulk.

- In a **door-to-door program**, volunteers or employees distribute kits to customers' homes either with or without a request. High quality kits can be distributed with this method. Without follow-up, however, many devices may not be installed. In a Phoenix, Arizona, program, 83 percent of households that received kits said they installed the devices. Of those who installed showerheads, 7 percent later removed them, and 9 percent of those who installed toilet tank dams later removed them.

- A **direct installation method** enlists volunteers or paid workers to install retrofit devices at either low cost or no charge to the householder. This method may be used in combination with a door-to-door distribution method, with installation only upon request. This direct method yields the highest installation rate and greatest total water savings of all distribution methods, but it also has the highest cost. There may be liability considerations, and homeowners may be hesitant in allowing installers into their homes. It is possible to hire private contractors to do the installation and to carry any necessary liability coverage. Proper publicity and identification can help settle home owner concerns about access. Such programs have been or are being carried out in San Jose, Monterey, Santa Monica and Los Angeles, California, Metropolitan Boston, Austin, Texas, and Howard and Charles Counties, Maryland.

A recent study of four retrofit distribution methods[42] compared the installation rate of various types of programs in 12 different areas. While follow up figures are not exact, the study's conclusions are as shown in Table 9 on page 46.

TABLE 9: Approximate Installation Rate of Retrofit Devices

Device	Condition	Mass Mailing %	Depot %	Door-to-Door With Follow-up Installation %	Direct Installation %
Toilet-tank dams/bags	Crisis	40	40	85	70
	No crisis	30	35	85	60
Shower restrictors/ Low-flow showerheads	Crisis	20	35	80	65
	No crisis	5	0	80	50
Leak-detection tablets	Crisis	20	20	50	70
	No crisis	15	15	50	60

c. Water-Conserving Toilets

Several manufacturers are currently marketing toilets that use 1.6 gallons or less per flush (gpf). Some governments, including the state of Massachusetts and the city of Los Angeles, have already amended their plumbing codes to require these low-consumption toilets in new buildings. New York State and the Delaware River Basin Commission have enacted the change, effective in 1992 and 1991 respectively. Models with 1.6 gpf will be increasingly available as major manufacturers Kohler and American Standard enter the market in the near future. Reduced water and sewer costs makes these new toilets more cost-effective than standard 3.5 gpf toilets in spite of the new toilets' higher purchase price. Research has shown that these toilets do not cause increases in sewer line clogs [43] and waste flow is not a problem.[44]

Water districts, authorities and companies should consider recommending the use of 1.6 gallon per flush toilets in new buildings, pending the effective date of the state law. Local governments might amend building regulations to require these toilets.

3. Residential Use Reductions: Reducing Customer Water Pressures

The previous section on system pressure controls explained that a 30 percent reduction in system water pressure results in about a 6 percent reduction in water use. In many water systems, however, local conditions or fire flow requirements preclude system pressure reductions. It may be feasible, though, for pressures to be reduced in some individual buildings or groups of buildings by installing pressure-reducing valves in service lines. This can be particularly effective for large water users because pressure reductions cut down on plumbing repairs as water use is reduced. For instance, in an Amherst, Mass., apartment complex, a pressure reduction from 115 psi to 45-55 psi resulted in a 33 percent drop in water use and half as many plumbing repairs than in the neighboring high pressure cluster.[45]

4. Residential Use Reductions: Pipe Insulation

Hot water pipe insulation with split foam tubing is often a component of household energy conservation programs. Water conservation is a fringe benefit, because the insulation reduces the amount of time the faucet or shower runs before the hot water arrives. Hot water pipe insulation could save between 1% and 4% of interior residential water use.[46] The New York State Energy Conservation Construction Code requires insulation of service hot water supply piping in new or renovated buildings. (S. 7813.34) Water suppliers would benefit by working with regional electric utilities to educate property owners about the benefits of pipe insulation, and to recommend enactment of a local code that requires hot water heater and pipe insulation in all new or renovated buildings.

5. Residential Use Reductions: Customer Leak Repair

Even a small leak with a slow drip from a faucet wastes up to 20 gallons a day, and a 1/16 inch faucet leak wastes 100 gallons a day. Faucet leakage is often caused by worn or improperly sized gaskets, which can be easily replaced with parts found in hardware stores. At a higher cost, washerless faucets can be installed. The higher cost may be justified by the washerless faucets' 10-15 year guarantees of tight service.

Many unrepaired leaks occur in apartment buildings, and plumbers are usually not called until leaks are quite large. Homeowners may respond more quickly than apartment dwellers to leaks because of the direct cost involved.

There are several approaches to the customer leakage problem. First and foremost, meters must be in place and operating well. Old meters generally fail to register low rates of water use which might indicate water wasted by leaks. The metered water rate must be set so that there is an incentive for property owners, whether they be homeowners or landlords, to look for and repair leaks. Public education programs are necessary to inform property owners of how much money can be saved through leak detection and repair. One- and two-family home owners should be urged to check for leakage by shutting off all faucets in the building and checking the water meter over about a one-hour period to see if water use registers. Owners of large buildings should be urged or required to conduct periodic water audits in which all faucets, toilets and hose connections in the building are checked for leaks and repaired. Direct technical assistance to building owners is advised.

6. Outdoor Water Use Reduction

Outdoor water use is frequently targeted by water conservation programs, especially during drought periods. While such usage is nowhere near as high on a per person basis in New York as in more arid states, it still represents nearly one quarter of total water demand in some suburban areas. About 90 percent of outdoor water use is used for lawn, landscape and garden watering.[47] This usage represents much of the seasonal peak demand which creates the greatest stress on a water system. Lawn watering increases during dry periods, placing further stress upon water systems during supply shortages.

Contrary to a widely held belief, outdoor water use does not replenish the aquifer as it percolates through the soil. Most water applied to landscapes evaporates, transpires through plants, or runs off to storm sewers.

There are two ways to reduce outdoor water use during non-drought periods. First, landscapes can be designed to require less water by reducing turf area or planting drought-tolerant species. Second, recommended or required restrictions can be placed on outdoor water use. The latter approach is easier for most water suppliers, but the former approach might yield greater long-term dividends. Plans to reduce outdoor water use will succeed only if residents are able to retain attractive lawns and landscaping. In both cases, water use reduction approaches are designed not to ban water actually needed to maintain vegetation, but to assure that the volume of water is minimized, and that water is used only for essential purposes.

a. Landscaping Techniques

Water-Conserving Landscaping uses landscape design to directly reduce outdoor water demand. For example, maintaining some natural or "wild" plants in the landscape, using mulches, planting drought-tolerant groundcovers, grasses and shrubs, and providing plants with shade, will reduce watering needs. Soil can be aerated and mixed with compost or woodchips to decrease runoff and increase water-holding capacity.

More information about water-conserving landscaping is available from the National Xeriscape Council, Inc., 8080 S. Holly, Littleton, CO 80122.

Contact county Cooperative Extension agents for detailed information about low-water-demanding plants appropriate to your area.

A good reference for Southeastern New York is a publication by the Rutgers Cooperative Extension: "Landscaping for Water Conservation," available from the Publications Distribution Center, Cook College, Rutgers, The State University of New Jersey, New Brunswick, NJ, 08903. In New York City, "N.Y. Water Saver's Guide to Gardening" is available from the New York City Department of Environmental Protection, Telephone: 212-669-8381. Your county Cooperative Extension agent or Cornell University Cooperative Extension are also good sources of information.

Developers can reduce water use in new developments by concentrating turf area within Planned Unit Developments or Cluster Housing. This type of concentrated development mixes small lots with large open spaces and natural vegetation. Clustering requires less pavement and shorter utility runs and preserves more natural drainage.

The manager of the North Marin County, California Water District suggests Planned Unit Development criteria as in Table 10. [48]

TABLE 10:
Recommended Water Conserving Landscape Criteria for Planned Unit Developments.

1.	Perimeter of Turf:	Less than 20 lineal ft/unit
2.	Area of Turf:	Less than 500 sq. ft./unit
3.	Turf Layout:	"Pooled" into high visual impact and functional use areas on shallow or level slopes. Not used along long narrow pathways, in sidewalk strips or along foundations of buildings.
4.	Turf: Total Landscape Area:	Less than 0.40
5.	Non-Turf Landscape Area:	To be planted predominantly with water conserving plant materials available locally.
6.	Irrigation System:	In ground, equipped with modern controllers and designed for at least 100 percent overlap (sprinklers should throw from head to head) at low pressure for the site in order to achieve highly uniform precipitation rates. Design to include recommended monthly irrigation schedule on plans (minutes of run time and frequency for each valve), consistent with field capacity of soil and local evapotranspiration data. Appropriate selection of sprinkler heads.
7.	Soil Preparation:	Prior to installation of landscape, tilling of ground, addition of organics and other additives as necessary to achieve a well drained soil with adequate water holding characteristics and chemically balanced to be a suitable environment for plant and grass roots.
8.	Encourage Use of:	Rock plants for color and water-loving plants in naturally wet or drainage areas.

Some ways to encourage landscape design changes are:[49]

- Distribute water conservation literature to nurseries, landscapers, garden centers, and other lawn service operations.

- Encourage nurseries/landscapers to recommend low-water consumptive shrubbery and vegetation.

- Restrict the size of lawn areas around new construction.

- Encourage use of drought-resistant vegetation in new or redone landscaping.

- Provide water service connection discounts for new homes with significantly reduced turf areas.

- Design demonstration gardens in public areas, including low-water-using plants, appropriate irrigation methods, and signs to explain plants and techniques.

- Cooperate with local nurseries to develop plant lists for public use and to promote low-water-using plants.

- Develop public information materials which promote water saving landscapes and point out the benefits in reduced water bills, less yard maintenance and attractiveness.

- Have an awards program to recognize property owners with low-water-using landscapes.

b. Watering Reductions

Low-water planting reduces water use by minimizing evapotranspiration, the amount of water evaporated from the ground surface and transpired by plants. Factors that influence evapotranspiration include sunlight, temperature, precipitation, advection (water loss due to heat reflected from surrounding structures), humidity, wind, clouds and fog.

Irrigation rates are typically figured by subtracting available precipitation from potential transpiration. Many plants, however, will do well with less available water. Irrigation needs should also be based on the amount of sunlight, wind, temperature and precipitation. Perhaps water suppliers in New York State should follow the example of the Denver Water Department in making such calculations available on local weather broadcasts and in the newspaper. With lawns watered only as needed, a lawn in an area as dry as Denver requires watering only once every four to five days.[50] Since average summer precipitation in New York is two to four times that in Denver, weekly watering in most areas, as long as it is done slowly and deeply, would sufficiently promote healthy root systems. Frequent light watering actually results in less healthy lawns by reaching only shallow soil zones and encouraging shallow root systems that are prone to drought stress. Time of day is an important consideration in minimizing evaporation. During the hottest part of the day, as much as 40 percent of the water applied to lawn areas evaporates without providing any benefit to the plant.[51] To eliminate that problem, many areas implement time-of-day watering restrictions. Early morning is probably the best time to water. For homeowners with automatic sprinkling systems, 3 AM to 8 AM is probably the best watering time. This is the period of lowest temperature and calmest winds, and the morning sun will dry the grass blades, preventing fungus growth.

The watering method also influences evaporation rates. Fine sprays and high trajectories result in high levels of evaporation; large droplets and low trajectories minimize evaporation. Sprinklers should be carefully placed to provide even application rates so that areas of over watering and under watering are avoided, and to avoid watering paved surfaces.

Timers, hose meters and moisture sensors help manage lawn irrigation. Hose meters measure the amount of water used in irrigation, and can be set for desired amounts. Timers allow irrigation to be timed for desired early morning hours. Timers should, however, have an override ability during rainy periods, and they should also be readjusted seasonally. In the spring, infrequent but deep watering is needed. Early summer, when roots are well formed, requires light watering, somewhat more frequently. Late summer watering should return to a less frequent schedule. In all cases, watering must be adjusted according to soil type, vegetation and temperature. More watering is required during hotter periods and for sandier soils.

During all seasons, irrigation should be reduced or eliminated during wet weather. An inch of water per week is a good rule of thumb for combined precipitation and irrigation. Customers should be urged to use rain gauges to measure rainfall and avoid watering when natural precipitation averages an inch or more in a week, with the exception of short, heavy thunderstorms which add little water to soil. An alternative is to measure moisture by inserting a pencil into the soil. If the tip comes up wet, the soil has sufficient moisture and watering is not yet needed.[52]

Avoid mowing too short, too frequently, or during dry periods. Grass maintained at 2.5 inches or higher develops healthier root systems and is better able to withstand drought periods. No more than one third of the grass height should be mowed off at a time to avoid shocking the plant. Mowing during drought stress can kill a lawn. Mowing is best a day after watering.

c. Automatic Moisture Sensors

New customers, particularly with large lawn areas and automatic sprinkling systems, should be urged to install automatic moisture-sensing devices to override sprinkling systems when rainfall or soil moisture is sufficient. The best type of moisture sensor device is an underground tensiometer which senses moisture content in the soil. Recently developed solid-state devices are extremely sensitive, have no moving parts, and are not damaged by freezing. When installed by outside contractors, unit installation averages about $200 to $400 per home. In commercial settings and golf courses, sensors could help reduce labor costs and fertilizer applications.

Another, simpler system is an above-ground, rain collector mounted on a building and wired into an automatic lawn sprinkling switch. When precipitation in the cup reaches about 1/4 inch, a washer swells which sends an electronic signal to interrupt timed sprinkling. There is no signal when water evaporates below 1/4 inch. The cups require no emptying and will function even when clogged with debris. Units are available for as little as $30.

Benefits of reduced outdoor watering include water savings, healthier landscapes and less expensive maintenance. Mowing, weeding, fertilizer applications, pruning, and fungicide applications can be reduced.[53] Potential water savings are varied. A Xeriscape project in Marin County, California saved 54 percent of long-term outside water use. A Denver project saved 63 percent compared to traditional landscaping.[54] Since Xeriscape type projects generally result in a 50 percent or greater reduction in turf area, about a 50 percent reduction in irrigation use can be expected for affected properties.

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Working Notes

APPENDIX:
Public Information and Education

As stated earlier in this document, developing a water conservation program starts with defining needs and establishing goals to meet those specific needs. To help in the formulation of the program's goals, public participation should be sought.

Many reports cite variations in water use reductions stemming from information and education efforts in nationally-recognized programs. These variations can be attributed to the amount of discretionary water use in the system, and the degree of consumer and public cooperation and participation in the water conservation program. While the amount of discretionary water use varies among water systems, achieving a high degree of cooperation and participation in a water conservation program depends to a great extent on whether a public information and education campaign is well-designed.

Objectives

Before individuals will take part in a water conservation program, it is important they understand what the water resource situation is, what conservation efforts can do, and what costs are involved. Therefore, primary objectives of a public information and education campaign could be to:

- Raise awareness for the need to conserve water, emphasizing both environmental and economic benefits;
- Encourage participation for both adults and youth; and
- Motivate customers to voluntary change their water use practices as well as to purchase water saving fixtures and fittings.

How a program meets the above objectives would depend on the identification of potential audiences, and how the program is communicated to each audience. It is important to note effective communication of a public information and education campaign can dictate the success or failure of a utility's water conservation program

Audiences or 'Publics'

'Publics' include homeowners, renters, government, the business community, civic groups, special interest groups, schools, and the news media. Key 'publics that a typical water utility should reach as part of its information and education campaign are discussed below .

Homeowners constitute the largest class of water users in most water systems. They also are typically responsible for the biggest chunk of water use, particularly during summer months when residential outdoor water use soars. Lawn and landscape watering often accounts for over half the water used during the summer months for many NY residential accounts.

Utilities can reach homeowners through various means, e.g., bill stuffers, newsletters, information hotlines. Since water conservation is a pocketbook issue, providing homeowners with information on indoor and outdoor water use, tips for saving water and energy, is essential. Water use can then be easily translated into dollars -- something homeowners can readily evaluate.

Renters respond differently than homeowners. Often they do not directly pay for water, and therefore may not initially be concerned about costs. However, renters can be reached through apartment managers and property owners who are financially motivated to implement conservation. Water saving brochures and household retrofitting devices can be distributed to tenants through property owners.

Government also is an important audience. State and local officials are responsible for implementing various ordinances and regulations that affect water use. Representatives of the water utility should keep in close touch with government officials, including legislators. At a minimum, the utility should seek to coordinate its water saving efforts with those of state and local government. This can be achieved through personal contacts, letters, and phone calls. Providing government representatives with periodic updates on the status of the utility's water use patterns and water supply conditions can also foster much-needed support and cooperation from this important public.

Business and industry account for a large volume of water use in many water systems. Often, small changes in water-use practices and procedures can result in significant system-wide savings. Encouraging businesses to conduct water audits is an important first step. The water utility can assist business and industry by providing information on water-audit procedures and water-saving practices for large users. Also, since the number of large businesses and industries is usually small, personal visits often pay big dividends.

Civic groups can help promote a water utility's conservation program by encouraging its support from members. Also, groups should be kept well-supplied with brochures, audio-visual aids and other conservation information to update their membership. Consideration should be given to attendance by water utility representatives at regularly scheduled meetings of civic groups to foster partnerships.

Special interest groups are similar to civic groups. However, while civic groups tend to promote the general "public interest," special interest groups are more selective. Seeking the support of special interest groups can be difficult at times as such groups often feel the need to make strong -- and sometimes unreasonable -- demands on the water utility. Because of this, special interest groups also merit personal attention, including personal visits at group meetings and giving oral presentations at annual and specialty conferences and seminars. Special interest groups can become strong proponents of a utility's water conservation program.

Schools are another important public. The water utility should give special attention to "in-school" programs because children can be motivated to become water-conscious consumers and, once informed, often put pressure on their parents, siblings, and other adults to conform. The water utility can reach students and teachers through school officials and teacher-training workshops. Well-prepared curriculum materials are available from professional associations such as the American Water Works Association (AWWA). A number of other efforts can be used by schools and water utilities to enhance water conservation education including: declaring "Water Awareness Week"; sponsoring poster contests and science fair projects; showing films on water conservation; conducting field trips to water and wastewater treatment facilities; and giving oral presentations at school functions.

The News media are a major source of publicity. Newspapers are read by millions, influence public opinion, appear regularly, and intensively cover local and regional issues. Radio and television reach ninety-nine percent of the American people.

Techniques for Reaching the 'Publics'

Techniques for best reaching the above publics vary considerably. Water utilities can reach their publics through: news releases and public service announcements; conferences and seminars; audio-visual media; literature dissemination; speakers bureau; curriculum guidebooks; and demonstration projects. These techniques have been used successfully throughout the country.

The **news release** is a basic tool of public information and education. It can include background information, announce events or new programs, and convey policy statements. The news release also allows the utility to go on the record with an issue or program the way it intends the issue or program to be presented. It can generate follow-up media interest and be used to answer subsequent inquiries.

However, news releases often are viewed with a degree of skepticism by the media because they are perceived as being biased in favor of the writer. A good reporter will dig deeper in order to find a balance, and sometimes discover sources disagreeing with a utility's views. The point is, one cannot control the news media, but one can work effectively with them through meetings with media editorial boards. Background information can be provided and controversial issues aired, and perhaps resolved, before getting into print. Developing goodwill between the water utility and the media, especially the local media, makes good sense.

Public service announcements can reach large audiences through radio and television. The voice of a utility official can be taped and offered to radio stations. Film clips also can be offered to television stations. Radio and television public service announcements are invaluable as a means to get people motivated (e.g., to conserve water) during emergencies.

Conferences and seminars permit a broad dissemination of information and provide for a detailed explanation of complex issues that cannot be done through many other techniques. They provide an opportunity for two-way communication with a utility's publics, and are a good learning experience for attendees. A water utility can sponsor conferences or seminars on potential efforts relating to water conservation (e.g., possible household retrofit campaigns, alternative rate structures to encourage conservation). Conferences and seminars can foster trust and goodwill with publics, particularly civic, business, government, and special interest groups.

Audio-visual (AV) media are being employed more extensively in public information and education. AV media possess versatility, flexibility, and controllability. In contrast to public service announcements and news releases where information must be generalized for all audiences, AVs are usually targeted at specific publics. The two most used AV media are films and slides.

- **Films** are particularly effective in communicating information to group members simultaneously and conveniently than by individual communication. Once completed, they require little public relations support. Unfortunately, films usually have a short "shelf life." However, for most utilities, it may be more cost-effective to purchase and rent films from others. The AWWA offers a wide array on various topics of interest to the water utility and its publics.

- **Slides** are convenient to use and economical to produce, costing as little as 75 cents apiece. New computer graphics software permits the development of professional quality slides at a reasonable price. Slide presentations can be developed on general topics (overall water conservation program) for the general public, or on specific topics for business or special interest groups (e.g., water audit methods and procedures, low water use landscaping).

The most notable are brochures, bill stuffers, guides, and newsletters and periodicals.

- **Brochures** are excellent vehicles for educating the public on water conservation and the need to reduce water use. They combine visual representations with summaries to reinforce goals and objectives. Brochures also can be used effectively for specific topics, such as a low water-use landscaping techniques brochure prepared by the National Xeriscape Council. Many effective brochures have also been developed by state and federal agencies, and associations such as the AWWA.

- **Bill stuffers** are small notices included with a water utility's bill. Gas, electric, and telephone companies frequently also use them. These well-illustrated and colorful notices are inexpensive to prepare and can be placed in the same envelope as the bill. Too many bill stuffers in one mailing, however, may reduce the chance they will be read. Bill stuffers should be limited to a few per year. Guides are available from state and federal agencies, as well as the AWWA, describing in detail how to conduct specific water conservation programs.

- **Newsletters and periodicals** reach a wide audience. The utility that ignores this fact is overlooking an important outlet. Unlike press releases, newsletters are controllable allowing the utility to go on record with a subject the way it intends the subject to be presented. Periodicals are underutilized as a possible outlet for information. In almost every field there are important trade publications directed to those in that field. Providing trade publications with feature stories on special topics is an excellent means to reach business and other interest groups.

Speakers bureaus are designed to obtain goodwill by having utility representatives share their expertise with important publics. A speakers bureau lists people available for speaking arrangements, cross-referenced by subject area. Typically, this list is put into directory form and sent to community organizations. Formal speeches by effective speakers are among the quickest and most effective ways to convey information to small groups. Many publics often do not know available, qualified individuals to speak on technical subjects.

Offering **curriculum guides** on water conservation to schools is another technique to improve public information and education. If the local school districts in the utility's service area do not have "in-school" water conservation programs, the water utility should, as a minimum, offer curriculum guides and sponsor teacher training workshops. There is an abundance of water conservation curriculum materials available from the state, and federal government, as well as the AWWA. For example, the New York Department of Environmental Conservation assists water utilities and school districts in establishing education programs by providing advice on curriculum materials, training for teachers, training for utility staff, and protocol for running a program.

Demonstrations by utilities, showing gardens with drought-tolerant plants and grasses, and using Xeriscaping as a landscape technique, is an another excellent tool for education. As noted by the National Xeriscape Council, landscapes can demand fifty percent of the water used for home consumption. Savings from thirty-to-eighty percent have been obtained with the use of Xeriscape. The water utility might consider having the demonstration garden on its own property. It is always a good idea to show customers and the general public that the water utility "practices what it preaches." Other demonstration projects might include retrofitting schools and office buildings with low-flush toilets and faucet aerators. Alternative water-conservation devices can be displayed at the utility's office.

In summary, public information and education are important components of a water utility's water conservation program. The education of the general public is critical in gaining their support and compliance.