The ABCs of Water Loss

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Depending upon the way in which one looks at water loss, the problem is either elementary or it presents a major hurdle for efficient utility operations. For some water system decision-makers, it may be as simple as asking the manager to take action to reduce the level of water loss. Sometimes, the expectations of a utility's governing board can be unrealistic, especially when they do not provide ample resources to the manager and operators. From another viewpoint, water loss is an ongoing problem that must be endured ("The problem was here when I became manager, and it will be here when I leave.") Admittedly, old water lines, high water pressure, and rocky, mountainous terrain impede the reduction of unaccounted-for water. However, given the proper tools and dedicated effort, unaccounted-for water can be reduced and managed.

Controlling water loss is as simple as ABC.

Step A—determine the amount of unaccounted-for water.

Step B—determine the source of the unaccounted-for water.

Step C—eliminate the sources responsible for unaccounted-for water. Agreed, it is easier said than done, but let's discuss some methods for attacking this age-old problem.

The Kentucky Rural Water Association has distributed hundreds of "Water Loss Report" forms over the years to attendees of our training seminars across the Commonwealth. This form, or a modified version customized to better fit individual water utilities, serves as an excellent tool for determining the amount of unaccounted-for water on a monthly basis. A free MicroSoft Excel version of this form is available as a download on Western Kentucky University's website. All you have to do is enter the appropriate numbers into the proper blanks, and your utility's water loss percentage will be calculated electronically. If you prefer lower technology, plugging the numbers into a hard copy form and using a handheld calculator will get the same results. Similar water loss report forms are available from commercial leak detection companies and from the Kentucky Public Service Commission.

Step A can be likened to the story of Farmer Brown who takes inventory of his herd of cattle and determines how many cows are missing or unaccounted-for. How does he then determine how many are missing from each pasture? Step B resolves this problem. The smaller the pasture, the easier it is to control the herd and to account for the missing cows. Likewise, the smaller the section of water distribution system, the easier it becomes to account for the volume of water lost. The key is to divide the distribution lines into subsections or zones. Pumping stations naturally divide water distribution systems by pressure zone, and sometimes each master meter from a wholesale water supplier serves an isolated area. Internal master meters can be installed to allow for monthly water loss reports on multiple sections of the distribution system. Although expensive, dual master meters measuring flows in both directions can be installed where water quality is jeopardized due to isolated sections of water line. An overall water loss report is derived by combining individual subsection calculations into one.

Portable flow meters and by-pass monitor meters can be used to determine the amount of water flowing into a zone at a particular point in time. This is a good way to check for water leaks but will not be as thorough as installing a permanent master meter. The difference in customer usage compared to the volume of water that flowed through a permanent master meter will measure all water unaccounted-for over a period of time; whereas, a portable flow meter or by-pass monitor meter will not account for inaccurate customer meters, and may not detect periodic theft or unauthorized use of water. The Kentucky Rural Water Association (KRWA) Circuit Riders use electronic, transit-time, portable meters to strap onto any type water line to measure water flow into a given area. In most cases, exposing the top half of a line two feet in length will be sufficient to acquire an accurate flow reading. By-pass monitor meters are best installed near gate valves in the distribution system. By closing the gate valve and forcing water to flow through the small by-pass meter, water flowing into a zone can be measured. These by-pass monitor meters are sized to meet the customer demand during periods of minimum usage (12:00 midnight to 4:00 a.m.).

Excessive flow rates usually indicate that leakage is occurring. In rural areas, demands above 0.115 gallons per minute (gpm), per customer meter connection, is a sign of potential leakage. The 0.115 gpm figure is based on an average customer demand of 5,000 gallons per month. Normally, a 5/8 x ¾-inch meter is adequate for a zone with 100 residential meter connections. A 1-inch meter will handle up to 300 residential meter connections, and a 2-inch meter, installed at the base of a water storage tank, can serve as a by-pass monitor meter for a section of distribution line with 1,000 customer meters.

Note: It is important to use a meter setter with a valve on both sides of the meter in order to remove the meter without getting wet!

Pumping stations can also be utilized as master meters. Granted, it is best to install a properly plumbed meter in each pumping station; however, knowing the pump flow rate and pump run-time (with electrical hour meter), a close estimate of water demand in that zone can be calculated. Pump flow rates vary according to discharge pressure relative to storage tank water levels, but are accurate enough to indicate potential water loss problems.

Just as Farmer Brown determines how many cows are missing from each pasture, zone flows into various sections of a water distribution system can determine excessive water demand. With this knowledge, the water utility manager and operators can prioritize their efforts relative to the zone flows. Here is where the fun begins! What could be more rewarding than finding a large water leak? Knowing what to look for when searching for a water leak is simplified with experience. Yes, electronic leak detection equipment is imperative in some instances; however, many telltale signs await the experienced operator. These signs come in many forms: low pressure complaints, water fountains occurring in abnormal places, huge flows of muddy water in ditches (obvious leaks when it has not rained recently), mounds in pavement or fields, sunken spots in pavement, fields, or lawns, spots of bright green grass or wet grass with a bleached white slime, unusual occurrences of ice, an unusual lack of snow or ice, steam or fog, areas with cattails and young willow tree growth, peculiar livestock and animal habits, and chlorine odors, especially on warm, humid nights. Suspicious waters can be subjected to field testing or laboratory analysis to confirm the presence of treated water. Total chlorine is the most frequent laboratory test, but fluoride and total trihalomethane can be used as well.

Whether a water leak is found through a methodical, investigative search or just plain luck, it is time to move on to Step C, eliminating the sources of unaccounted-for water. A monthly water loss report will itemize areas such as known line breaks, hydrant flushing, storage tank overflows, treatment plant use, fire department usage, unmetered connections, and computer adjustments to account for water that has been produced or purchased, but not sold. The remaining portion of unaccounted-for water is normally attributed to inaccurate meters or water line leaks.

Following Public Service Commission (PSC) guidelines for meter testing and change-out program is crucial to the revenue sufficiency of all water utilities. Testing of small residential meters should be set up on a ten-year cycle, and 4-inch and larger meters and all wholesale meters should be tested annually. Although municipal water systems are not under PSC jurisdiction in regards to water meter testing, a meter testing and change-out program is recommended as an effective management tool. It is not uncommon for meter inaccuracy to account for 5-10% of a water utility's total unaccounted-for water loss.

The second part of Step C goes without saying: repair your water line breaks just as Farmer Brown would mend his fences to keep his cows from escaping the pasture.

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Water Loss Determination: For What it's Worth

By Joan Kenny
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The standing-room only crowd at the KRWA session on Water Loss Problems last March is one indication of how important this subject is for water providers. It's easy to understand that controlling water loss saves money, but it's not always easy to determine what your water loss is, why it's there, or how to reduce it. What's more, water loss awareness is a never-ending job, and one that is as individual as each water supply system. This article summarizes the main concepts in water loss determination, suggests ways to keep loss under control, and describes some of the reasons why water loss determination is essential to good management.

In my work for State water agencies, I have looked at countless annual water use reports from systems of all sizes and from all parts of Kansas. The only thing that's certain is that each report is different. I've also had the opportunity to meet or speak to many operators, bookkeepers, city clerks and public works superintendents who provide information for the water use reports. The one thing they have in common is a great attitude about their work. I'm always impressed with how well these people handle the challenging tasks of operating a water system. Because of their efforts at keeping water records, we all know more about identifying water loss.

What is water loss?

Simply put, water loss is the difference between the water entering the supply system (through wells, surface intakes, and/or wholesale purchases) and water used (sold to customers or used for free). All systems experience some water loss as an ordinary part of operation. Water loss is also called 'unaccounted for water' to distinguish it from losses that occur for known reasons, such as for water treatment processes or hydrant flushing. Amounts of unaccounted for water are typically expressed as a percentage of the total amount pumped and/or purchased. In 1997, unaccounted for water among systems that completed water use reports ranged from less than 3% to more than 65% of the total amount. The average was 15%. What is a reasonable percentage for your system depends on the type of treatment required, the condition of your system, and how much of your use is metered. The American Water Works Association recommends that the loss occurring after treatment be maintained at 10% or less.

How do I calculate water loss?

The first thing to do is to have believable figures. There's no use chasing down leaks if your master meter is grossly overregistering, or if your sales figures are erroneous. Periodically test raw, finished, and wholesale meters, and keep them within 2% of actual flow. Check that all metered uses have been properly accounted for. Correct misreads promptly, and make sure any necessary conversions from cubic feet to gallons are correct. Also, record the actual usage at each metered location even if the gallons used are less than the gallons included on the minimum charge. Showing that more water was used than actually passed through the meters will obscure your true water loss and may even result in an apparent negative loss. (Underregistering master or finished meters can also cause an apparent low or negative loss, which doesn't help you detect real losses.) Try to compare production and usage for the same monthly time periods, if possible. Water loss percentages may show more monthly variation if service meters are read in several cycles, if customers read their own meters, or if there is a combination of wholesale water sources each with different meter reading dates. Rural water districts with self-read meters should check those meters at least annually to catch up with delinquent payments and amounts of water used.

Records of water produced, purchased, sold to wholesale and retail customers, and used for free are the basis of annual water use reports. Maintaining such records is useful even if the State isn't asking you to do it. Subtract metered uses from the total amount pumped and/or purchased on a monthly basis to figure the amount of unaccounted for water as a volume. Divide this number by the total to get the percentage. Monthly comparison of water in and water out is the key to monitoring water loss. A graph or table showing the amount and percentage of unaccounted for water each month of the year can be a good way to present information to your city council or rural water district board. Of course, sudden large losses often are detected in the short term by noticing changes in daily pumpage.

What are common reasons for water loss?

Water loss can occur at many different points in a system, both pre- and post-distribution. It's important to ask what areas of a system you are determining water loss for, then obtain reliable information on water quantities at all appropriate locations.

On the State water use reports, withdrawals are reported from the point where water is taken from the source, and loss is computed on the basis of that entire pre-treatment amount. If you pump from wells, it is important to meter any loss from lube lines and to make sure that check valves are not letting water flow back down the wells after being metered. If there is some distance between the points at which water is initially metered (such as at a well, lake, or wholesale connection) and a treatment plant, it is helpful to meter the water again as it enters the plant or tower to detect any losses occurring during transmission.

Water treatment often involves using water for backflushing, cleaning basins, and chlorine mixing. This water will show up as a loss unless it is metered. Accounting for treatment plant water use is very important for some systems, especially those using surface water. Some operators meter individual processes within a treatment plant; others simply meter the raw water coming in and the finished water leaving to arrive at the amount used in treatment. Of course, multiple meters can complicate matters when one or both is inaccurate. Keep good records of treatment plant use by reading and testing raw and finished meters regularly. If your meters are accurate and it still appears that more water is leaving your plant than is coming in, check that you are not metering some water twice. This can happen when finished water already metered is used for chlorine feed and then metered again going out. In this case, it would be helpful to meter the chlorinator water and account for it as you would any other metered use.

Losses occurring in the distribution system, after water leaves the plant or tower, are those most commonly associated with the term 'water loss.' These include leaks, line breaks, unmetered uses, and theft. The best way to determine the amount of water lost in your distribution system is to meter all uses, whether they are billed or not, and read the meters regularly. Leaks on the customer side of the line can go unnoticed if meters are only estimated. Substantial amounts of water can be used at free services such as parks, pools, and city operations. It may seem unnecessary to meter infrequently used connections at community buildings, churches, and bulk outlets, but without a meter you do not know how much water may really be used or lost at these locations. An unattended leaky toilet can waste a lot of water before it's discovered. Bulk sales recorded on the honor system are rarely accurate. Some towns have used tremendous quantities of water for irrigation of parks or a newly seeded ballfields. Accounting for as much usage as possible will help you identify the amount of water that is truly unaccounted for.

Other water losses cannot easily be measured, such as loss from tower repairs, tower overflows, line breaks, fire use, or flushing. It's a good idea to keep a log noting when any such losses happened, so that you know what to expect when you compare production figures with sales and find a large difference. Knowing approximately how much water is lost through flushing can help you determine whether the remainder of your unaccounted for water is really a problem. Some operators who flush hydrants frequently have portable meters for measuring amounts of water used, or they estimate the amounts by timing each flush at known flow rates.

In many cases, large water losses are not due to leaks but to underregistering service meters. As meters wear with age or high usage, many tend to stop moving at low flows. The result is a gradual decrease in amounts of water metered (and paid for), which can add up to a lot of unaccounted for water and lost revenue for a water system. If your records indicate significant water loss and there are no known leaks or unmetered uses, check the age, volume recorded, and accuracy of your service meters. A meter changeout program is an investment that will pay for itself.

Is my water loss a problem?

Whether or not your water loss percentage represents a problem that should be resolved depends on the volume lost, the cost of your water, and the causes of the loss. If you operate a very small system, a single line break or tower repair can represent a large percentage of the annual total pumped but not indicate a chronic problem. Sometimes it's helpful to look at an unexplained volume of water lost in terms of rate of leakage to determine whether there is a problem worth worrying about. For example, an unexplained loss of 500,000 gallons per year could result from a leak of less than 1 gallon per minute, which may be hard to find. When small volumes of water are lost, searching for the cause should be weighed against the cost-effective use of your time and resources.

Some people are more conscious of volumes of unaccounted for water because of high costs to purchase or produce it. In many parts of eastern Kansas, the cost of delivering water reflects the expense of building and maintaining a treatment plant or developing a new, regional source of water. A system with high costs for water has additional incentive to monitor water loss and may not tolerate as high a percentage of unaccounted for water as a system in which the water is inexpensive to pump.

Finding the causes of water loss in any given month or year can help you determine whether there is a problem that needs to be addressed. Losses from ordinary operations and repairs are to be expected. Operators who routinely flush hydrants can expect a larger percentage loss, especially if the systems are small. Other persistent losses may result from situations that need attention; for example, a leaky pool, a slow meter on your largest customer, a flawed billing program, or a faulty altitude valve on the tower.

What can be done to reduce water loss?

- Keep good figures on production and use, and review them regularly.
- Maintain appropriate lube line flows, and ensure that check valves are holding.

- Keep all meters in good working condition. Test raw, finished, and booster meters every few years or as warranted by conflicting readings. Replace customer meters on a regular basis.
- Meter all uses as practical, and read the meters regularly. Note the dates of any large unmetered losses such as line breaks, tower repairs, frequent flushing, and usage by road crews or fire departments.
- Maintain good tower control.
- Fix leaks promptly.
- Call KRWA for free help with leak detection. This service is partly funded through Kansas State Water Plan fees.
- Determine the cause of chronic leaks, such as those from old corroded lines or glue joints, and whether line replacement is necessary. A grant or loan to replace problem areas may be appropriate if the cost is outside your budget.
- Prepare a conservation plan (the Kansas Water Office will assist you with this for free), and then follow the conservation measures that you have chosen for maintaining an efficient system.

Why is all this important?

Lost water is lost money. If losses are due to underregistering customer meters, you lose revenue on water you paid to deliver. If losses are caused by leaks, you've lost the money it cost to produce or purchase that water. In some cases, curbing large water losses from leaks can save a town or district the cost of finding additional water sources.

> **Wasted water means wasted dollars. Since 1989, KRWA has completed 564 water loss surveys locating an annual loss of 2.387 billion gallons. The annual costs to purchase or produce this loss would have been $3.586 million.**

Water loss percentages indicate to others how efficient your system is. This may be an issue if you are applying for additional water rights, contracting to purchase or sell water, seeking a grant or loan for system improvements, or trying to stay within established conservation goals. A high loss percentage may work against you if unabated waste is occurring, or it may work in your favor if you need evidence that replacement of leaky corroded lines is warranted.

Information is a powerful tool in the business of providing water service. Good records help you understand your system's own unique needs and recognize any problems that may occur.

Keep Track of That Water!
Water Accounting for Management and Conservation

by Janice A. Beecher and John E. Flowers

Today, the commodity water systems deliver has greater value than ever before. Extraction, treatment, storage, and pumping all add value to the water resource. Given mounting infrastructure costs and growing constraints on water resources, water managers must strive to account for all the water that travels from source to end users.

Conservation is a key rationale for improving methods for tracking water. Conservation on the supply side can be particularly effective because the supply side is under utility managers' direct control, and water savings translate directly to cost savings (without adversely affecting revenues). In *Water Conservation Plan Guidelines*, published by the US Environmental Protection Agency in August 1998, water accounting and loss control, along with universal source and end-user metering, are discussed as basic and essential conservation measures for water systems of all sizes. (On the World Wide Web at <http://www.epa.gov/OWM/genwave.htm#guideline>)

The guidelines' approach to water accounting is similar to existing practices common to many systems. The emphasis on accounting, however, shifts attention from any single standard or percentage to the process of tracking water through the water delivery system and identifying potential areas for improvement.

Confusing Terms and Standards

Numerous imprecise terms are used to represent the difference between the water that is withdrawn from the source and water that is eventually distributed to end users. For example, the terms "water losses" and "unaccounted-for water" are sometimes used interchangeably. But not all unaccounted-for water is lost; some might be given away or used for authorized purposes. Some water labeled "nonrevenue" or "nonrevenue producing" might also include authorized and unauthorized uses. The term "uncompensated usage" has been used to include water used by public authorities, water used for flushing and other maintenance purposes, leakage, and uncollected accounts from customers.

A 1987 study by Lynn P. Wallace for the American Water Works Association Research Foundation made this distinction between "account" and "nonaccount" water:

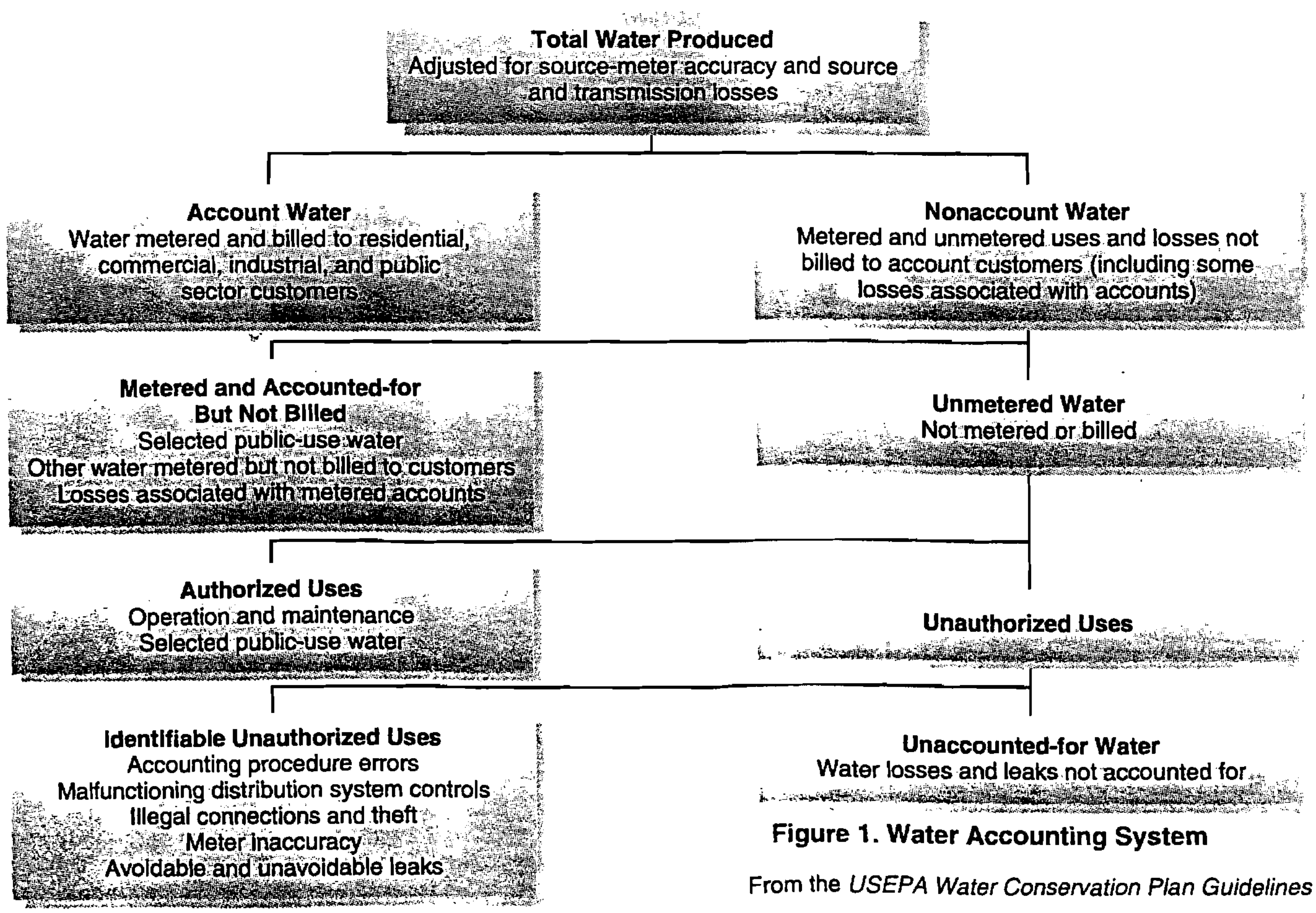


Figure 1. Water Accounting System

From the *USEPA Water Conservation Plan Guidelines*

- *Account water* is all water for which an account exists; the water is metered, and the account is billed.
- *Nonaccount water* is the sum of all water produced or purchased by a water utility that is not covered by the term "account water."

This proposed nomenclature, which is adopted in the guidelines' accounting system, has not really caught on in the water industry. For the most part, the industry uses the similar term "unaccounted-for water" to mean leaks and other kinds of avoidable losses. However, the measurement of unaccounted-for water can be confusing because the numerator and the denominator used to calculate the percentage are not obvious. Is the percentage amount supposed to represent all water not metered and sold, or only water lost through leaks? How the percentage is calculated makes a meaningful difference.

On top of the confusion about terms is confusion about standards. Any single standard (expressed in terms of volume or a percentage) for unaccounted-for water will not be valid, realistic, or appropriate for many water systems. Many system characteristics—such as size, age, service population density, physical terrain, soil characteristics, and pipe materials—will affect leakage rates. Systems also have different production-cost profiles against which the cost-effectiveness of leak detection and control programs can be evaluated.

In 1996, AWWA's Leak Detection and Accountability Committee recommended 10 percent as a benchmark for unaccounted-for water, replacing a 15 percent standard that apparently was based more on folklore than analysis. Even the 10 percent benchmark has not achieved consensus in the water industry.

The AWWA committee suggested that "regardless of the water system's size, water loss should be expressed in terms of actual volume, not as a percentage." This volumetric measure, the committee points out, is essential for estimating the monetary value of losses. The volume of lost water can be multiplied by the unit cost of water production (or the retail rate) to estimate the cost of the lost water. From an economics perspective, the true value of losses is the *marginal* or *incremental* unit cost of production (that is, the cost of producing the next increment of supply). Incremental or marginal costs more accurately reflect water's value, which will increase as supply alternatives become scarcer. Reducing leakage and loss can help systems avoid high supply-side operating and capital costs.

A clearer system of water accounting could be used to improve data collection and evaluation and eventually establish a standard (or set of standards for the different water subaccounts) based on a sound empirical understanding. In the long term, the water industry may move toward a common terminology for water accounting purposes. Benchmarks or ranges for systems with similar characteristics could be established, based on a formula to represent key characteristics. A more immediate need, however, is to build understanding and agreement about the basic purpose and concepts of water accounting.

Metering and Accounting

An accurate system of water accounting is very dependent on an accurate system of metering. Water systems should meter at the source, at key points in the distribution system, and at customer premises.

A Water Accounting System

All water systems, even smaller systems, should implement a basic system of water accounting. AWWA Manual 36, *Water Audits and Leak Detection*, provides guidance for this process. Water system managers should try to track water throughout the system—from water sources to end users—and identify areas that may need attention, particularly large volumes of nonaccount water.

A system of water accounting should be based on experience and observation. Thus, metering and audits play an important role in implementing a system of water accounting. A system of water *accounting* is essential to water *valuation*, that is, placing a monetary value on losses.

Nonaccount water includes water that is *metered but not billed*, as well as *all unmetered* water. Unmetered water may be authorized for certain utility purposes, such as operation and maintenance, and for certain public uses, such as fire hydrant maintenance. Unmetered water also includes unauthorized uses, including losses from accounting errors, malfunctioning distribution system controls, thefts, inaccurate meters, or leaks. In some cases, nonaccount water may represent losses such as meter inaccuracy and theft that are associated with specific customer accounts. Some unauthorized uses may be identifiable. When they are not, these unauthorized uses constitute *unaccounted-for water.*

Implementing a system of water accounting is a necessary first step in developing strategies for loss control, as well as for metering nonaccount water. A system of water accounting is provided in Figure 1, opposite. This system for tracking water begins with total water produced and ends with unaccounted-for water. In this system, "unaccounted-for water" has a more literal meaning. Table 1 (on page 10) provides a worksheet that water system managers can use to account for water.

Additional Strategies

USEPA's *Water Conservation Plan Guidelines* identify a number of management strategies that can be used in conjunction with a system of water accounting. These conservation measures can be highly effective in reducing nonaccount, unaccounted-for, and lost water. Key strategies include:

- ***Repair known leaks.*** Water lost produces no revenues for the utility. The cost of water leakage can be measured in terms of the operating costs associated with water supply, treatment, and delivery. Repairing larger leaks can be costly, but it also can produce substantial savings in water and expenditures over the long run.
- ***Universal metering.*** Source water, service connections, and all water provided free of charge for public use should be metered to provide the most accurate usage data. If source water is unmetered, usage can be estimated by multiplying the pumping

continued on page 11

Table 1: Water Accounting and Loss Control

Line	Item	Volume *gal*		% of Amount in Line 1
1	**Total Source Withdrawals and Purchases**			100%
2	*Adjustments to source water supply [a]*			
2A	Adjustment for source meter error (+ or –)			
2B	Adjustment for change in reservoir or tank storage (+ or –)			
2C	Adjustment for transmission line losses (–) [a]			
2D	Adjustments for other source contributions or losses (+ or –) [a]			
3	Total adjustments to source water (add lines 2A through 2D)			
4	**Adjusted Source Water (subtract line 3 from line 1)**			%
5	*Metered Water Sales*			
5A	Metered residential sales			
5B	Metered commercial sales			
5C	Metered industrial sales			
5D	Metered public sales			
5E	Other metered sales			
6	Total metered sales (add lines 5A through 5D)			
7	Adjustment for meter reading lag time (+ or –)			
8	Adjustment for meter errors (+ or –) [a]			
9	Adjusted total meter sales (add lines 6 through 8)			
10	**Nonaccount Water (subtract line 9 from line 4)**			%
11	*Metered and accounted-for but not billed*			
11A	Public-use water metered but not billed			
11B	Other water metered but not billed			
12	*Authorized unmetered water: operation and maintenance*			
12A	Main flushing			
12B	Process water at treatment plant			
12C	Water quality and other testing			
13	*Authorized unmetered water: public use*			
13A	Storm drain flushing			
13B	Sewer cleaning			
13C	Street cleaning			
13D	Landscaping in large public areas			
13E	Firefighting, training, and related maintenance			
14	*Other authorized unmetered use*			
14A	Swimming pools			
14B	Construction sites			
14C	Other unmetered uses			
15	Total authorized unmetered water (add lines 11A through 14C)			
16	**Total Unauthorized Losses (subtract line 15 from line 10)**			%
17	*Identifiable water losses and leaks*			
17A	Accounting procedure errors [a]			
17B	Malfunctioning distribution system controls			
17C	Illegal connections and theft			
17D	Meter inaccuracy			
17E	Unavoidable water leaks			
17F	Avoidable water leaks			
18	Total identifiable water losses and leaks (add lines 17A through 17F)			
19	**Unaccounted-for Water (subtract line 18 from line 16)**			%

[a] Methodology subject to industry and regulatory standards

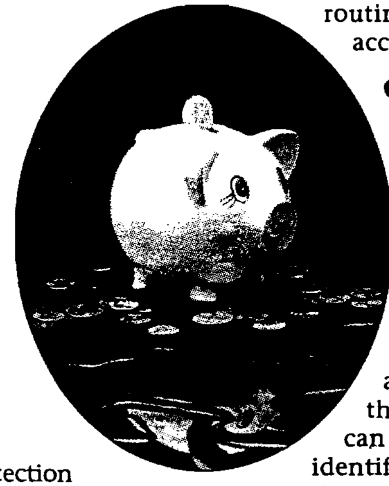
From the *USEPA Water Conservation Plan Guidelines*

Keep Track of That Water!

Water Accounting for Management and Conservation continued from page 7

rate by the time of operation based on electric meter readings.

- ***Analysis of nonaccount water.*** Nonaccount water use should be analyzed to identify potential revenue-producing opportunities, as well as recoverable losses and leaks. Some utilities might consider charging for water previously given away for public use and increasing efforts to reduce illegal connections and other forms of theft.
- ***System audit.*** A system audit can identify and measure authorized metered and unmetered uses and provide a more accurate analysis of nonaccount water. AWWA's Manual 36 is an excellent resource for information on conducting water audits.
- ***Leak detection and repair strategy.*** Systems also should institute a comprehensive leak detection and repair strategy. This strategy may include regular on-site testing using computer-assisted leak detection equipment, a sonic leak-detection survey, or another acceptable method for detecting leaks along water distribution mains, valves, services, and meters. Divers can be used to inspect and clean storage tank interiors.
- ***Automated sensors/telemetry.*** Remote sensor and telemetry technologies can be used for ongoing monitoring and analysis of source, transmission, and distribution facilities. These sensors and monitoring software can alert operators to leaks, fluctuations in pressure, problems with equipment integrity, and other concerns.
- ***Loss-prevention program.*** Periodic pipe inspections, cleaning, lining, and other maintenance efforts can improve the distribution system performance and prevent leaks and ruptures from occurring. Utilities might also consider methods for minimizing water used in routine water system maintenance procedures in accordance with other applicable standards.



Conclusion

As water costs and prices rise, the benefits of water accounting and loss control are becoming more obvious. Shifting the focus from a single performance standard to a more refined system of accounting could be very beneficial to the water industry. USEPA's *Water Conservation Plan Guidelines* introduce terms that clearly identify where all the water produced goes, and by using this system of water accounting, managers can track water throughout their systems and identify opportunities for improvement. As experience with water accounting grows, this system can be fine-tuned and adopted to provide additional guidance for reducing avoidable leaks and losses.

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Striking Distance

A Three-Tiered Approach to Lightning Control continued from page 8

Other Transient Problems

Lightning damage is not the only problem solved with this three-tiered protection approach. Lightning is just the most dramatic form of transient. By solving the lightning problem, you automatically protect your equipment from the more pedestrian types of transients caused by such incidents as an electric utility company switching, trees brushing against power lines, and traffic accidents with utility poles. Not only are you protecting your equipment from catastrophic damage, you are creating an environment in which it will last longer and operate more reliably.

Damage from transients accumulates. It may cause microscopic damage that leads to intermittent or unreliable operations. In many cases, this type of fault may be worse than catastrophic failure. It certainly is more aggravating.

Benefits to the Bottom Line

Water plants are highly susceptible to lightning-related damage to SCADA systems, communications systems, AC power systems, tanks, and other structures. Nationally, lightning-induced problems cause water plants to lose millions of dollars in equipment, repair costs, customer service interruptions, total or partial system outages, and downtime.

So, to protect the equipment in your plant, make it more reliable and extend its service life, take the systems approach to transient protection. Keep in mind the various ways in which lightning can cause damage and then design and implement a coordinated systems approach to damage control.

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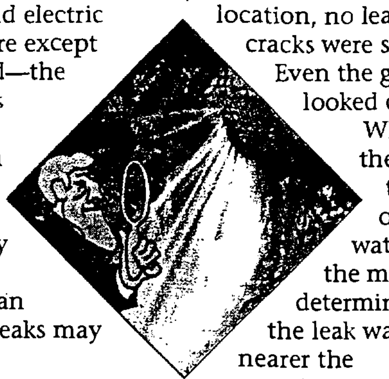
Surveys Uncover Undetected Leaks

by Gary A. Fenney

Utilities unwittingly lose hundreds of millions of gallons of water every year. Escaped water flows undetected into the ground, sewers, lakes, rivers, basements, telephone and electric ducts—almost everywhere except where it should be found—the surface. Unsurfaced leaks ranging from 500 to 500,000 gpd escape from broken mains and service lines, hydrants, valves, and meters. Many utilities never know the leaks exist and, without an effort to find them, the leaks may never be discovered.

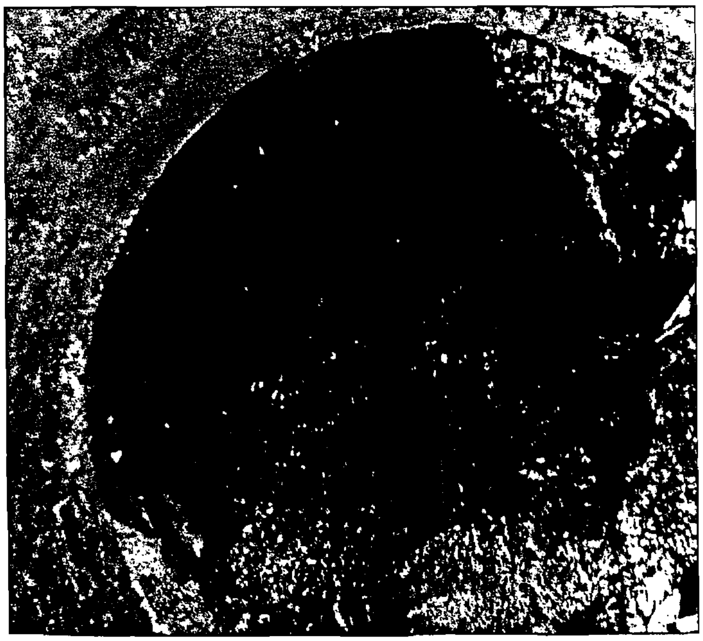


Leaky Situations

One particular utility within a deep glacial moraine overburden area was having trouble filling and keeping water in a new water tower. Glacial moraine overburden areas are common in Wisconsin and the Great Lakes area where glacier deposits of large areas of sand and gravel over the original terrain can be found. The areas are very porous and water has no trouble filtering down through them and never surfacing. During a comprehensive leak detection survey on a 10-in. main just one mile from the tower, a leak was discovered. During excavation, the main was shut down at the leaking section, but when the main was exposed at the measured leak location, no leaks or cracks were seen. Even the gravel looked dry. When the crew turned on the water to the main to determine if the leak was nearer the excavation, a geyser erupted from the excavated hole. The main had a circular crack that was not detected on the pipe and didn't appear suspicious because the rocks and sand around the pipe appeared dry, but the ground was so porous that it quickly absorbed the estimated 80 gpm leaking out of the pressurized main. The crack was repaired and the tower-filling problem fixed.

Accurate detection methods are critical when the leaky water pipe is inappropriately laid next to a sewer pipe, such as these pipes.

Another example occurred in a community with approximately 35 miles of mains. After a cannery closed for the winter, higher than normal pumping continued despite less demand on the system. The utility spent several days looking in obvious places for evidence of a leak. An estimated 350,000 gpd was being lost, and logic told investigators that they should be able to find the leak by looking in sewers and ditches for an over-abundance of water. Eventually, a leak detection survey was conducted on the entire system. A leak was discovered around an 8-in. fire protection main that ran through a swamp. After excavating, the leak was found to be on a defective 8-in. saddle tee.



Sometimes water line leaks are unseen because they immediately are absorbed into a sanitary sewer system.

Surveying the Scene

Pinpointing a leak can be more of an art form than a science. A leak survey uses sensitive electronically amplified sensors that allow the technician with headphones to hear leaks through pipes from fire hydrants, main line valves, and service valves and meters up to several hundred feet away from the leak, depending on pipe size, material, and pressure on the system. With a good working knowledge of a system's pipe measurements, and a computer correlator that computes the theoretical speed of sound through that pipe material of hydrants, valves, and meters to the leak, the leak location is found.

Using this technique, an operator can systematically eliminate the pipe where the leak is *not*, until the leak is straddled between the correlators' transmitters, one on either side of the leak. Then the distance from the access points is calculated, effectively locating the leak. The greater the complexity of mains near the leak, the more finesse a technician needs to have. By process of elimination, the leak is pinpointed.

continued on page 11

Surveys Uncover Undetected Leaks

continued from page 8

There are two types of leak detection surveys. The first type listens on fire hydrants only. Following a system map, technicians systematically go through a system, stopping at all fire hydrants and listening to them with an electronic surveyor, while marking the map at each location. A leak sound is given a rating from "zero" (no leak sound) to "10" (very loud sound). The technician does a second survey to verify the sound isn't caused by natural water flow, pumps, electrical transformers, traffic, or other means. After the second survey, the correlation process begins.

Ideally, sound ratings are good and only one or two correlation procedures will be needed to pinpoint a leak. Leaks that are found are usually marked at their location, sketched, and reported to the utility for repair.

This type of leak detection survey finds hydrant leaks and larger leaks in a relatively short time period. Depending on the technician, equipment, and the number of leaks in a system, this survey should be effective in finding all hydrant and most large main and service leaks. It is the fastest and cheapest way to locate leaks.

The Paper Trail

A more expensive and more effective survey includes listening on all fire hydrants and as many gate valves as needed to cover the system as extensively as possible. During this survey, the technician can also review and update system maps and locate more system defects.

Pumping and storage records can also be reviewed in correlation with metered water sold to consumers for up to three previous years. Discrepancies in pumping and metered usage, along with testing master meters, provide an idea of potential water loss and how much loss to be looking for. This type of survey, known as a water audit, takes longer than listening on hydrants only, but more leaks and system defects can be located. Defects such as buried valves filled with debris and valve packing leaks are more likely to be found through the more comprehensive survey.

Payback Time

Professional leak detection experts consistently find that only a small percentage of utilities know about their system's unseen leaks. Once aware of how much water is lost and how much money can be saved by finding and fixing undetected leaks, utilities make leak surveys an annual event. Repairing holes in the system saves the utility more in treatment costs (electricity and chemicals only) than a leak survey costs, as often the survey pays for itself in less than six months.

If the cost of producing water is $0.35/1000 gal, and a few service leaks and several leaky hydrants add up to 130,000 gpd, these leaks could cost approximately $8,300 in treated water over six months. If the lost water is going into the sewer system, costs further increase to handle the water again in the wastewater treatment facility.

A typical leak detection survey costs anywhere from $100 to $400 per mile of main surveyed, depending on the size of the system, the material of mains to be surveyed, and the travel distance. Leaks are difficult to locate in polyvinyl chloride and polyethylene pipes, or in pipes and appurtenances of any other plastic-type material, because sound does not travel very far through these materials. Special listening equipment may be needed in these cases. Cast iron, ductile iron, steel, and asbestos concrete are conducive to a hydrant- and valve-listening survey, thus it is easier and cheaper to conduct a survey on these pipes.

General surveying equipment costs between $2,000 and $5,000, while correlators run from $35,000 to $60,000, depending on extras desired. Training on this equipment is usually included in the price, but accompanying a technician on a leak survey would provide the most comprehensive training in all aspects of leak detection.

Out of sight should not mean out of mind. Water utilities that conduct leak detection surveys may be surprised at what they find. The payback is water and money saved, and increased customer satisfaction as service and construction disruptions are kept to a minimum.

■ *Gary Fenney is a project administrator for Earth Tech, formerly Rust Environment and Infrastructure. He can be reached at 1020 N. Broadway, Ste. 400, Milwaukee, WI 53202; (414) 225-5740, or gary_fenney@earthtech.com.*

Preparing for the Leak Detection Survey

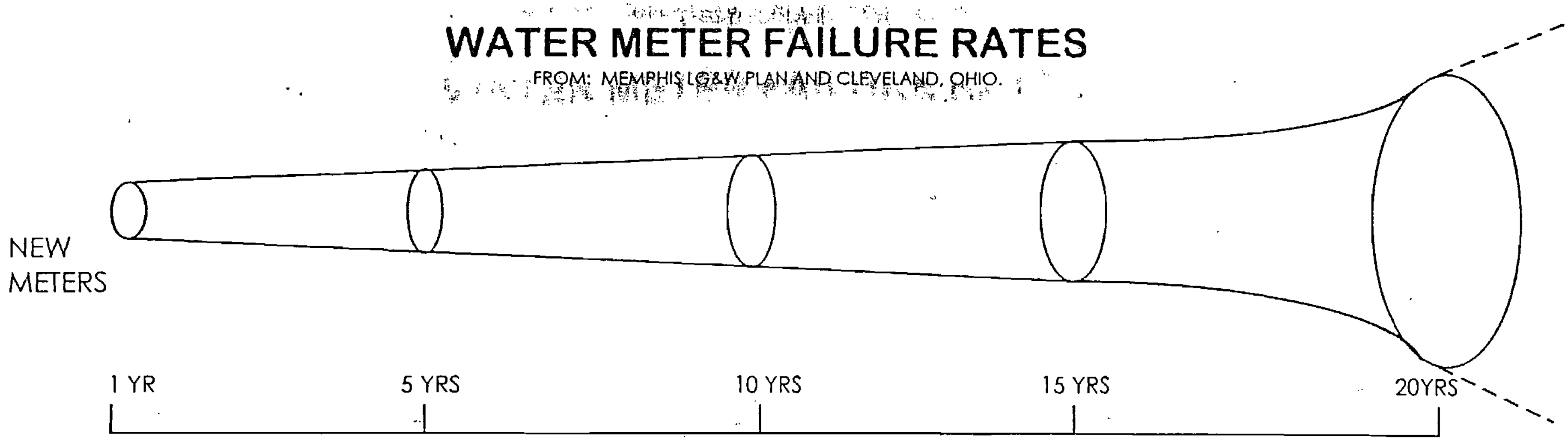
—Excerpted from AWWA Manual 36, Water Audits and Leak Detection, *1997*

Before conducting a leak detection survey, review the specifics of your distribution system, including the following:

- results of the water audit: How much water is lost from the system?
- mains and services: types, ages, diameters, joints, installation methods, inspections, leak histories, and operating pressures.
- meters and meter-box assemblies: types, brands, and sizes of meters; ages; types of installations; meter shutoffs; couplings; and meter reading frequency.
- valves: locations, types, left- or right-handed, number of turns to exercise, and how often exercised.
- hydrants: types, sizes, locations, flushing frequencies, and unmetered usage.
- pressure-reducing valves, pressure-sustaining valves, and pressure-relief valves: locations and how often they are exercised.
- blowoffs and air-release valves: locations and how often they are exercised.
- distribution system maps: What is shown on the maps, how current is the information, and how often is the information updated?

WATER METER FAILURE RATES

FROM: MEMPHIS LG&W PLAN AND CLEVELAND, OHIO.



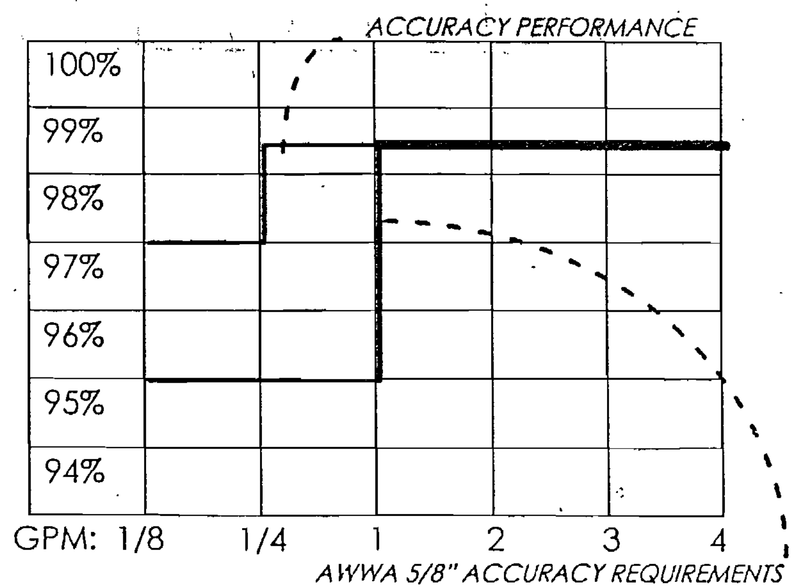
FLOW FAILURE UNDER 1 GPM.

BASED ON PRESSURE OF 60 PSI:
1/32" LEAK WASTES 211 GAL/24 HOURS
1/16" LEAK WASTES 833 GAL/24 HOURS
1/8" LEAK WASTES 3333 GAL/24 HOURS

*PERCENT OF TOTAL FLOW THROUGH DOMESTIC METERS**

RATE OF FLOW GPM	WATER USED PERCENT OF TOTAL
0 - 1/4	13.0
1/4 - 1/2	3.4
1/2 - 1	6.8
1 - 2	13.3
2 - 4	43.0
MORE THAN 4	20.5

*SOURCE: JOURNAL AMERICAN WATER WORKS ASSOC, VOL 56, NO.2, FEB, 1964



23% OF HOUSEHOLD WATER USAGE OCCURS AT LOW FLOW RATES BELOW 1 GPM

The Economics of Water Lo$$

What is unaccounted for water?

by **Steve Wyatt**,
MTAS Utility Operations Consultant,
University of Tennessee

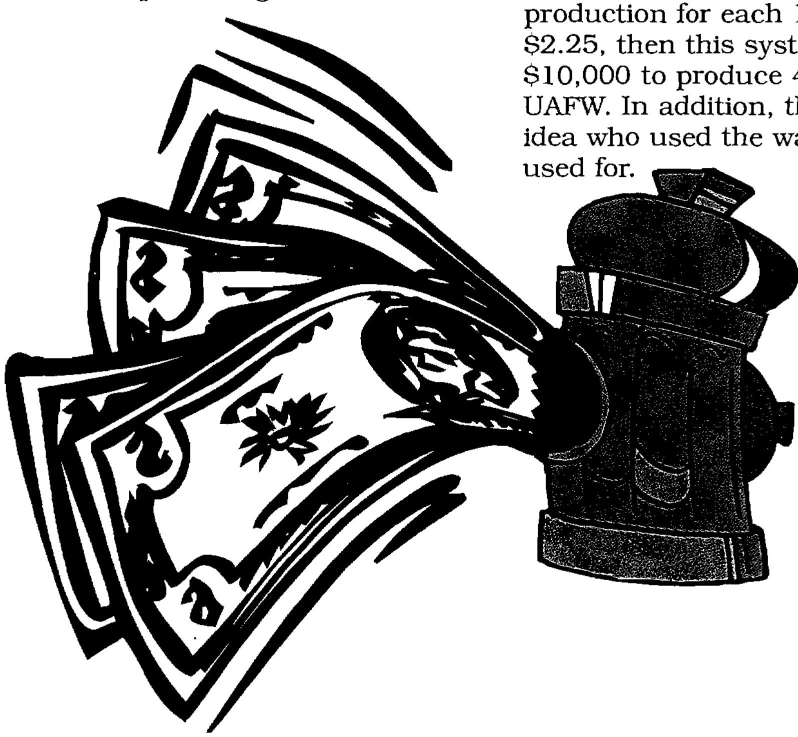
No drinking water system can avoid water loss. It comes with the territory. And let's face it: old or poorly constructed distribution systems are the main culprits. No matter where the fault lies, though, water loss is more than a nuisance—it's an economic menace. But small drinking water systems can rest assured that good news does exist. These systems can minimize revenue loss just by calculating unaccounted for water (UAFW).

Drinking water utilities can describe UAFW as the difference between the amount of water that they produce or purchase versus the amount that they sell or are able to account for within their systems. UAFW is usually expressed as a percentage.

Surprisingly, across the U.S the water industry seems to accept an UAFW loss of 10–12 percent as normal. Unfortunately, UAFW of greater than 30 percent is not uncommon. As water resources become more limited throughout the U.S., we must emphasis reducing UAFW volumes. Besides conserving precious water resources, low UAFW also indicates a well-managed operation.

The example on the following page illustrates how to calculate UAFW. This example looks at a 30-day cycle. Thirty days is not long enough for a legitimate study, but that amount of time effectively illustrates how most systems calculate UAFW:

Here, the water system cannot account for almost 20 percent of the water it produced in the 30-day period. If the cost of production for each 1,000 gallons is \$2.25, then this system spends about \$10,000 to produce 4,445,248 gallons of UAFW. In addition, the system has no idea who used the water or what it was used for.



Water the production meter measures at the plant	22,455,323 gallons
Water sold to customers	16,789,000 gallons
Water that the plant uses (backwashing filters, chemical feeds, etc.)	21,075 gallons
Water that city facilities use	200,000 gallons
Estimated fire department use	1,000,000 gallons
TOTAL ACCOUNTED FOR WATER	18,010,075 gallons
Water produced minus water accounted for equals UAFW	22,455,323 gallons
	- 18,010,075 gallons
UAFW	4,445,248 gallons

Unaccounted for water divided by water produced times 100 equals percent UAFW

4,445,248 ÷ 22,455,323 x 100 19.8% UAFW

Another method of finding water-loss rates uses how much water a system loses per mile of distribution line instead of the UAFW formula. Either method works to find a system's overall water-loss rates. The real point to remember when calculating water-loss rates is that if a system has high volumes of unaccounted for water, it can negatively affect the system's physical capacity and financial health.

To be viable, a water system must monitor and manage UAFW. A number of different elements contribute to UAFW, including:

- leaks,
- inaccurate or broken meters,
- unmetered use, and
- errors in the billing process.

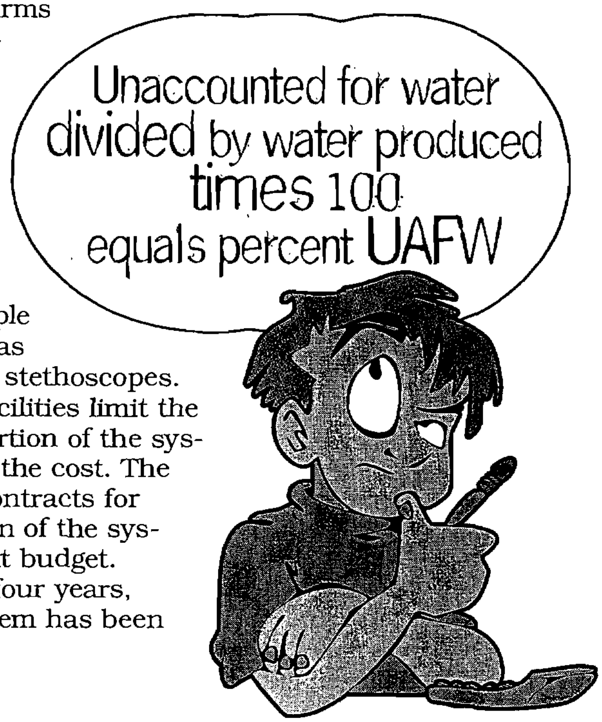
Leaks Account for Much UAFW

Leaks can account for a large portion of UAFW, or they may be a relatively small portion of the problem. Water systems will always have leaks and line loss, but the trick is to keep water loss as low as possible. Leak detection is a chronic chore for water systems. A system may choose to purchase detection equipment and train staff to check for leaks, or they may hire an outside firm to perform a leak detection survey. Some systems use a combination of internal checks and contracting. Both practices have pros and cons.

Leak detection equipment ranges from simple, inexpensive sonoscopes/stethoscopes to mid-priced acoustic amplifiers to expensive leak correlators. All of these require some level of experience and training to obtain consistent results. Water system personnel use sonoscopes/stethoscopes to detect leaks at meters, valves, or hydrants. They are easy to use and require minimal training and experience.

As equipment becomes more complicated, though, workers will need more experience and may require additional training. Also, if a system purchases expensive leak detection equipment that it will not use very often, it is not necessarily money well spent. Most water systems can get by with inexpensive, simple equipment to find leaks at valves, meters, and hydrants, which is a good value for any water system.

Outside leak detection firms rely on experienced staff trained to use sophisticated equipment. Their services are not as easy on the pocket as simple devices, such as sonoscopes or stethoscopes. Some water facilities limit the survey to a portion of the system to reduce the cost. The facility then contracts for another portion of the system in the next budget. After three to four years, the whole system has been surveyed.



Investing in more elaborate, expensive equipment is justified if trained, experienced staff frequently use it. Medium to large water systems purchase leak detection equipment and train their staff to operate it. As these trained individuals gain experience, they produce good results for their systems.

Most small to medium water systems could get a better return on their money if they contracted with an outside firm to conduct a leak detection survey. In addition, small and medium systems can use less sophisticated equipment to locate leaks prior to using an outside firm. Thus, system personnel find and repair easy leaks prior to the arrival of the experts, and save the system a lot of time and money. The experts can then concentrate on more difficult leaks.

Inaccurate or Broken Meters

Meters supply the data that generate revenue for your water and wastewater system. Basically, water meters are the cash registers for the system. If the cash registers are inaccurate or inoperable, the system loses money. Over time, meters age and lose accuracy. Missed volumes tend to occur during periods when the flow through the meter is low.

Every water system should have a written meter calibration and replacement policy. A written policy provides a tool to manage the meters.

Listed here are at least three essentials to a meter calibration/replacement policy:

1. Check and certify production meters and large customer meters on an annual basis. System personnel can either take meters to a testing facility, or they can check them in place. Checking the meter in place is the best option because the testing facility cannot duplicate exact operating conditions in the field.
2. Install production and large customer meters to meet flow requirements, not pressure requirements.
3. Make sure smaller meters are on a written replacement rotation. Meter suppliers can provide an estimate of how long a meter is expected to work accurately. The policy can specify that the meter should be replaced after a certain number of years or after a certain volume of water flows through the meter.

Unmetered Use

Typically, communities have legitimate uses for a portion of water that their water systems produce, and the systems never bill or meter for it. However, systems should record these volumes monthly, even if they only take an educated guess at how much water is used for:

- fighting fires;
- flushing fire-hydrants;
- washing streets; or
- maintaining city parks, pools, or other facilities.

To keep up with how much water is used for these activities, encourage fire departments to provide monthly estimates of their water use. The same policy holds for the public works department. For example, street sweepers could carry portable meters that document water use. Further, meter any facility that uses water and record the reading monthly.

Occasionally, water theft occurs—generally from fire hydrants. The volume the thieves take is difficult to quantify, but the system should make a good faith effort to estimate the amount of water stolen. A spike in the UAFW level could be an indicator of water theft.

Billing-Process Errors

Another culprit that accounts for some UAFW is billing-process errors. Normally, these errors are a very small portion of UAFW. Here are some common errors:

- inaccurate meter reading—either a misread on the old-style dial meter or the meter reader errs as he or she records the reading;
- an incorrect factor is used to calculate the volume used;
- transcription error in the billing system;
- rounding error in the billing process; and

- estimates used are either totally unacceptable or estimates are used too frequently in the billing process.

Management and Tracking UAFW

A water system must have a management plan in operation so that it can monitor and reduce UAFW. Various technical publications are available to guide water system personnel in this process. To monitor water loss, system personnel should:

- walk the system and check for leaks and unmetered use,
- perform a review of all pumping records, billing, and accounted for water,
- review meter histories and calibration records,
- produce and budget for a written meter program,
- determine whether the system needs a leak detection survey,
- clarify how the system will monitor for leaks in the future,
- track UAFW monthly, and
- stay on task, and work on UAFW regularly.

Tracking UAFW can be frustrating especially if a system looks at data over short time spans—billing and production volumes don't necessarily coincide. One approach is to use a running 12-month percentage for UAFW. This method identifies trends and does not falsely skew data. But remember, tracking UAFW is useless without accurate meters.

How a Small System Reduced UAFW

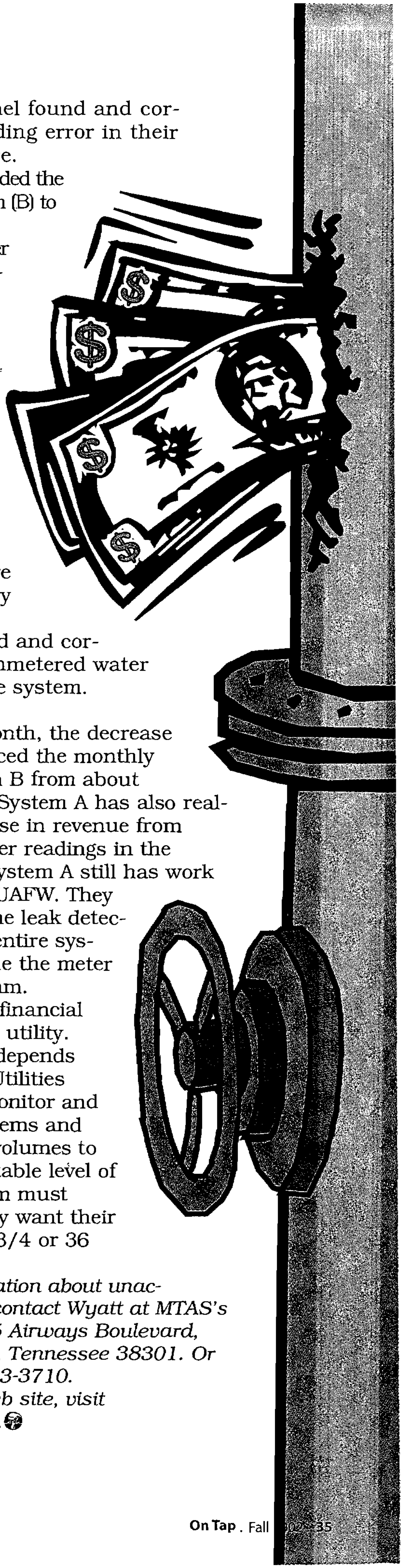
System A serves a population of less than 500 people and purchases water from neighboring System B. The master meter at the connection of the two systems was an early 1980s mechanical meter. System B historically billed volumes 50–76 percent higher than volumes that System A bills to its customers.

System A:

- did not have a meter change-out program;
- had not performed an active leak detection program; and
- marginally accounted for volumes used in fire protection and other unmetered uses.

With outside assistance, System A reduced its UAFW to the 10–30 percent range. Here's how:

- It started a meter replacement program. In the first year, System A replaced 15 percent of the meters within the system. The system targeted these meters because of age and location.
- System A hired a leak detection company to survey a portion of the system.
- Office personnel found and corrected a rounding error in their billing software.
- System A persuaded the supplying system (B) to replace the old mechanical meter with a new ultrasonic meter.
- System A's water manager worked closely with the fire department to obtain reliable estimates of how much water was used in fire protection every month.
- Staff discovered and corrected other unmetered water uses within the system.



For a typical month, the decrease in UAFW has reduced the monthly payment to System B from about $2,300 to $1,270. System A has also realized a slight increase in revenue from more accurate meter readings in the replaced meters. System A still has work to do on reducing UAFW. They plan to complete the leak detection survey of the entire system and to continue the meter replacement program.

UAFW can be a financial drain on any water utility. How large a drain depends upon the system. Utilities must constantly monitor and maintain their systems and account for water volumes to maintain an acceptable level of UAFW. Each system must decide whether they want their UAFW drain to be 3/4 or 36 inches in diameter.

For more information about unaccounted for water, contact Wyatt at MTAS's Jackson Office, 605 Airways Boulevard, Suite 109, Jackson, Tennessee 38301. Or call him at (731) 423-3710. To view MTAS's Web site, visit www.mtas.utk.edu.

Tech Brief

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Leak Detection and Water Loss Control

by Zacharia M. Lahlou, Ph.D.
Civil and Environmental Engineer, Wiley and Wilson, Lynchburg, VA

Summary

Utilities can no longer tolerate inefficiencies in water distribution systems and the resulting loss of revenue associated with underground water system leakage. Increases in pumping, treatment and operational costs make these losses prohibitive. To combat water loss, many utilities are developing methods to detect, locate, and correct leaks.

Photo by Eric Merrill

Shawn Menear, a graduate student in Technology Education at West Virginia University, uses geophones to listen for water main leaks. Similar to a doctor or nurse's stethoscope, geophones are an inexpensive leak detection device used by water utilities.

Old and poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves and mechanical damage are some of the factors contributing to leakage. One effect of water leakage, besides the loss of water resources, is reduced pressure in the supply system. Raising pressures to make up for such losses increases energy consumption. This rise in pressure makes leaking worse and has adverse environmental impacts.

Of the many options available for conserving water, leak detection is a logical first step. If a utility does what it can to conserve water, customers will tend to be more cooperative in other water conservation programs, many of which hinge on individual efforts. A leak detection program can be highly visible, encouraging people to think about water conservation before they are asked to take action to reduce their own water use. Leak detection is an opportunity to improve services to existing customers and to extend services to the population not served.

In general, a 10 to 20 percent allowance for unaccounted-for-water is normal. But a loss of more than 20 percent requires priority attention and corrective actions. However advances in technologies and expertise should make it possible to reduce losses and unaccounted-for-water to less than 10 percent. While percentages are great for guidelines, a more meaningful measure is volume of lost water. Once the volume is known, revenue losses can be determined and cost effectiveness of implementing corrective action can then be determined.

Benefits of Leak Detection and Repair

The economic benefits of leak detection and repair can be easily estimated. For an individual leak, the amount lost in a given period of time, multiplied by the retail value of that water will provide a dollar amount. Remember to factor in the costs of developing new water supplies and other "hidden" costs.

Some other potential benefits of leak detection and repair that are difficult to quantify include:

- increased knowledge about the distribution system, which can be used, for example, to respond more quickly to emergencies and to set priorities for replacement or rehabilitation programs;
- more efficient use of existing supplies and delayed capacity expansion;
- improved relations with both the public and utility employees;
- improved environmental quality;
- increased firefighting capability;
- reduced property damage, reduced legal liability, and reduced insurance because of the fewer main breaks; and
- reduced risk of contamination.

Causes of Leaks

Water produced and delivered to the distribution system is intended to be sold to the customer, not lost or siphoned from the distribution system without authorization. Not long ago, water companies sold water at a flat rate without metering. As water has become more valuable and metering technology has improved, more and more water systems in the U.S. meter their customers. Although all customers may be metered in a given utility, a fairly sizable portion of the water most utilities produce does not pass through customer meters. Unmetered water includes unauthorized uses, including losses from accounting errors, malfunctioning distribution system controls, thefts, inaccurate meters, or leaks. Some unauthorized uses may be identifiable. When they are not, these unauthorized uses constitute unaccounted-for water. Some unmetered water is taken for authorized purposes, such as fire fighting and flushing and blowoffs for water-quality reasons. These quantities are usually fairly small. The primary cause of excessive unaccounted-for water is often leaks.

There are different types of leaks, including service line leaks, and valve leaks, but in most cases, the largest portion of unaccounted-for water is lost through leaks in the mains. There are many possible causes of leaks, and often a combination of factors leads to their occurrence. The material, composition, age, and joining methods of the distribution system components can influence leak occurrence. Another related factor is the quality of the initial installation of distribution system components. Water conditions are also a factor, including temperature, aggressiveness, and pressure. External conditions, such as stray electric current; contact with other structures; and stress from traffic vibrations, frost loads, and freezing soil around a pipe can also contribute to leaks. All water plants will benefit from a water accounting system that helps track water throughout the distribution system and identifies areas that may need attention, particularly large volumes of unaccounted-for water.

Leak Detection and Repair Strategy

There are various methods for detecting water distribution system leaks. These methods usually involve using sonic leak-detection equipment, which identifies the sound of water escaping a pipe. These devices can include pinpoint listening devices that make contact with valves and hydrants, and geophones that listen directly on the ground. In addition, correlator devices can listen at two points simultaneously to pinpoint the exact location of a leak. (See the drawing on page 3.)

Large leaks do not necessarily contribute to a greater volume of lost water, particularly if water reaches the surface; they are usually found quickly, isolated, and repaired. Undetected leaks, even small ones, can lead to large quantities of lost water since these leaks might exist for long periods of time. Ironically, small leaks are easier to detect because they are noisier and easier to hear using hydrophones. The most difficult leaks to detect and repair are usually those under stream crossings.

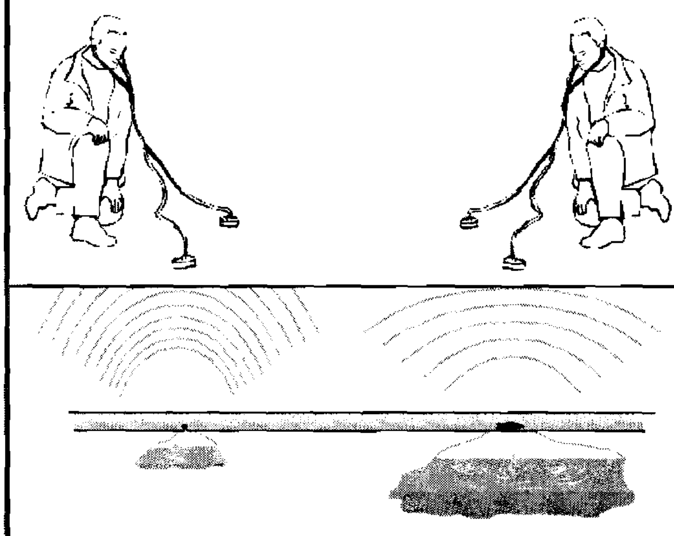
Leak detection efforts should focus on the portion of the distribution

Calculating Unaccounted-for Water

Unaccounted-for water is the difference between water produced (metered at the treatment facility) and metered use (i.e., sales plus non-revenue producing metered water). Unaccounted-for water can be expressed in millions of gallons per day (mgd) but is usually discussed as a percentage of water production:

Unaccounted-for water (%) = $\frac{\text{(Production - metered use)} \times 100\%}{\text{(Production)}}$

Listening for Leaks



An important goal of leak detection is to find exactly where a leak is located. Typically, the louder the noise, the closer you are to the leak. Small leaks under high pressure usualy make more noise than larger leaks under low pressure. In fact, many large leaks make almost no sound whatsoever.

system with the greatest expected problems, including:

- areas with a history of excessive leak and break rates;
- areas where leaks and breaks can result in the heaviest property damage;
- areas where system pressure is high;
- areas exposed to stray electric current and traffic vibration;
- areas near stream crossings; and
- areas where loads on pipe exceed design loads.

Of course, detecting leaks is only the first step in eliminating leakage. Leak repair is the more costly step in the process. Repair clamps, or collars, are the preferred method for repairing small leaks, whereas larger leaks may require replacing one or more sections of pipe.

On average, the savings in water no longer lost to leakage outweigh the cost of leak detection and repair. In most systems, assuming detection is followed by repair, it is economical to completely survey the system every one to three years.

Instead of repairing leaking mains, some argue it is preferable to replace more leak-prone (generally older) pipes. Selecting a strategy depends upon the frequency of leaks in a given pipe and the relative costs to replace and repair them.

Deciding whether to emphasize detection and repair over replacement depends upon site-specific leakage rates and costs. In general, detection and repair result in an immediate reduction in lost water, whereas replacement will have a longer-lasting impact to the extent that it eliminates the root cause of leaks.

The most important factor in a leak detection and repair program is the need for accurate, detailed records that are consistent over time and easy to analyze. Records concerning water production and sales, and leak and break costs and benefits, will become increasingly important as water costs and leak and break damage costs increase and as leak detection and rehabilitation programs become more important. In order to optimize these programs by allocating funds in such a way that results in the greatest net benefits, adequate information is needed on which to base decisions and determine needs. Three sets of records should be kept: (1) monthly reports on unaccounted-for water comparing cumulative sales and production (for the last 12 months, to adjust discrepancies caused by the billing cycle); (2) leak-repair report forms; and (3) updated maps of the distribution system showing the location, type, and class of each leak.

Coordinating Leak Detection and Repair with Other Activities

In addition to assisting with decisions about rehabilitation and replacement, the leak detection and repair program can further other water utility activities, including:

- inspecting hydrants and valves in a distribution system;
- updating distribution system maps;
- using remote sensor and telemetry technologies for ongoing monitoring and analysis of source, transmission, and distribution facilities. Remote sensors and monitoring software can alert operators to leaks, fluctuations in pressure, problems with equipment integrity, and other concerns; and
- inspecting pipes, cleaning, lining, and other maintenance efforts to improve the distribution system and prevent leaks and ruptures from occurring. Utilities might also consider methods for minimizing water used in routine water system maintenance.

Beyond Leak Detection and Repair

Detecting and repairing leaks is only one water conservation alternative; others include: meter testing and repair/replacement, rehabilitation and replacement programs, installing flow-reducing devices, corrosion control, water pricing policies that encourage conservation, public education programs, pressure reduction, requests for voluntary cutbacks or bans on certain water uses, and water recycling.

Where can I find more information?

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For further information, comments about this fact sheet, or to suggest topics, contact Lahlou via e-mail at lahloum@hotmail.com.

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Tech Brief: Organics Removal, item #DWBLPE59;
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Tech Brief: Radionuclides, item #DWBLPE84.
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Tech Brief: Ultraviolet Disinfection, item #DWBLPE101.
Tech Brief: Leak Detection and Water Loss Control, item #DWBLPE102.

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Fact Sheet

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Water Conservation Measures

Summary

Water is a finite resource, and in many areas, future water supplies are uncertain. Individuals are usually aware when there is a drought, however, because water is inexpensive, there are often few incentives to reduce water loss. Water has no viable substitutes, and its depletion bodes profound economic and social impacts. Citizens and utilities need to consider water conservation programs.

This fact sheet considers the role of water conservation as an integral part of long-term resource planning. It might be more appropriate to use the term "water demand management." Traditional water supply management seeks to provide all the water the public wants, which, in some sections of the country, translates to a constant search for untapped sources.

What methods conserve water?

The water demand management methods described in this fact sheet incorporate the methods the August 1998 U.S. Environmental Protection Agency (EPA) *Water Conservation Plan Guidelines* recommend for water systems serving 10,000 or fewer people. EPA's Basic guidelines suggest (1) metering, (2) water accounting and loss control, (3) pricing and costing, and (4) education or information.

EPA's Guidelines are not regulations, but recommendations that suggest 11 different conservation methods. How appropriate and desirable any given method is must, in the end, be accepted by the individual community and utility. Pricing may be the primary way to encourage conservation, however, utilities should not automatically rely on any single method.

Meter All Water

Metering is a most important part of water demand management. In fact, unless a utility is 100 percent metered, it is difficult to enforce any conservation program. According to a U.S. Housing and Urban Development document, metered customers use an average of 13–45 percent less water than unmetered customers because they know they must pay for any misuse or negligence. A U.S. General Accounting Office report states that metering also assists in managing the overall water system, since it can help to:

- locate leaks in a utility's distribution system by identifying unaccounted-for blocks of water,
- identify high use customers, who can be given literature on opportunities for conserving, and
- identify areas where use is increasing, which is helpful in planning additions to the distribution system.

Once water meters are installed, equipment begins to deteriorate. Eventually meters will fail to measure flows accurately. The question of how long to leave a meter in service has long troubled the waterworks industry. According to a *Journal of the American Water Works Association* (AWWA) article by Tao and a Community Consultants report, average losses of accuracy, for periods greater than 10 years, range from 0.03–0.9 percent per year. To be fair to both customers and the utility, meters must be maintained at regular intervals.

Account for Water, Repair Leaks

The EPA Guidelines recommend that all water systems—even smaller systems—implement a basic system of water accounting. The cost of water leakage can be measured in terms of the operating costs associated with water supply, treatment, and delivery. Water lost produces no revenues for the utility. Repairing larger leaks can be costly, but it also can produce substantial savings in water and expenditures over the long run.

Water accounting is less accurate and useful when a system lacks source and connection metering. Although the system should plan to meter sources, unmetered source water can be estimated by multiplying the pumping rate by the time of operation based on electric meter readings.

A utility may want to consider charging for water previously given away for public use or stepping up efforts to reduce illegal connections and other forms of theft.

Drinking water systems worldwide have begun to implement programs to address the problem of water loss. Utilities can no longer tolerate inefficiencies in water distribution systems and the resulting loss of revenue associated with underground leakage, water theft, and under registration. As pumping, treatment, and operational costs increase, these losses become more and more expensive.

If a utility does what it can to conserve water, customers will tend to be more cooperative in other water conservation programs, many of which require individual efforts. In *Economics of Leak Detection*, Moyer states that of the many options available for conserving water, leak detection is a logical first step. A highly visible leak detection program that identifies and locates water system leakage encourages people to think about water conservation before they are asked to take action to reduce their own water use. When leaks are repaired, water savings result in reduced power costs to deliver water, reduced chemicals to treat water, and reduced costs of wholesale supplies.

According to Le Moigne's technical paper *Using Water Efficiently: Technologies Options*, old and poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves and mechanical damage are major factors contributing to leaks. In addition to loss of water, water leaks reduce pressure in the supply system. Raising pressure to compensate for such losses increases energy consumption and can make leaking worse, as well as causing adverse environmental impacts.

A World Bank technical paper by Okun and Ernst shows that, in general, it is normal to be unable to account for 10–20 percent of water. However a loss of more than 20 percent should raise a red flag. It should be noted that percentages are great for guidelines, but volume of water lost is probably more meaningful. According to AWWA's *Leak Detection and Water Loss Reduction*, once a utility knows the volume of water lost, it can determine revenue losses and decide the best way to correct the problem.

EPA's Guidelines recommend that each system institute a comprehensive leak detection and repair strategy. This strategy may include regular onsite testing using computer-assisted leak detection equipment, a sonic leak-detection survey, or another acceptable method for detecting leaks along water distribution mains, valves, services, and meters. Divers can inspect and clean storage tank interiors.

Increasingly, water systems are using remote sensor and telemetry technologies for ongoing monitoring and analysis of source, transmission, and distribution facilities. Remote sensors and monitoring software can alert operators to leaks, fluctuations in pressure, problems with equipment integrity, and other concerns.

Each system should institute a loss-prevention program, which may include pipe inspection, cleaning, lining, and other maintenance efforts to improve the distribution system and prevent leaks and ruptures. Whenever possible, utilities might also consider methods for minimizing water used in routine water system maintenance procedures.

Costing and Pricing

In a Journal of the *American Water Works Association* article "Long-Term Options for Municipal Water Conservation," Grisham and Fleming stress that water rates should reflect the real cost of water. Most water rates are based only on a portion of what it costs to obtain, develop, transport, treat, and deliver water to the consumer. Experts recommend that rates include not only current costs but those necessary for future water supply development. Only when rates include all costs can water users understand the real cost of water service and consequently, the need to conserve.

When utilities raise water rates, among other factors, they need to consider what members of the community can afford. According to Schiffler, the ability to pay for water depends on a number of variables, including its intended use. In households, the assumption is that if the share of water costs does not exceed 5 percent of total household revenue it can be considered as socially acceptable. This rule of thumb has no specific foundation, but is widely used.

Many utility managers argue, correctly, that an effective water conservation program will necessitate rate increases. In *Water Conservation*, Maddaus states that a reduction in water use by customers in response to a water conservation program can decrease a water utility's revenues, and the utility may need to re-examine the water rate structure needs and possibly raise rates to compensate for this effect.

Water charges have typically been looked at as a way of financing the operation and maintenance (O&M) costs of a water agency, rather than as a demand management measure to encourage water-use efficiency. As a World Bank document states, political objections and constraints to increasing water charges are often seen as insurmountable. However, low water charges encourage consumption and waste and can put pressure on O&M budgets, leading to poor water treatment and deterioration in water quality.

In *Water Strategies for the Next Century*, Rogers et al. advocate a positive price for water that is less than the cost of desalination, but not zero. Desalination presently costs about $2 a cubic meter. The ideal is to charge a reasonable amount that sends the message to the users.

EPA suggests that systems consider whether their current rate structures promote water usage over conservation. Nonpromotional rates should be implemented whenever possible.

Systems that want to encourage conservation through their rates should consider various issues, such as the allocation between fixed and variable charges, usage blocks and breakpoints, minimum bills and whether water is provided in the minimum bill, seasonal pricing options, and pricing by customer class.

Numerous sources recommend tying sewer prices to water prices. Billing for wastewater is not included in this analysis; however, it is expected to become a more significant motivation for reducing water use over the next 15 years.

Information and Education

According to Maddaus, water conservation initiatives are more likely to succeed if they are socially acceptable. Measuring social acceptability, an exercise in anticipating public response to a potential water conservation measure, may be measured with a two-part survey technique. First, conduct interviews with community leaders to assess the political and social atmosphere. Second, assess the response to selected specific measures via a questionnaire mailed to a random sample of water customers.

The public tends to accept lawn watering restrictions, education, home water-saver kits, low-flush toilet rebates, and a low-flow fixtures ordinance for new construction. Overall acceptance of conservation is strongly related to attitudes about the importance of water conservation, as well as to age, income, and type of residence.

Howe and Dixon note that, "Public participation is now widely understood to be a necessary input for both efficiency and equity." Public participation should be part of any long-term public education program, as well as an element of plan development. A plan responsive to public needs usually receives continuing support.

The EPA Guidelines state that water systems should be prepared to provide information pamphlets to customers on request. Consumers are often willing to participate in sound water management practices if provided with accurate information. An information and education program should explain to water users all of the costs involved in supplying drinking water and demonstrate how water conservation practices will provide water users with long term savings.

An informative water bill goes beyond the basic information used to calculate the bill based on usage and rates. Comparisons to previous bills and tips on water conservation can help consumers make informed choices about water use. Systems can include inserts in their customers' water bills that provide information on water use and costs or tips for home water conservation.

School programs can be a great way to get information out. Systems can provide information on water conservation and encourage the use of water conservation practices through a variety of school programs. Contacts through schools can help socialize young people about the value of water and conservation techniques, as well as help systems communicate with parents.

Workshops and seminars can be used to solicit input, and water equipment manufacturers can be invited to these sessions to exhibit their equipment. Maddaus suggests that a number of groups may have a role in water conservation planning:

- Elected officials from all jurisdictions immediately affected by the process;
- Staff persons from private water companies, key personnel from local government agencies, and state agency people;
- Representatives of major local economic interest groups—major industries, chambers of commerce, builders' associations, farm bureaus, boards of realtors, and landscape contractors;
- Representatives of major community forces, such as federated civic associations, neighborhood associations, school boards, local unions, churches, and local press and media owners;
- Representatives of local government interest groups;
- Local professionals, such as economists and engineers; and
- Representatives of major water users, for example, food processing plants and homeowners' associations.

Where can I find information?

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