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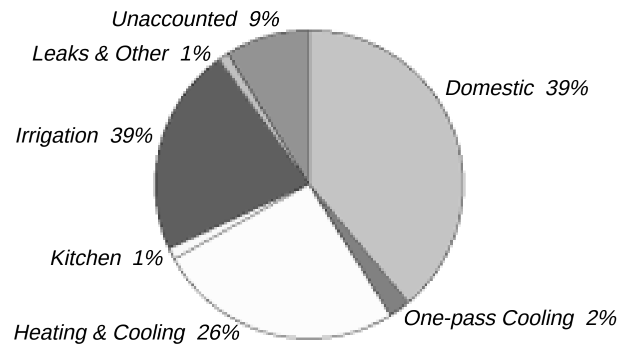
6.1 Water Management

The goal of effective water management is to reduce water consumption without compromising the performance of equipment and fixtures. Using water more efficiently is a green strategy for several reasons: it reduces pressure on sometimes-limited water resources, reduces the amount of energy and chemicals used for water and wastewater treatment, and, to the extent that the use of *hot* water is reduced, increases energy savings—with associated environmental benefits. In addition to these benefits, water conservation in Federal facilities saves tax dollars. Facility managers should conduct comprehensive audits of water use in all buildings and landscapes under their supervision. Not only is this an excellent idea, it is mandated by Executive Order 12902, "Energy Efficiency and Water Conservation at Federal Facilities." The water audit should be accompanied by an examination of available water management techniques and be followed by implementation and monitoring of appropriate measures.

Water Use in Commercial Buildings



Opportunities

Water management techniques can and should be implemented in all Federal facilities. These techniques include (1) reducing losses by repairing leaky faucets and pipes; (2) reducing the overall amount of water consumed (replacing toilets with low-flush models, for example); (3) finding more sustainable sources of fresh water (rainwater harvesting, for example); (4) managing water more responsibly after use (using graywater for irrigation, for example, and more responsible wastewater treatment); (5) where appropriate, enforcing conservation-based water pricing; and (6) forming partnerships with local utilities. Water management also involves emergency planning for droughts and implementation of those plans when conditions require. Most water management strategies can be implemented at any time, although a few—such as installation of an alternative wastewater treatment system—are far more easily done during major building renovations or as part of new construction. An important integration opportunity is to reduce hot water use, which both reduces overall water consumption and saves energy.

Technical Information

Water use in the United States has more than doubled in the past half-century—from about 180 billion gallons (680 billion liters) a day in 1950 to more than 400 billion gallons (1.5 trillion liters) a day in 1995. Federal agencies collectively spend more than $500 million annually on water and sewer costs.

Replacing old plumbing fixtures can save huge quantities of water. The standards established for water consumption by the Energy Policy Act restrict showerheads to 2.5 gallons (9.5 liters) per minute, urinals to 1 gallon (3.8 liters) per flush, faucets to 2.2 gallons (8.3 liters) per minute at 60 psi (410 kPa), and toilets to 1.6 gallons (6 liters) per flush at 80 psi (550 kPa).

Water management measures that are cost-effective—that is, with a payback of 10 years or less—can be implemented immediately. Note that the true cost of water must include costs to heat, cool, and pump it; costs of treatment before use (such as softening or filtration); and costs to treat or dispose of wastewater. Dollar savings from reduced water and energy use as a result of water conservation projects can be substantial.

A successful water management program begins with the development of a comprehensive plan that includes a thorough analysis of water use throughout a facility (see "Eight Steps to a Successful Water Management Plan") and a review of the relationship between the facility and water supplier (typically, a municipal utility company).

In 1992 the Nuclear Regulatory Commission's Phillips Building saved 1.4 million gallons (6.4 million liters) of water compared with usage for the previous year. This was achieved by replacing many plumbing fixtures that were more than 30 years old and retrofitting other fixtures to improve efficiency—sometimes at very low cost. One hundred faucets were retrofitted with new seats and washers, for example, at a cost of about $1,000. Monthly inspections ensure the continuation of this very successful program. How did it get started? It began with a water management plan similar to the one outlined on the next page.

EIGHT STEPS TO A SUCCESSFUL WATER MANAGEMENT PLAN

1. **Gather information.** Start with the facility floor plan, operating schedules, number of employees and visitors, and maintenance/janitorial schedules. List all fixtures and the manufacturers' data on rated flow rates. Determine outdoor water applications, quantity, and schedule. Obtain utility name and water/sewer bills for at least the past two years. Check meter calibration results to adjust quantities, if necessary.

2. **Conduct a comprehensive facility survey.** A basic water audit can be completed by qualified staff using published tools and fixture-use assumptions; a more complete audit may require assistance from water efficiency professionals.

3. **Explore and evaluate water management options.** With a water audit in hand, determine whether fixture replacement and changes in maintenance procedures are needed. Just a single constantly running toilet, for example, can waste 6,000 gallons (23,000 liters) per day!

4. **Conduct life-cycle cost analyses and explore financing options.** Total water cost must include water purchased from utilities, pumping energy, pretreating, water heating and cooling, chemical treatments (e.g., cooling towers), and sewer costs. Use the NIST BLCC program to compare alternative plans. Where appropriate, consider the GSA Federal Buildings Fund if there are energy savings involved. Check into utility programs or ESPCs with private firms. Review the water utility's rate structure and determine whether it encourages conservation.

5. **Develop a water management plan and work schedule.** Set priorities for the changes to be made based on current water use, occupant needs, and life-cycle cost analysis. Determine the schedule of implementation and associated funding.

6. **Inform building occupants about water management.** Send a letter to everyone telling them about the plan. Post signs near equipment to make occupants aware of water savings initiatives. Set up a "hotline" to report leaks or other wastes of water. Start a water information section in an in-house newsletter detailing water savings.

7. **Implement the water management plan.** Check with contractors to ensure that work is going as planned. Check bills to verify consumption reductions as the program evolves. Immediately address problems that arise for users.

8. **Monitor the water management plan.** Carefully check to ensure that savings are occurring. Make regular contact with the operating and maintenance staff to insure their active participation.

The following sections of this guide address more specific aspects of water conservation, as well as innovative water source and wastewater treatment options.

More than 300 Waterless urinals like this, made by the Waterless Company of Del Mar, California, were installed at the Jet Propulsion Laboratory in Barstow, California. The urinals have reduced annual water consumption by 13 million gallons (49 million liters), saving $52,000 per year in water and sewer costs. A lightweight biodegradable oil in the sophisticated EcoTrap® allows urine to pass through while serving as a trap to block odors from entering the restroom. The oil is replenished on a regular maintenance schedule based on usage.

Source: The Waterless Co.

References

Water Management: A Comprehensive Approach for Facility Managers, General Services Administration, Washington, DC, 1995.

Water Audits and Leak Detection, American Water Works Association, Denver, CO, 1997; (703) 684-2492.

Facility Manager's Guide to Water Management and *Water Efficiency Manual for Commercial, Industrial, and Institutional Facilities*. Though regional (Arizona and North Carolina, respectively), both reports are useful and can be downloaded as pdf files from the WaterWiser Web site (www.waterwiser.org).

Contacts

Water management training courses are offered by FEMP. *WATERGY, A Water and Energy Conservation Model for Federal Facilities* is also available to aid in water conservation audits. Call the FEMP Help Desk, (800) DOE-EREC (363-3732), and see the FEMP Web site, www.eren.doe.gov/femp/.

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6.2 Toilets and Urinals

There are three common varieties of toilets: gravity flow, (siphon-jet) flush valve, and pressurized tank systems. Similarly, there are four common varieties of urinals: the siphonic jet urinal, washout/wash-down urinals, blowout urinals, and waterless urinals. All of these must meet Federal water efficiency standards, though waterless urinals go far beyond the conservation minimums. Composting toilets also use no water, but potential applications are generally limited to national park facilities and small highway rest stops.

Opportunities

The vast majority of toilets and urinals in Federal facilities were installed at a time when there was little or no regard for using water efficiently. Consequently, there are ample opportunities to make significant savings in water usage. Complete replacement is the desired option. Retrofit of existing toilets and urinals is a second choice that may be more attractive if there are budget constraints. While retrofits reduce the amount of water used per flush, most fixtures were not designed to use reduced amounts of water and their performance may suffer. Only complete replacement of porcelain fixtures ensures that, even with less water, they can still perform efficiently and effectively.

Technical Information

Toilets account for almost half of a typical building's water consumption. Americans flush about 4.8 billion gallons (18.2 billion liters) of water down toilets each day, according to the U.S. Environmental Protection Agency. According to the Plumbing Foundation, replacing all existing toilets with 1.6 gallons (6 liters) per flush, ultra-low-flow (ULF) models would save almost 5,500 gallons (25,000 liters) of water per person each year. A widespread toilet replacement program in New York City apartment buildings found an average 29% reduction in total water use for the buildings studied. The entire program, in which 1.3 million toilets were replaced, is estimated to be saving 60–80 million gallons (230–300 million liters) per day.

There is a common perception that ULF toilets do not perform adequately. A number of early 1.6-gallons-per-flush (gpf) (6-liter) gravity-flush toilets that were simply adapted from 3.5-gpf (16-liter) models—rather than being designed from the ground up to operate effectively with the ULF volume—performed very poorly, and some low-cost toilets today still suffer from that problem. But studies show that most 1.6-gpf (6-liter) toilets work very well. Where flush performance is a particular concern, or water conservation beyond that of a 1.6-gpf (6-liter) model is required, pressurized-tank toilets, vacuum toilets, and dual-flush toilets should be considered. Carefully choose toilet models based on recommendations from industry surveys or experienced plumbers and facility managers. You may also want to contact some managers of facilities that have already installed the toilets under consideration.

While some retrofit options for toilets reduce water use (see next page), none of these modifications will perform as effectively or use as little water as quality toilets manufactured after January 1, 1994. These retrofits will merely allow the fixture to operate using less water until it is replaced.

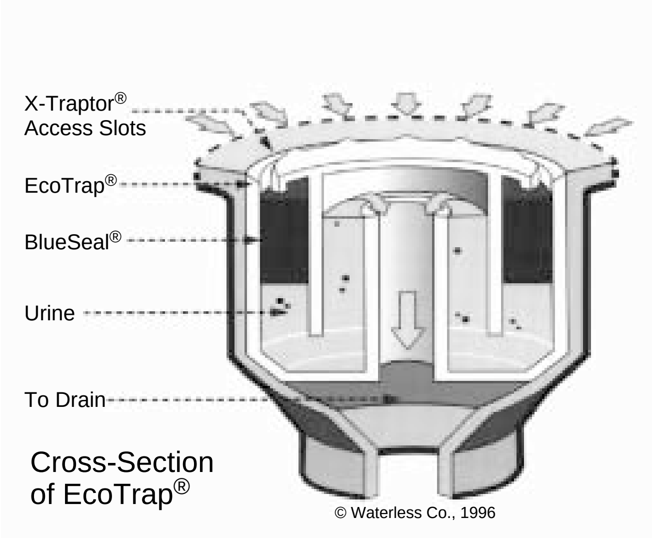
Even greater water conservation can be achieved in certain (limited) applications with composting toilets. Because of the size of composting tanks, lack of knowledge about performance, local regulatory restrictions, and higher first-costs, composting toilets are rarely an option except in certain unique applications, such as national park facilities. Composting toilets are being used very successfully, for example, at Grand Canyon National Park.

With urinals, water conservation well beyond the standard 1.0-gpf (4.5-liter) performance for new products can be obtained using waterless urinals. These products, available from The Waterless Company, use a special trap with a lightweight biodegradable oil that lets urine and water pass through but prevents odors from escaping into the restroom; there are no valves to fail, and clogging does not cause flooding. Three Waterless

PROJECTED WATER SAVINGS FROM INSTALLING WATERLESS URINALS

Building Type	No. Males	No. Urinals	Uses/ Day	Gal/ Flush	Days/ Year	Ann. Water Savings/Urinal Gallons	Liters
Small Office	25	1	3	3.0	260	58,500	220,000
New const.	25	1	3	1.0	260	19,500	73,800
Restaurant	150	3	1	3.0	360	54,000	204,000
New const.	150	3	1	1.0	360	18,000	68,100
School	300	10	2	3.0	185	33,300	126,000
New const.	300	10	2	1.0	185	11,100	42,000

Source: *Environmental Building News*, February 1998.



The low-specific-gravity BlueSeal® fluid in this Waterless Urinal allows urine to pass through while serving as a trap to block odors from entering the restroom.

urinals at the Bureau of Recreation's Glen Canyon Visitor Center are saving an estimated 225,000 gallons (850,000 liters) of water per year, according to *Environmental Building News* (February 1998). Furthermore, installing those urinals enabled the Bureau to avoid spending $600,000 to expand its on-site sewage treatment capacity. Projected water savings from waterless urinals in different types of facilities are shown in the table on page 136—both for retrofits and new construction.

TOILET AND URINAL RETROFITS

Adjust the flush valve to reduce the water used per flush without impeding waste removal or violating the manufacturer's requirements.

Regularly check for leaks and periodically replace valves and ballcocks. Use toilet cleaners that are not highly corrosive to flapper valves.

Check water pressure to ensure that the pressure is proper for optimal toilet or urinal operation.

Early closure devices can save 1 to 2 gallons (4.5 to 9 liters) per flush. These devices cause the same force to be exerted with each flush but with half the water.

Dual-flush adapters can be used with some toilets; these allow two types of flushes, saving up to 1.2 gallons (5.5 liters) per flush. One flush is standard and removes solids; the second is smaller and removes paper and liquids.

Toilet refill diverters are extremely low-cost devices that balance the flow of refill water in gravity-flush toilets. With most toilets, the bowl fills a lot faster than the tank, and excess water in the bowl simply flows down the drain—this occurs even in 1.6-gpf (6-liter) toilets. Products made by the Fuller Group of Marietta, Georgia, and Niagara Conservation Corp. of Cedar Knolls, New Jersey, divert most of the bowl-refill water into the tank, typically saving 1/2 to 1 gallon (2 to 4 liters) per flush on an older toilet and about 1/4 gallon (1 liter) on a new toilet. *Environmental Building News* (March 1999) reported that the Marriott Corporation has installed the Fuller AquaSaver product on 280,000 of their 480,000 toilets and is saving $3.4 million per year in water bills.

For siphonic jet urinals, retrofit with infrared sensors to eliminate double flushing, or replace. Choose 0.5-gpf (1.9-liter) models instead of 1.0-gpf (3.8-liter) models for greater savings.

Blowout urinals, which discharge at intervals as the water tank reaches a given level, can be modified (with sensors) to function only when the building is occupied.

☐ Displacement devices, such as bags or bottles, and toilet dams are not recommended for 5-gpf (23-liter) or 3.5-gpf (16-liter) toilets because they can compromise flushing performance, resulting in double-flushing or increased need for cleaning. Early-closure flappers work better but must be properly calibrated.

The Prince Kuhio Federal Building and Post Office in Honolulu is a 10-story building housing 1,400 employees. A complete toilet and urinal replacement program is saving 8.8 million gallons (40 million liters) of water there annually. With the total cost of replacement estimated to be about $235,000, annual savings in sewer and water bills are about $31,000.

References

"Water Saving Restroom Fixtures," Federal Energy Management Program, U.S. Department of Energy, 1995. This publication and the *WATERGY* software, which quickly screens facility water consumption, are available by calling the FEMP Help Desk, (800) DOE-EREC (363-3732); also see the FEMP Web site, www.eren.doe.gov/femp/.

The WaterWiser Web site includes hundreds of useful links on water conservation practices and products: www.waterwiser.org.

Wilson, Alex, "Big Savings from Waterless Urinal," *Environmental Building News*, Vol. 7, No. 2, February 1998; BuildingGreen, Inc., Brattleboro, VT; (800) 861-0954; www.BuildingGreen.com.

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6.3 Showers, Faucets, and Drinking Fountains

According to the water efficiency plumbing standards of the Energy Policy Act of 1992, new showerheads and faucets must have a maximum flow rate of 2.5 gallons per minute (gpm) at 80 psi (9.5 liters per minute at 550 kPa). Many new products are available (at widely varying prices) to achieve this reduced flow rate. Although drinking fountains are not regulated by the government, they should be included in water management programs.

Opportunities

It is becoming common for showers to be installed in office buildings, reflecting the trend toward healthier life-styles, commuting by bicycle or foot, and exercise programs. Military and national park housing, of course, contains large numbers of showers and faucets. There are many shower and faucet retrofits for achieving (or exceeding) the water conservation standards that provide rapid payback. The fact that water-efficient showerheads and faucets also save energy (by reducing hot water use) makes them attractive *energy* retrofit options as well.

Technical Information

Equipment selection and water conservation retrofit options for showers, faucets, and drinking fountains are as follows:

SHOWERS

A conventional showerhead is rated to use 3 to 7 gallons (11 to 27 liters) per minute at normal water pressure, about 80 psi (550 kPa). A 5-minute shower with a conventional showerhead typically consumes 15 to 35 gallons (60 to 130 liters) of water.

High-quality replacement showerheads that deliver 1.0 to 2.5 gallons (3.8 to 9.5 liters) per minute can save many gallons per shower when used to replace conventional showerheads. Products vary in price from $3 to $95—and many good models are available for $10 to $20. A variety of spray patterns are available, ranging from misty to pounding and massaging. They typically have narrower spray jets and a greater mix of air and water than conventional showerheads, enabling them to provide what feels like a full-volume shower while using far less water. Facility managers should consult *Consumer Reports* or other objective comparisons of different models before making large purchases.

Flow regulators on the shower controls and temporary cutoff buttons or levers incorporated into the showerhead reduce or stop water flow when the individual is soaping or shampooing, further lowering water use. When the water flow is reactivated, it emerges at the same temperature, eliminating the need to remix the hot and cold water.

Flow restrictors are washer-like disks that fit inside showerheads, and they are tempting retrofits. However, flow restrictors provide poor water pressure in most showerheads. Flow-restrictor disks were given away by many water conservation programs, leading to poor acceptance of water conservation in general. Permanent water savings are better provided through the installation of well-engineered showerheads.

$ The actual amount of water savings from showerhead retrofits is difficult to establish because savings tests are often performed at full flow, while users often do not operate showers at maximum flow. There is also a high variability in shower length.

FAUCETS

Federal facilities deal with three kinds of faucets: bathroom (residential or institutional), kitchen (residential or institutional), and industrial/workroom. Flow rates and operation of these three types of faucets differ. Bathrooms need no more than 1.5 gallons (5.7 liters) per minute, for example, while residential kitchens rarely need less than 2.5 gallons (9.5 liters) per minute. Institutional bathroom faucets may include automated controls and premixed temperatures. Institutional kitchen faucets may include special features such as swivel-heads and foot-activated on/off controls.

Older faucets with flow rates of 3 to 5 gallons (11 to 19 liters) per minute waste tremendous quantities of water. Federal guidelines mandate that all lavatory and kitchen faucets and replacement faucet tips (including aerators) manufactured after January 1, 1994, consume no more than 2.5 gallons (9.5 liters) per minute at 80 psi (550 kPa). Metered-valve faucets are restricted to a 0.25-gallon (0.95 liters) per cycle discharge after this date.

Variations in water pressure are problematic for water management programs. Pressure-compensating

Photo: Pedal Valves, Inc.

By making it easy to run water only when it is actually being used, foot-pedal controllers save a surprising amount of water and energy.

faucets can be used to automatically maintain 2.5 gallons (9.5 liters) per minute at varying water pressures.

With manual-valve faucets, replacing the screw-in tip of the faucet is all that is usually necessary to reduce water use. While faucet aerators that mix air into the water stream are commonly used in residential faucets, they are specifically prohibited in health facilities because they can harbor germs and pathogens. Use nonaerating, low-flow faucet tips (including those providing a smooth, laminar stream of water). These devices are inexpensive. Choose 2.2- to 2.5- gpm (8.3- to 9.5-liter) devices for kitchens. In washrooms, 0.5- to 1.25-gpm (1.9- to 4.7-liter) models will often prove adequate for personal washing purposes.

Metered-valve faucets deliver a preset amount of water and then shut off. For water management purposes, the preset amount of water can be reduced by adjusting the flow valve. The Americans with Disabilities Act requires a 10-second minimum on-cycle time.

Foot controls for kitchen faucets provide both water savings and hands-free convenience. The hot-water mix is set and the foot value turns the water on and off at the set temperature.

Hot-water recirculation systems reduce water wasted while users wait for water to warm up as it flows from the faucet. To prevent these water-saving systems from wasting large amounts of energy, hot-water pipes should be well-insulated.

Electronic faucet controls are discussed in *Section 6.4 – Electronic Controls for Plumbing Fixtures*. To maximize water savings, choose the lowest-water-use models—typically 0.5 gpm (1.9 liters per minute).

☑ Repair leaky faucets: Institute a regular maintenance program to ensure that leaky faucets are regularly inspected and immediately repaired. A single leaky faucet (one drip per second) will waste 8.6 gallons (33 liters) of water per day. The thinnest stream of water running continuously will waste 43 gallons (160 liters) per day.

DRINKING FOUNTAINS

Self-contained drinking fountains have an internal refrigeration system. Adjusting the exit water temperature to 70°F (21°C) versus the typical 65°F (18°C) will result in substantial energy savings. Insulate the piping, chiller, and storage tank to save energy. If appropriate, add an automatic timer to shut off the unit during evenings and weekends.

Remote chillers or central systems are used in some facilities to supply cold drinking water to multiple locations. To conserve energy, the temperature can be raised from 65°F to 70°F (18°C to 21°C); piping should be well insulated, and a timer can be used to turn off the unit when the building is unoccupied.

Metering faucets are priced at $100 to $150. Sensor-operated metering faucets cost between $260 and $310. Sensor faucets require either electrical wiring for the connection of AC power or regular replacement of battery power supplies.

Contacts

American Water Works Association, 6666 W. Quincy Avenue, Denver, CO 80235; (800) 559-9855, (303) 794-6303 (fax); WaterWiser Web site: www.waterwiser.org.

Water Efficiency Program, Office of Wastewater Management (4204), U.S. Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460; (202) 260-7288 or (202) 260-7259; www.epa.gov/OWM/genwave.htm.

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6.4 Electronic Controls for Plumbing Fixtures

Automated controls for faucets, toilets, and urinals help address occupants' concerns about disease transmission via contact with bathroom surfaces and fixtures—they can also reduce water consumption. These controls are rapidly gaining popularity in all types of commercial and institutional facilities, though the driver is generally hygiene rather than water or energy savings.

Opportunities

Electronic controls can be installed with new plumbing fixtures or retrofitted onto many types of existing fixtures. Potential water savings are greater with retrofits because current fixtures generally do not meet water-conservation standards unless they are upgraded as part of the retrofit. Though water savings depend greatly on the type of facility and the particular controls used, some facilities report a 70% savings. This type of on-demand system can also produce proportional savings in water heating (for faucets) and sewage treatment.

Technical Information

Electronic controls for plumbing fixtures usually function by transmitting a continuous beam of infrared (IR) light. With faucet controls, when a user interrupts this IR beam, a solenoid is activated, turning on the water flow. Dual-beam IR sensors or multispectrum sensors are generally recommended because they perform better for users with dark skin. With toilets and urinals, the flush is actuated when the user moves away and the IR beam is no longer blocked. The cost of automated-control fixtures is quite high.

Some brands of no-hands faucets are equipped with timers to defeat attempts to alter their operation or to provide a maximum on-cycle—usually 30 seconds.

Depending on the faucet, a 10-second handwash typical of an electronic unit will consume as little as 1-1/3 cups (0.3 liters) of water. A 10-second cycle is required as a minimum by the Americans with Disabilities Act. Choose the lowest-flow faucet valves available—typically 0.5 gpm (1.9 liters per minute).

Electronic controls can also be used for other purposes in restrooms. Sensor-operated hand dryers are very hygienic and save energy (compared with conventional electric hand dryers) by automatically shutting off when the user steps away. Soap dispensers can be electronically controlled. Electronic door openers can be employed to further reduce contact with bathroom surfaces. Even showers are now sometimes being controlled with electronic sensors—for example, in prisons and military barracks.

Electronic fixtures are particularly useful for handicapped installations and hospitals, greatly reducing the need to manipulate awkward fixture handles and removing the possibility of scalding caused by improper water control.

No-touch faucets are available with (1) the sensor mounted in the wall behind the sink, (2) the sensor integrated into the faucet, and (3) the sensor mounted in an existing hot- or cold-water handle hole and the faucet body in the center hole. For new installations, the first or second option is usually best; for retrofit installations, the last option may be the only one feasible.

At sports facilities where urinals experience heavy use, the entire restroom can be set up and treated as if it were a single fixture. Traffic can be detected and the urinals flushed periodically based on traffic rather than per person. This can significantly reduce water use.

Computer controls can be used to coordinate water usage to divert water for fire protection when necessary.

Thermostatic valves can be used with electronic faucets to deliver water at a preset temperature. Reducing hot water saves a significant amount of energy.

A 24-volt transformer operating off a 120-volt AC power supply is typically used, at least with new installations. The transformer should be UL-listed, and for security reasons the transformer and the solenoid valve should be remotely located in a chase.

Many commercial faucets can be retrofitted very quickly, requiring just 7 to 9 minutes per fixture, according to Sloan Valve, a supplier of electronic plumbing fixture controls.

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Electronic faucet controls offer the convenience and sanitary benefits of hands-free operation. If the system is properly set up, significant water and energy savings are achieved.

Photo: Sloan Valve

Battery-powered controls are often used for retrofit applications because connecting AC electricity to each fixture can be costly. For battery-controlled units, most manufacturers recommend standard alkaline batteries, which last two to three years with typical usage; lithium batteries require less frequent replacement (they can last up to five years), but they are more expensive. In heavy usage areas, such as airports, battery-powered controls are not recommended because of the need for frequent replacement.

For battery-powered controls, provide a plan for proper disposal of used batteries.

For hospitals or other medical facilities, electronic fixtures should be used to the maximum extent possible because they can help health care professionals meet the Occupational Safety and Health Administration (OSHA) protocols for handwashing after patient contact.

Automated faucets are much easier to clean since there are no handles in the way. The industrial-grade solenoid valves used in these devices are far more durable than their mechanical counterparts and are virtually unaffected by chemicals and other constituents of the water supply.

Some manufacturers estimate a payback period of less than 6 months when a conventional fixture is replaced with an electronic one. With faucets, this includes savings in water, energy, and maintenance. With toilets and urinals, some of the water savings may be attributable to reduced incidence of intentional multiple-flushing—a common practice with toilets and urinals.

Careful calibration is required with some electronic controls to prevent (or lessen the likelihood of) *unintentional* multiple flushes —which can happen, for example, in airport toilet stalls when they are used for changing clothes.

References

Marsch, Donald R., "Getting a Hand on No-Hands Fixtures," *The Construction Specifier,* August 1990, pp. 61–66.

American Water Works Association, 6666 W. Quincy Avenue, Denver, CO 80235; (800) 559-9855, (303) 794-6303 (fax); WaterWiser Web site: www.waterwiser.org.

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6.5 Reclaimed Water

Reclaimed or recycled water is water from a wastewater treatment plant (WWTP) that has been treated and can be used for nonpotable uses such as landscape irrigation, cooling towers, industrial process uses, toilet flushing, and fire protection. In some areas of the United States, reclaimed water may be referred to as Irrigation Quality or "IQ" water, but potential uses can extend well beyond irrigation. In fact, with higher levels of treatment, such as reverse osmosis, using reclaimed water as a *potable* source is technically and economically feasible. New technological breakthroughs in membrane filtration and combined biological and filtration treatment offer unprecedented opportunities for water recycling, especially in isolated locations and regions where the water supply is severely limited.

Per capita water use in the United States has quadrupled since the beginning of the 20th century. Americans typically consume between 60 and 200 gallons (230 to 760 liters) per capita each day. The use of reclaimed water for nonpotable purposes can greatly reduce the demand on potable water sources—this use is encouraged by diverse organizations such as FEMP, EPA, and the American Water Works Association (AWWA). Municipal wastewater reuse now amounts to about 4.8 billion gallons (18 million m^3) per day (about 1% of all freshwater withdrawals). Industrial wastewater reuse is far greater—about 865 billion gallons (3.2 billion m^3) per day.

Opportunities

Facility managers with buildings in areas of chronic water shortage should check with their local water utility and inquire whether they have a program to provide reclaimed water to the building's location. Reclaimed water programs are particularly popular in California, Florida, Arizona, Nevada, and Texas. There are a host of potential applications for reclaimed water: landscaping, golf course, or agricultural irrigation; decorative features such as fountains; cooling tower makeup; boiler feed; once-through cooling; concrete mixing; snowmaking; and fire main water. Making use of reclaimed water is easiest if planned for at the outset of building a new facility, but major renovations or changes to a facility's plumbing system provide opportunities as well. For certain uses, such as landscape irrigation, required modifications to the plumbing system might be quite modest. Note that the use of reclaimed water may be restricted by state and local regulations. If the government facility or base has its own WWTP, there may be an opportunity to modify it to provide *on-site* reclaimed water.

Technical Information

For a successful reclaimed water project, one or more of the following ingredients are required: (1) high-cost water or a need to extend the drinking water supply, (2) local public policy encouraging or mandating water conservation, (3) availability of high-quality effluent from a WWTP, and (4) recognition of environmental or other nontangible benefits of water reuse.

Technologies vary with end-uses. In general, tertiary or advanced secondary treatment is required, either of which usually includes a combination of coagulation, flocculation, sedimentation, and filtration. Virus inactivation is attained by granular carbon adsorption plus chlorination, or by reverse osmosis, ozonation, or UV exposure.

Dual water systems are beginning to appear in some parts of the country where the water supply is limited, such as southern California. Office buildings may have two water lines coming in—one for "fresh" water and the other for reclaimed water. The former is for all potable uses, the latter for nonpotable uses.

Piping and valves used in reclaimed water systems should be color-coded with purple tags or tape. This minimizes piping identification problems and cross-connection problems when installing systems. Liberal use of warning signs at all meters, valves, and fixtures is also recommended. Note that potable water mains are usually color-coded blue, while sanitary sewers are green.

Reclaimed water should be maintained at 10 psi (70 kPa) lower pressure than potable water mains to prevent backflow and siphonage in the event of accidental cross-connection. Although it is feasible to use backflow prevention devices for safety, it is imperative never to connect reclaimed and potable water piping directly. One additional precaution is to run reclaimed water

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mains at least 12 in. (30 cm) lower (in elevation) than potable water mains, and separate them from potable or sewer mains by a minimum of 10 ft (3 m) horizontally.

Reclamation can be complex when the water supplier and the wastewater utility are not the same. In addition, issues of water ownership arise when discharged wastewater is withdrawn from one use to accommodate another.

> The quality of reclaimed water must be reviewed in order to ensure that there will be no adverse effects from long-term use, such as landscape damage caused by salt buildup, specific ion toxicity, and nutrient buildup.

> In St. Petersburg, Florida, more than 5,500 acres (2,200 hectares) of greenspace are irrigated with reclaimed water. More than 7,300 customers are served with reclaimed water by the water utility, and usage averages 20 million gallons (76,000 m^3) per day. The water is supplied to commercial and residential customers via a "third" main consisting of more than 80 miles (130 km) of piping that ranges from 2 to 48 in. (5 to 122 cm) in diameter. The system also serves 289 fire hydrants and numerous building fire protection systems. The William C. Cramer Federal Building, operated by the GSA, is connected to this system. The building saved 1.4 million gallons (5,300 m^3) of fresh water in 1992. Built in 1967 and housing 900 employees, it has more than 15,000 square feet (1,400 m^2) of turf, 17 trees, and hundreds of shrubs. This successful use of reclaimed water for irrigation has prompted the GSA Field Office Manager, John F. Bennett, to plan the use of reclaimed water for cooling tower makeup water.

> Although water prices vary greatly around the country, reclaimed water costs significantly less than potable water. For example, in Jupiter, Florida, the price of potable water is now $1.70/1,000 gallons ($0.45/m^3) versus $0.26/1,000 gallons ($0.07/m^3) for reclaimed water. Similar pricing differences occur wherever reclaimed water is available.

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WateReuse Association, 915 L Street, Suite 1000, Sacramento, CA 95814; (916) 442-2746. Washington, DC office: 4748 N. 40th Street, Arlington, VA 22207; (703) 536-7533. Offers public information packet designed for use in education and public outreach.

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6.6 Graywater Collection and Use

Graywater reuse is an increasingly accepted practice to (1) provide irrigation water and some fertilizer to landscapes, (2) reduce wastewater loads to sewage systems, (3) improve the effectiveness of on-site wastewater disposal, and (4) reduce pressure on limited potable water resources in some communities, especially during drought crises. The State of California now allows graywater systems, and various municipalities and utility districts have passed specific graywater ordinances.

Opportunities

The primary motivation for installing graywater systems has been the ability to irrigate landscapes during dry seasons and times of more extreme drought. The installation of graywater systems requires modifications to existing plumbing systems and the addition of certain components. In new construction, it is relatively easy to incorporate a graywater system. Retrofitting such systems in existing buildings will be easiest when plumbing modifications are already planned. Buildings with basements or crawl spaces are far more amenable to plumbing system retrofits than those with slab-on-grade construction (where piping runs under the slab). Currently, the separation and use of graywater is not permitted in many parts of the country; be sure such a system is acceptable to local building officials before moving ahead with design and construction. Even if this is not permitted by code, it may make sense during new construction to install plumbing in such a way that a graywater system can be added later. Graywater collection and use can be especially important in buildings served by composting toilets.

Technical Information

TERMINOLOGY

Graywater is usually defined as water from showers, bathtubs, bathroom sinks, washing machines, and drinking fountains. It may also include condensation pan water from refrigeration equipment and air-conditioners, hot tub drainwater, pond and fountain drainwater, and cistern drainwater. Graywater contains a minimum amount of contamination and can be reused for certain landscape applications. Although this is still being debated by public health officials, no case of illness has ever been traced to graywater reuse. Graywater is distinguished from *blackwater*, which is usually defined as heavily soiled water from toilets and urinals. Wastewater from kitchen sinks and dishwashers is occasionally included with "graywater," but more commonly it is lumped with blackwater because it contains oil, grease, and food scraps, which can burden the treatment and disposal processes. Both graywater and blackwater contain pathogens—humans should avoid contact with either—but blackwater is considered a much higher risk medium for the transmission of waterborne diseases. Though they are not blackwater, the following water sources should not be included in graywater that is to be used for irrigation: garden and greenhouse sinks, water softener backflush, floor drains, and swimming pool water. In buildings served exclusively by composting toilets and thus producing no true blackwater, it may be necessary to include kitchen wastewater in the graywater by taking special precautions to eliminate organic matter.

Note that graywater is very different from reclaimed wastewater, which is covered in *Section 6.5*. Reclaimed, treated wastewater can be used for other applications, such as toilet flushing and above-ground irrigation, which are not permitted with untreated graywater.

GRAYWATER COLLECTION

Graywater collection involves separating graywater from all other sources of wastewater in a building—including wastewater from toilets, urinals, dishwashers,

CALIFORNIA REGULATIONS FOR GRAYWATER SETBACKS

Minimum Horizontal Distance From:	Surge Tank (feet)	Surge Tank (meters)	Irrigation Field (feet)	Irrigation Field (meters)
Buildings or structures	5	1.5	8	2.4
Property lines	5	1.5	5	1.5
Water supply wells	50	15.2	100	30.5
Streams and lakes	50	15.2	50	15.2
Seepage pits or cesspools	5	1.5	5	1.5
Disposal field and 100% expansion area	5	1.5	4	1.2
Septic tank	0	0.0	5	1.5
On-site domestic water service line	5	1.5	5	1.5
Pressure public water main	10	3.0	10	3.0
Water ditches	50	15.2	50	15.2

Note: Some variations and exceptions apply; see specific regulations.

and kitchen sinks. Graywater waste lines should run to a central location in the basement or crawl space where a surge tank can collect and hold the water until it drains or is pumped into the below-ground irrigation lines. It is very important to provide an overflow from the graywater collection system that feeds directly into the sewer line in case filters get clogged or some other problem occurs. A controllable valve should also be included so that graywater can be shunted into the sewer line when the area(s) being irrigated become too wet or other reasons preclude the use of graywater (see cautionary note on protecting plants).

Graywater should not be stored for extended periods of time before use. Decomposition of the organic material in the water by microorganisms will quickly use up available oxygen, and anaerobic bacteria will take over, producing a foul smell. Some graywater systems are designed to dose irrigation pipes with a large, sudden flow of water instead of allowing the water to trickle out as soon as it enters the surge tank. For the dosing systems, holding the water for some amount of time will be necessary, but this should be limited to no more than a few hours, if possible.

If a filter is used in the graywater system, it should be one that is easy to clean or self-cleaning. Filter maintenance is one of the biggest problems with many graywater systems.

GRAYWATER DISPOSAL

For complete protection from pathogens, graywater should flow by gravity or be pumped to a below-ground disposed field (subsurface irrigation). Perforated plastic pipe—3 in. (76 mm) minimum diameter—is called for in California's graywater regulations, though with filtering, smaller-diameter drip irrigation tubing can also be used. The California standards require that untreated graywater be disposed of at least 9 in. (about 230 mm) below the surface of the ground.

Some graywater systems discharge into planter beds—sometimes even beds located inside buildings. Some ready-made systems are available by mail order, but these should be modified for specific soil and climate conditions.

As a general rule, graywater can be used for subsurface irrigation of lawns, flowers, trees, and shrubs but should not be used for vegetable gardens. Drip irrigation systems have not yet proven to be effective for graywater discharge because of clogging or maintenance costs.

☐ Do not connect roof drains, downspouts, or patio runoff to a graywater system.

☑ For optimal breakdown of organic matter in the graywater, the discharge should be in the biologically active portion of the ground (near the surface), so do not bury irrigation pipes too deeply.

MAINTENANCE

A maintenance program for graywater systems should include (1) inspecting the system for leaks and blockages, (2) cleaning or replacing any filters bimonthly or as recommended by the manufacturer or designer, (3) periodically flushing the entire system if called for by the manufacturer or designer, and (4) regularly inspecting the ground being irrigated to make sure that not too much water is being delivered (in which case, graywater should be shunted into the sewage line).

☐ To protect plants being irrigated with graywater, it is important to control what cleaning and washing chemicals are used in the building. Avoid powdered detergents, which tend to be high in sodium and salts (liquid detergents are better); avoid boron, which can be toxic to some plants; and avoid chlorine bleach, caustic drain cleaners, petroleum distillates, and other chemicals with unknown effects on plants. In homes where cloth diapers are being rinsed or washed and in buildings where contagious illnesses are present, it is advisable to send graywater into the sewage line instead of collecting it for reuse.

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6.7 Rainwater Harvesting

Rainwater harvesting refers to the collection, storage, and use of rainwater. Most systems use the roof surface as the collection area and a large galvanized steel, fiberglass, polyethylene, or ferro-cement tank as the storage cistern. When the water is to be used just for landscape irrigation, only sediment filtration is typically required. When water is being collected and stored for potable uses, additional measures are required to purify the water and ensure its safety. Rainwater harvesting offers several important environmental benefits, including reduced pressure on limited water supplies and reduced stormwater runoff and flooding. It can also be a better-quality source of water than conventional sources. After purification, rainwater is usually very safe and of high quality. “Hardness” (mineral content) is low, and in areas with groundwater that is polluted, hazardous (from arsenic or other natural toxins), saline, or hard, properly purified rainwater may be a higher-quality and safer source of drinking water than water pumped out of the ground.

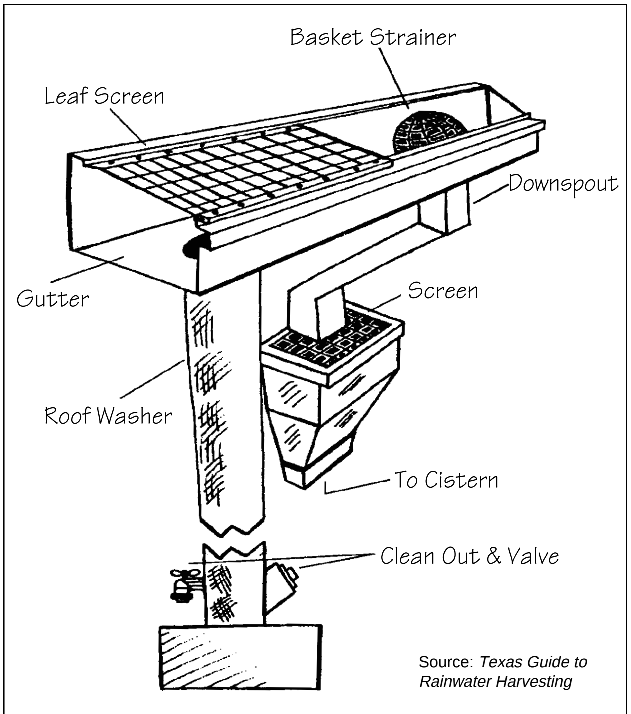
Opportunities

Consider rainwater harvesting in the following situations: (1) locations where aquifer-based water supplies are very limited or ecologically fragile (i.e., where excessive pumping of groundwater can lower the water table, threatening ecologically valuable surface waters and springs); (2) where pumped groundwater is polluted or excessively mineralized (hard) and requires extensive treatment; and (3) where stormwater runoff is a major concern. Installation of a rainwater harvesting system will be easiest if planned for in the design of a new building or considered when reroofing is planned. Though rainwater harvesting is feasible on commercial as well as residential buildings, commercial applications may be more restricted in many locations—uses may, in fact, be limited to landscape irrigation or cooling-tower use. To be viable as the sole water source for residential and small commercial applications, an average annual rainfall of at least 24 in. (600 mm) is generally required; if total annual rainfall is less than about 40 in. (1 m) per year or highly seasonal, aggressive water conservation measures will probably be required.

Technical Information

A typical rainwater harvesting system designed for potable uses has seven primary components; one of these—the roof-wash system (number 2)—may be eliminated in systems not used for potable water:

1. **Catchment area.** With most rainwater harvesting systems, the catchment area is the building’s roof. The best roof surface for rainwater harvesting does not support biological growth (algae, mold, moss, etc.), is fairly smooth so that pollutants deposited on the roof are quickly removed by the “roof-wash” system, and should have minimal overhanging tree branches above it. Galvanized metal is the roofing material most commonly used for rainwater harvesting.
2. **Roof-wash system.** This is a system for keeping dust and pollutants that have settled on the roof out of the cistern. It is *necessary* for systems used as a source of potable water but also recommended for other systems since it keeps potential contaminants out of the tank. A roof-wash system is designed to purge the initial water flowing off a roof during rainfall.
3. **Prestorage filtration.** To keep large particulates, leaves, and other debris out of the cistern, a domed, stainless-steel screen should be secured over each



This schematic shows the primary means of keeping leaves and pollutants out of a rainwater cistern. The roof washer fills with the first 10–20 gallons of rainfall. After it fills, water flows to a downspout leading to the cistern. After the rain ends, the roof washer is drained—or the valve can be left open slightly so that water trickles out, even during a rainstorm.

Rainwater catchment system at the U.S. Post Office in Volcano, Hawaii. Photo: Alex Wilson

inlet leading to the cistern. Leaf guards over gutters can be added in areas with significant windblown debris or overhanging trees.

4. **Rainwater conveyance.** This is the system of gutters, downspouts, and (generally plastic) pipes used to carry water from the roof to the cistern.
5. **Cistern.** This is usually the largest single investment required for a rainwater harvesting system. Typical materials used include galvanized steel, concrete, ferro-cement, fiberglass, polyethylene, and durable wood (e.g., redwood or cypress). Costs and expected lifetimes vary considerably among these options. Tanks may be located in a basement, buried outdoors, or located above ground outdoors. Light should be kept out to prevent algae growth. Cistern capacity should be sized to meet expected demand. Particularly for systems designed as the sole water supply, sizing should be modeled on the basis of 30-year precipitation records, with sufficient storage to meet demand during times of the year having little or no rainfall.
6. **Water delivery.** A pump is generally required to deliver water from the cistern to its point of use, though gravity-fed systems are occasionally possible with appropriate placement of system components.
7. **Water treatment system.** To protect plumbing and irrigation lines (especially with drip irrigation), water should be filtered through sediment cartridges to remove particulates, preferably down to 5 microns. For systems providing potable water, additional treatment is required to ensure a safe water supply. This can be provided with microfiltration, UV sterilization, reverse osmosis, or ozonation (or a combination of those methods). With some systems, higher levels of treatment are provided only at a single faucet where potable water is drawn. (If not all faucets in a building are delivering fully purified potable water, be sure to educate building occupants as to where water for drinking or cooking should be drawn.)

Costs of rainwater harvesting systems vary widely, from almost nothing (for a simple rain barrel beneath a downspout) to more than $75,000 (for a large commercial system). The greatest variability in cost has to do with the choice of a cistern. A typical rule of thumb is $1.00 per gallon ($264/m^3) of storage capacity for systems under 10,000 gallons, and $0.50 per gallon ($132/m^3) for larger systems.

The town of Volcano on the Island of Hawaii is an ideal location for rainwater harvesting. Being volcanic, the land is extremely porous, so pockets of groundwater (aquifers) generally do not exist or are extremely deep. But there is plenty of rainfall—more than 60 in. (1.5 m) per year. As a result, nearly all buildings in the town, including the post office (above), harvest rainwater as their primary water source.

References

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6.8 On-site Wastewater Treatment Systems

When the collection, treatment, and discharge (or reuse) of wastewater occurs on or near the site where the wastewater has been generated, it is called an "on-site" system. These systems are distinguished from a "centralized" system that has an extensive network of collection pipes feeding a central sewage treatment plant—an approach that relies on energy- and chemical-intensive treatment methods to quickly process large volumes of wastewater. On-site wastewater systems are typically designed to handle a few hundred to a few hundred thousand gallons per day. On-site technologies can range from compost privies in national forests, to high-tech membrane-filtration systems that recycle wastewater for toilet flushing in large buildings, to sophisticated yet elegant designs that use ecosystems, such as constructed wetlands, to treat wastewater. On-site treatment can reduce construction, operations, and maintenance costs while conserving resources and providing an aesthetically and ecologically attractive feature for the facility.

Opportunities

On-site wastewater treatment should be considered (1) when the Federal facility is distant from an existing treatment plant or sewer main, (2) when sewage treatment capacity is severely limited, (3) when topography necessitates expensive pumping and excavation, and (4) when the system can serve multiple functions. On-site systems are particularly suited for semi-arid and arid regions, and for locations that require riparian restoration, groundwater recharge, an increase in surface-water flow, on-site fire control storage, or irrigation of nearby landscapes (such as golf courses). When water is at a premium, treatment and reuse for toilet flushing and other purposes can be cheaper if handled on site. Many Federal facilities are part of larger communities that wish to manage sprawl, and on-site facilities are often the best option for serving a diverse matrix of greenbelts and developed areas. On-site systems can also provide safety advantages in difficult ecological conditions such as areas subject to earthquakes, slope movement, and rapid, repeated changes of grade (hilly areas). Keep in mind, however, that local codes and building departments may prohibit certain on-site wastewater treatment systems, or require costly and time-consuming permitting processes (because these systems are new and often poorly understood).

Technical Information

With almost all small-volume on-site wastewater systems, the flow first enters a septic (or Imhoff) tank for primary treatment. Secondary, or more advanced, treatment can be handled by:

- Modified septic tanks with an anaerobic/aerobic treatment device or a specially equipped aerobic tank;
- Specially designed filters, such as intermittent or recirculating sand filters;
- Constructed wetlands that rely on algae, microbes, macrophytic plants such as water hyacinths or bulrushes, and other organisms for wastewater treatment; or
- Membrane filtration (micro-, nano-, or ultra-filtration and reverse osmosis).

Very small daily volumes can also be treated on site by composting toilets and proper management of the resultant (composted) solids.

Most on-site wastewater systems utilize evapo-transpiration by plants for "disposal" of a portion of the treated effluent—this process "treats" the wastewater as well as disposing of it. At times, it is impossible to distinguish treatment from disposal and reuse processes. An on-site system may perform multiple tasks simultaneously—for example, a constructed wetland also provides wildlife habitat and recreational opportunities. Treatment/disposal/reuse options include the following:

- Shallow sand-filled beds and trenches that provide near-surface irrigation;
- Mound systems with vegetation;
- Wetlands (marshes) that discharge to connected riparian habitats;
- On-surface irrigation with restricted public access.
- After disinfection, treated effluent can be used for spray irrigation and nonpotable uses such as toilet flushing, steam heating, and industrial or coolant feedwaters (see *Section 6.5 – Reclaimed Water*).

An on-site wastewater management district is an organizational framework for community or larger-scale facilities such as military bases. Recent technical advances have helped make on-site districts more feasible. These include improved septic tanks; larger-volume

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septic tanks fed from multiple sources via small-diameter sewers; and low-cost septic tank innovations—especially in-tank effluent filters and pressure-dosing pumps and chambers—that improve soil-based treatment and water-holding capacity, thereby extending drainfield longevity. In-tank modifications also improve flow through small-diameter sewers, which, in turn, reduce the required earthwork, materials, and energy costs.

Typical cluster-systems, managed by on-site districts, include the following:

- Septic tanks with effluent filters and small-diameter sewers for gravity-delivery to an on-site treatment facility;
- Septic tanks with pressure sewer lines for collection in hilly areas (STEP systems);
- Septic tanks with grinder pump and pressure sewer lines that actually begin to "pretreat" sewage before delivery to the on-site treatment facility; and
- Vacuum sewers with extensive in-line oxidation and pretreatment—these are more expensive but appropriate for areas subject to earthquakes and slope movement.

Another important addition to the on-site management toolkit is membrane filtration. Though energy-intensive, membrane filtration is appropriate for situations in which the wastewater may contain hazardous components—for example, low-level radioactive pollutants in wastewater from military facilities, nitrocellulose from ammunitions plants, or other contaminants in bilge water from ships and submarines. Membrane filtration can also be considered in areas lacking acreage for biological treatment, such as urban locations.

Peak usage periods, such as Labor Day or Memorial Day in Federal parks or visitors' day in prisons, require special attention. Holding tanks are a cost-effective component that feeds the on-site treatment system at a later time and at rates optimal for biological or soil treatment.

With soil-based treatment systems, the wettest season places limits on how much effluent can be effectively treated and discharged (hydraulic assimilation capacity). In biologically reliant systems, the coldest months can slow treatment processes.

Steps to Choosing a Technology: Federal facilities vary widely and include research facilities, prisons, military bases, office buildings, employee homes, and trailside comfort stations. Before deciding on a treatment option, characterize the waste and wastewater. Then set out ideal environmental goals and carefully evaluate the site. Finally, keeping in mind the water quality, site, and cost considerations, work with a knowledgeable engineer to examine and select from the menu of available technologies.

Retrofitting: Many existing on-site systems do not meet modern engineering standards. Retrofitting septic tanks with effluent filters and pressure-dosing pumps should be considered an option. Constructing artificial soil profiles and/or diverting graywater for on-site irrigation or riparian restoration may be appropriate alternatives for overloaded systems.

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