A Survey of Methods for Implementing and Documenting Water Conservation in New York

By Kristin S. Linsey and Richard J. Reynolds
U.S. Geological Survey, 425 Jordan Rd., Troy, N.Y., 12180

October 2013

Contents

I. Abstract 1
II. Introduction 1
  A. Purpose and Scope....1
  B. What is Water Conservation?....2
  C. How Water Conservation Fits into the Hydrologic Cycle....2
  D. Non-Potable Water Use 2
III. Water Conservation Methods....4
  A. General Suggestions for Water Conservation....4
  B. Water conservation Measures: By Water-Use Activity....5
    1. Indoor Domestic Use 5
      a. Restrooms and Shower Facilities 6
      b. Kitchens, Cafeterias, and other Food Preparation Areas 7
    2. Laundries 9
    3. Building Maintenance and Exterior Areas....11
      a. Building Maintenance....11
      b. Exterior Areas....12
    4. Landscape Irrigation....13
    5. Pools....15
    6. Cooling and Heating....16
  C. Water conservation Measures: by Specific Process, Industry, or Water-Use Sector....19
    1. Agricultural Uses....19
      a. Agricultural Irrigation....19
      b. Livestock 21
      c. Aquaculture 22
    2. Golf Course Irrigation 23
    3. Food and Beverage....24
    4. Rinsing and Cleaning 25
    5. Plating and Metal Finishing 25
    6. Medical Facilities 26
    7. Textiles 28
    8. Mining 29
  D. Water Reuse, Reclaimed Wastewater, and Alternate Sources of Water....30
    1. Water Reuse....30
    2. Utilizing Reclaimed Wastewater....30
    3. Alternate Sources of Water....30
IV. Methods of Documenting Water Use and Conservation Efforts....31
  A. Water Audit 31
  B. Water Conservation Plan 32
  C. Public Information and Education 32
V. Appendix 33
  A. Annotated Bibliography 33
  B. Relevant Web sites....48

Conversion Factors

Multiply	By	To obtain
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	7.48	cubic feet (ft^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second (m^3/s)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.6463	million gallons per day (Mgal/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute (gal/min)	1440	gallons per day
gallon per day (gal/d)	0.003785	cubic meter per day (m3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	1.55	cubic feet per second (ft^3/s)
	Energy	
kilowatthour (kWh)	3,600,000	joule (J)

A Survey of Methods for Implementing and Documenting Water Conservation in New York

By Kristin S. Linsey[1] and Richard J. Reynolds[1]

I. Abstract

Water conservation methods and best management practices (BMPs) for water conservation are described for major categories of non-drinking-water users, including—but not limited to—industrial, commercial, power-generation, agricultural, and institutional categories. The BMPs were drawn from a literature search of reports published by state agencies, Federal agencies, the U.S. military, colleges and universities, and water-related organizations that have studied and evaluated various water conservation methods in the municipal supply, industrial, commercial, institutional, and agricultural water-use sectors. An annotated bibliography of references pertinent to water conservation and (or) best management practices in water conservation is included.

II. Introduction

New York, together with the other states that contain portions of the Great Lakes Drainage Basin, is a signator State of the Great Lakes Compact, which became State and Federal law December 8, 2008. One of the many goals of the Compact is "to promote the orderly, integrated, and comprehensive development, use, and conservation of the water resources of the Great Lakes Basin." The Compact requires each state to develop and implement a water conservation and efficiency program for all withdrawals greater than or equal to 100,000 gallons per day.

Moreover, New York State Governor Cuomo signed into law the *Water Resources Bill* (effective February 15, 2012), which requires that all individuals, corporations, or government entities with the capacity to withdraw greater than or equal to 100,000 gallons of water per day obtain a New York State Department of Environmental Conservation (NYSDEC) permit. Existing agricultural withdrawals of greater than or equal to 100,000 gallons per day in any thirty day consecutive period (3 million gallons during a 30 day period) would also require registration. The law requires all of these water withdrawals to implement environmentally sound and economically feasible water conservation measures.

This report provides a survey of water conservation methods for non-drinking-water uses, including—but not limited to—industrial, commercial, power-generation, agricultural, and institutional categories. It complements a previous report on water conservation methods for public water supplies, which was published by NYSDEC and is available at *http://www.dec.ny.gov/lands/39346.html* (New York State Department of Environmental Conservation, 1989). To develop this report, the U.S. Geological Survey (USGS), in cooperation with the NYSDEC, conducted a literature search to compile a list of best management practices (BMPs) for water conservation in the areas of industrial, commercial, institutional, and agricultural water use.

II.A. Purpose and Scope

This report provides examples of best management practices for water conservation and loss mitigation for non-drinking-water uses such as industrial, commercial, power-generation, and institutional water users. These BMPs were drawn from a literature search of reports published by state and Federal agencies, the U.S. military, colleges and universities, and water-related organizations that have studied and evaluated various water conservation methods in the municipal, industrial, commercial, institutional, and agricultural water-use sectors. This report has been released to provide examples of selected BMPs for water conservation and loss mitigation to non-drinking-water users in New York State, based on a search of available literature. The USGS does not provide evaluation of the effectiveness of any BMPs or methods of documenting water use beyond that described in the literature. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

[1]U.S. Geological Survey, 425 Jordan Rd., Troy, N.Y., 12180

II.B. What is Water Conservation?

Water conservation can be defined as (1) any beneficial reduction in water loss, use, or waste, and the preservation of water quality, (2) a reduction in water use accomplished by implementation of water conservation or water-efficiency measures, or (3) improved water-management practices that reduce or enhance the beneficial use of water (Vickers, 2001). A water conservation measure is an action, behavioral change, device, technology, or improved design or process implemented to reduce water loss, waste, or use. Water efficiency is a tool of water conservation that results in more efficient water use and thus reduces water demand. The value and cost-effectiveness of a water-efficiency measure must be evaluated in relation to its effects on the use and cost of other natural resources (for example, energy or chemicals) (Vickers, 2001).

The overall goals of any water conservation effort should include

- Sustainability—To ensure availability for future generations, the withdrawal of freshwater from an aquifer system or watershed should not exceed its natural replacement (recharge) rate. Emergency water conservation measures are often put in place to provide for water sustainability in the face of a short-term water shortage, such as a drought.

- Energy conservation—Water pumping, delivery, and wastewater treatment facilities consume a large amount of energy. In some regions of the world, a large percentage of total electricity consumption is devoted to water management. Energy efficiency and conservation can, therefore, result in water conservation. For example, reducing the amount of energy required at a facility that produces its own electricity will reduce the amount of water needed to generate that electricity.

- Habitat conservation—Minimizing human water use helps to preserve freshwater habitats for local wildlife and migrating waterfowl, as well as reducing the need to build additional infrastructure such as new dams, reservoirs, or other water diversion or conveyance structures.

- Reduction of per capita (per person) water consumption—Reducing the per capita water consumption in any given water distribution system (1) reduces the energy costs to pump, store, and distribute the water, (2) reduces the volume of the subsequent wastewater stream and thereby reduces the costs to treat that water, and (3) reduces the overall operating cost of the business in industrial or commercial settings.

- Optimal water efficiency—In irrigation practices, optimal water efficiency means minimizing losses due to evaporation, runoff, or subsurface drainage while maximizing production of the crop, whether it is vegetables, fruit, landscape trees and shrubs, or golf course turf. Similarly, increased water efficiency can result in improved water conservation in all water-use sectors.

II.C. How Water Conservation Fits into the Hydrologic Cycle

The hydrologic cycle, also known as the water cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Although the balance of water on Earth remains fairly constant over time, water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes of condensation, precipitation, infiltration, evaporation, transpiration, runoff, and subsurface groundwater flow (indicated by the arrows in fig. 1). In so doing, the water goes through different phases: liquid, solid, and gas.

Most of Earth's water is in the oceans, and most of the freshwater is stored as ice or below ground in aquifers (groundwater). Thus, comparatively little freshwater is available for human use on a global scale. For example, only 0.77 percent of all Earth's water is available as fresh groundwater or surface water. Only 0.008 percent is available in lakes, rivers, and wetlands. Most of the freshwater available for human use is groundwater (Shiklomanov, 1993). Thus, water conservation efforts of any kind and in any water-use sector are desirable, considering the relatively small amount of freshwater that is available on a global scale. Water conservation efforts become much more important to everyday life in arid parts of the world or in areas subject to prolonged periods of drought or areas where population growth could result in inadequacy of available supplies.

II.D. Non-Potable Water Use

"Potable water" is drinking water pure enough to be consumed or used with low risk of immediate or long-term harm to one's health and which meets minimum public health standards. "Non-potable water" can be defined as either (1) "potable" water that is used for a purpose or process other than drinking water or (2) water that does not meet minimum public health requirements for drinking water and is, therefore, used for other purposes. An example of this might be so-called greywater, such as water that was used in an industrial process that could be reused at that facility to irrigate the landscape around the facility. In this report, the most common uses of non-potable water are described, and water conservation practices, as found in the literature, for each non-potable water use are given.

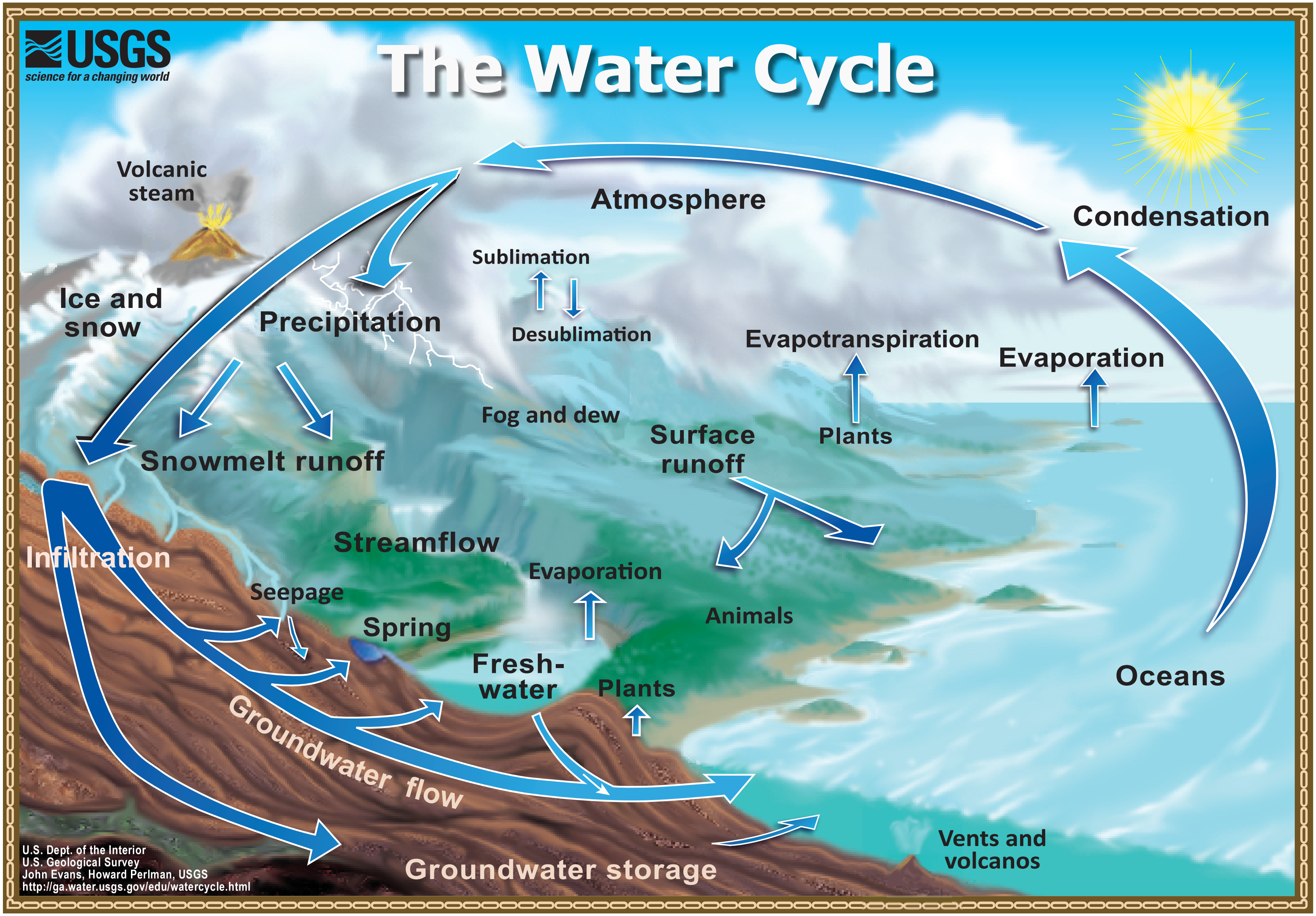

Figure 1. Major physical processes acting on the hydrologic (water) cycle on a global scale (accessed January 16, 2013, at *http://ga.water.usgs.gov/edu/watercycle.html*).

III. Water Conservation Methods

Water is used within an establishment in different ways. For example, the largest water use for an office building can be the amount of water used for indoor activities such as restrooms and kitchens, whereas the largest water-using activities at a power generation facility can be for cooling purposes. Water conservation measures can be implemented that incorporate changes in hardware, changes in how water-using activities are done, and changes in employee awareness. Some water conservation methods can apply to a variety of facilities, whereas some methods are applicable only to a specific industry or water-using process. The following sections describe BMPs for water conservation for a wide range of water-using facilities. The BMPs that follow are listed first as general suggestions that may be applicable to many types of facilities, then by water-using activity, and finally by specific process, industry, or sector of water use. Most BMPs include a reference and (or) link that can provide more details about the management practice and how it might be implemented. The lists below can be downloaded, printed, and used as checklists within an individual water conservation plan.

III.A. General Suggestions for Water Conservation

Some water conservation methods can apply to a variety of facilities and are not dependent on the product that a facility produces or the services that are rendered at the facility. Such general water conservation practices include the following:

□ Increase awareness of water conservation among employees, faculty and students, or the general public.

□ Solicit suggestions for water conservation from employees, faculty and students, or the general public.

□ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.

□ Meter water use throughout the facility by using source meters to measure how much water is supplied to the facility and submeters to measure how much water is used for specific activities.

□ Monitor water conservation efforts and effectiveness through weekly meter reading (See example worksheet; Pennsylvania Department of Environmental Protection, 2010d, p. 1).

□ Identify and repair leaks within the water-distribution system of the facility or leaks from a particular process or piece of equipment. A table showing potential water losses from water leaks can be found in U.S. Environmental Protection Agency, 2012, table 2–2. Some of the best practices for leak detection include conducting visual and auditory inspections, reading meters, and installing leak-detection systems within the facility.

□ Repair leaks as soon as possible, and do so according to manufacturer specifications. Consider replacing leaking equipment with new equipment that is more water efficient (such as ones that are labeled as WaterSense models).

□ Follow codes and standards that are applicable to the water-using equipment, water-using appliances, and overall water use within the facility. Following these codes and standards, along with other voluntary programs and guidelines, can result in water-efficient products and practices at the facility. A table showing selected organizations that have developed standards for products and (or) equipment can be found in U.S. Environmental Protection Agency, 2012, table 2–3. A table showing selected organizations that have developed green building codes, standards, and voluntary guidelines that address water efficiency in commercial and institutional buildings can be found in U.S. Environmental Protection Agency, 2012, table 2–4.

□ Place signs in restrooms and showers encouraging water conservation.

□ Limit the amount of water used for cleaning purposes to a budgeted amount. For example, use wet wash rags instead of hoses.

□ Supply paper cups for drinking water instead of allowing free-flowing drinking fountains.

□ Close down potential water-using areas that are not being used.

□ Install timers or sensors to automatically shut off water flow when water is not required.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 26.
- Pennsylvania Department of Environmental Protection, 2010d, p. 1.
- U.S. Environmental Protection Agency, 2012, p. 2–4, 2–9, 2–11, and 2–19.

III.B. Water conservation Measures: By Water-Use Activity

The following water conservation measures are organized by the water-use activity they are designed to control.

III.B.1. Indoor Domestic Use

Indoor domestic use includes water-using activities such as restrooms and shower facilities; kitchens, cafeterias, and other food preparation areas; and laundries. Although water conservation measures are listed for each of these types of activities, the following measures can apply to all indoor domestic use:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Consider replacing high-volume sprayers and continuous flow fixtures with units that shut off when the operator releases the nozzle.
- □ Use signs throughout the facility to remind users about water conservation efforts at the facility. Such signage can be used to remind users to turn off faucets when they are not in use or to report leaking or otherwise improperly functioning equipment.
- □ Sweep materials from floor and (or) use a mop and squeegee instead of washing with a hose whenever possible.

The information in this section was obtained from the following reference.

- U.S. Environmental Protection Agency, 2012, p. 3–18, 4–52, and 4–53.

New York City Water Conservation Success

New York City implemented ongoing conservation initiatives beginning in 1985. These methods included education, metering, leak detection, and water-use regulation. The following are examples of the water conservation methods implemented by the city:

- A door-to-door water-efficiency survey was conducted which provided homeowners with educational information, free showerheads and aerators, and a free leak inspection.
- Water meters were installed at unmetered residences.
- Owners of homes, apartment buildings, and commercial properties received rebates for replacing existing toilets with high-efficiency models (1.6 gallons per flush).
- Computerized sonar leak detection and an advanced flow-monitoring program were used to detect leaks in large sewer mains.
- Magnetic locking hydrant caps were installed to keep hydrants from being opened by residents in the summer months.

The water conservation efforts implemented by New York City resulted in an overall drop in per capita water use from 195 gallons per person per day in 1991 to 167 gallons per person per day in 1998. These results included water savings of 200 Mgal/d from meter installation, 70 to 80 Mgal/d from the toilet replacement program, 30 to 50 Mgal/d from the leak-detection program, and 4 Mgal/d from homeowner inspections.

[U.S. Environmental Protection Agency, 2002, Cases in water conservation: How efficiency programs help water utilities save water and avoid costs, EPA832-B-02-003, p. 31–32]

III.B.1.a Restrooms and Shower Facilities

Water is used in restroom and shower facilities for flushing toilets and urinals, and supplying faucets and showerheads. While toilets, faucets, and urinals can be found in nearly all type of facilities, showerheads are likely to be found in healthcare facilities, hotels, schools, universities, gyms, and other buildings where showers are provided for employee use (U.S. Environmental Protection Agency, 2012, p. 3–2). BMPs for these activities focus on the plumbing fixtures in these areas:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Install water-saving devices, such as low-flow faucets and showerheads, to decrease water consumption.
- □ Keep toilets in good working order. Periodic inspection can identify worn parts and prevent leaks. Have an inspection and maintenance plan and document that it is followed. Inspect toilets and urinals on at least an annual basis.
- □ Use signs in restrooms to educate and inform users. Such signage can remind users to report restroom facilities that are not in proper working order, such as continuously flushing or leaking toilets, leaking pipes, and dripping faucets.
- □ Consider retrofitting or replacing older plumbing devices with new water-efficient models, such as WaterSense-labeled models.
- □ Inspect showerheads periodically for scale buildup to ensure flow is not being restricted. Remove any scale buildup found according to manufacturer recommendations.
- □ Encourage users to shorten the length of showers. This can be done by providing a way for users to track showering time, such as by placing clocks or timers in or near the showers.
- □ Convert restrooms to cold water only. Thousands of gallons of water are wasted every year as water is left running while the user is waiting for hot water to arrive. This is not applicable at facilities where hot water is required for health purposes. In buildings where hot water is required, investigate the potential savings from installing a circulating pump in the hot water line to speed delivery of hot water to fixtures.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 26 and 32.
- U.S. Environmental Protection Agency, 2012, p. 3–5 through 3–7, 3–12 through 3–13, 3–18 through 3–19, and 3–24.

Waterless Options Pursued on University Campus

Institutional and commercial facilities across the Nation have looked into the feasibility of using waterless urinals in order to address cost and environmental concerns. The University of Southern Maine has installed and maintained a growing number of waterless urinals in its facilities. As of January 2005, the university had installed about 40 units in 10 buildings on 2 of its 3 campuses. Water and sewer costs can be reduced through the use of these units.

[Hounsell, Dan, 2005, Making Waterless Work, January 2005, accessed August 8, 2012, at *http://www.facilitiesnet.com/plumbingrestrooms/article/Making-Waterless-Work--2442*]

III.B.1.b Kitchens, Cafeterias, and other Food Preparation Areas

Food preparation areas can contain high-water-use appliances such as dishwashers, garbage disposals, ice makers, and frozen yogurt machines. The commercial dishwasher and pre-rinse spray valve can account for over two-thirds of the water use in most commercial kitchens (U.S. Environmental Protection Agency, 2012, p. 4–2). Boiler-based food preparation equipment and sluice-trough food disposal systems can also account for a large part of water use in a commercial kitchen (U.S. Environmental Protection Agency, 2012, p. 4–2). BMPs for this category include the following:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Turn off the continuous flow used to clean the drain trays of the coffee/milk/soda beverage island; clean the drain trays only as needed.
- □ Turn dishwasher off when not in use. Operate conveyor-type dishwashing machines in automatic mode, so that energy is saved by running the conveyor motor only when needed.
- □ Only run a dishwasher when there is a full load.
- □ Operate dishwashers based on manufacturer recommendations for minimum flow rates and rinse cycle times. Have an inspection and maintenance plan and document that it is being followed.
- □ Do not use running water to melt ice or to thaw frozen foods. If necessary, use basins or sinks filled with warm water to thaw frozen items.
- □ Remind users to turn off food preparation faucets that are not in use. Consider installing foot triggers to control faucets.
- □ Reduce water flow by replacing spray heads with low-flow, high-pressure spray heads or by installing flow-reduction valves in the water supply line.
- □ Train users to manually scrape food waste from utensils and dishes to decrease the amount of water needed from using the pre-rinse spray valve. Scrape larger food scraps into a trash receptacle to reduce the amount of food waste entering the food disposal system.
- □ Educate users about items that should not enter the food disposal system. For instance, pouring grease into the food disposal system can clog pipes over time, and placing hard objects into the food disposal system can dull the blades and reduce the unit's efficiency.
- □ Presoak utensils and dishes in a basin filled with water to loosen food residue.
- □ Reduce water flow to minimum required at prewashing stations. For example, use manual pre-wash units which shut off when the operator releases the nozzle, and check prewashing fixtures frequently for leaks because they tend to receive a lot of rough handling.
- □ Inspect pre-rinse spray valves periodically for scale buildup (which can restrict flow) and for leaks and broken or loose parts. Train users to identify and report leaks.
- □ Recycle water where feasible, consistent with Federal, state, and county health requirements. For example, final rinse water might be stored and used in the next dishwasher load or prewash load, or it might be used in the garbage disposal.
- □ Unless advised otherwise, wash vegetables in basins or sinks filled with water; do not let water run in preparation sink.
- □ Consider switching from boiler-based equipment to connectionless equipment. A boiler-based system can waste large amounts of water because a continuous stream of water is required to cool the condensed steam before it is disposed down the drain. A connectionless system has a self-contained water reservoir and heat source which eliminates the use of a separate, central boiler system. Choose equipment that is the appropriate size for the cooking needs of the facility.
- □ Use water from steam tables in place of freshwater to wash down the cooking area.
- □ Turn equipment off or down during slow times or when not in use. This includes equipment such as combination ovens, steam cookers, and food disposal systems.
- □ Use water-conserving ice machines. Choose an ice machine that is appropriate for the quality and quantity of ice needed at the facility.

- ☐ Replace water-cooled equipment (for example, ice makers, frozen yogurt, and soft-serve ice cream machines) with an air-cooled model that does not require water for condenser cooling. ENERGY STAR qualified models of ice machines are all air cooled.
- ☐ Consider replacing older dishwashing equipment with new, more water-efficient models such as ENERGY STAR qualified models. Select a commercial dishwasher that is appropriately sized, since a larger machine will waste water if it is run when not loaded to capacity.
- ☐ Provide table signs in the cafeteria urging water conservation.
- ☐ Serve water only when requested by customers.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 38 and 40.
- Pennsylvania Department of Environmental Protection, 2010b, p. 1.
- U.S. Environmental Protection Agency, 2012, p. 3–18, 4–7, 4–11 through 4–12, 4–15 through 4–16, 4–25, 4–37, 4–41, and 4–48 through 4–49.

How Much Water Does a Leaking Faucet Waste?

Check your faucets at home—do any of them drip? Well, maybe it's just a small drip—how much water can a little drip waste? True, a single drip won't waste much water. But think about each faucet in your home dripping a little bit all day long. What if every faucet in every home, on your block, in your town, in your state also dripped? The drips would add up to a flood of water wasted down the drain.

There is no scientific definition of the volume of a faucet drip, but after measuring a number of kitchen and bathroom sink faucets, the U.S. Geological Survey calculations below (numbers are rounded) use 1/4 milliliter (mL) as the volume of a faucet drip. So, by these drip estimates:

- One gallon equals 15,140 drips
- One liter equals 4,000 drips

At first glance, it seems as if that drop of water down the drain is insignificant. But, by using the drip estimator on the USGS Water Science Web site (*http://ga.water.usgs.gov/edu/sc4.html*), you will see how all the drops flowing in "real time" can add up to a flood.

[U.S. Geological Survey, Water Science Web site, accessed August 8, 2012, at *http://ga.water.usgs.gov/edu/sc4.html*.]

III.B.2. Laundries

Laundry facilities can be found in a wide range of establishments from hospitals and convalescent homes to hotels and motels to commercial linen services (U.S. Environmental Protection Agency, 2012, p. 3–2). Self-service laundromat facilities typically use commercial single-load, residential style washers. On-premises laundry facilities, such as those found in hotels, hospitals, nursing homes, prisons, and universities, and industrial laundry facilities that launder fabrics from other businesses may use large, multi-load washers or washer extractors. Very large on-premises laundry facilities may use tunnel washers (U.S. Environmental Protection Agency, 2012, 3–27).

Laundry facilities are a high-water-use area, primarily because the commercial washing machines typically used in these facilities do not recycle the water used; freshwater is added for each wash and rinse cycle (New Mexico Office of the State Engineer, 1999, p. 41). Water conservation methods available for laundries include the following:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Consider replacing older equipment with new, more water-efficient models. Implement an equipment replacement cycle, so new water-conserving equipment is cycled into production. New equipment could include (1) front loading washers that use less water, and (or) (2) new washers with high speed spin cycles that dry laundry further, thus reducing drying time and saving energy. ENERGY STAR qualified washers use significantly less energy, water, and detergent compared to standard models.
- □ Wash only full loads of laundry.
- □ Install coin-operated washing machines in laundry rooms of rental housing, instead of washers in each apartment.
- □ Utilize the programmable features of some multi-load washers and washer extractors to improve efficiency by setting the amount of water used by the machine. The number of cycles and the water level per cycle may be controlled in these types of machines.

Photograph courtesy of Peter deVries, U.S.Geological Survey

- □ Work with the equipment supplier to develop an ongoing service and maintenance program.
- □ Evaluate wash formula and machine cycles for water-use efficiency.
- □ Use detergents formulated for high-efficiency washing machines.
- □ Install simple or complex recycling systems to existing laundry equipment. A simple recycling system recovers the discharge from the final rinse in a multi-cycle operation for use in the first rinse of the next cycle. A complex recycling system treats the reclaimed water from wash and rinse cycles for use in all the cycles of the next load.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 41.
- Pennsylvania Department of Environmental Protection, 2010f, p. 1.
- U.S. Environmental Protection Agency, 2012, p. 3–28 through 3–31.

Encouraging Hotel Towel Reuse Through Descriptive Social Norms

A study was done by Goldstein and others (2008) to analyze the affects social norms have on hotel guests to help conserve water by the reuse of their towels. Instead of the typical request to reuse towels to help save the environment, guests were provided informational cards in their rooms that described how their reuse of towels would compare to other guest's behaviors. For instance, a guest might read that "the majority of guests staying in this hotel reuse their towels" or, even more specifically, "the majority of guests staying in this room reuse their towels."

The results of the study showed that the requests for towel reuse that included the descriptive norm of that particular room's previous occupants resulted in a greater percentage of towel reuse than the standard environmental message.

[Goldstein, Noah J., Cialdini, Robert B., and Griskevicius, Vladas, 2008, A room with a viewpoint: Using social norms to motivate environmental conservation in hotels: Journal of Consumer Research, October 2008, accessed August 8, 2012, at http://csi.gsb.stanford.edu/room-viewpoint]

III.B.3. Building Maintenance and Exterior Areas

The following section describes water conservation methods that can be implemented by a wide variety of facilities, as they apply to general recommendations for building maintenance and the exterior areas of buildings, no matter the purpose for which the buildings are used. Types of outdoor water use include landscape irrigation, swimming pools, and vehicle washing. Water savings can be realized through improved landscaping and pool maintenance practices and from the use of more efficient irrigation equipment (U.S. Environmental Protection Agency, 2012, p. 5–2).

III.B.3.a Building Maintenance

Many procedures used to maintain the buildings at a facility can provide opportunities for water conservation. The following water conservation measures can be applied to building maintenance:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Sweep materials from floor instead of washing down with a hose, whenever possible.
- □ Change window cleaning schedule from periodic to an on-call/as-required basis.
- □ Check for leaks in plumbing and fixtures and stop any unnecessary flows.
- □ Repair fixtures such as dripping faucets and showers or continuously running or leaking toilets.
- □ Install low-flow or no-flow (waterless) plumbing fixtures, whenever possible.
- □ Reduce the amount of water used in toilet flushing by adjusting the vacuum flush mechanism or installing toilet tank displacement devices.
- □ Replace water-using appliances and fixtures with water-saving models as they wear out. Alternatively, offer incentives to retire inefficient water-wasting equipment and update local building codes to mandate improvements for new equipment.
- □ Turn off water supply to equipment and rooms that are not in use.
- □ Keep hot water pipes insulated.
- □ Instruct clean-up crews to use less water for mopping. For example, use a broom or wet cloth instead of mopping, when possible.
- □ Switch from wet or steam carpet cleaning methods to dry powder methods.
- □ Use high-pressure, low-volume sprays instead of low-pressure, high-volume ones.
- □ Avoid excessive water filter or water softener back flushes. Back flush only when needed. Inspect annually to document proper function.

The information in this section was obtained from the following references.

- North Carolina Department of Environment and Natural Resources, 2009, p. 61 through 63.
- Pennsylvania Department of Environmental Protection, 2010a, p. 1.
- Pennsylvania Department of Environmental Protection, 2010c, p. 1.

Fix a Leak Week

What Is Fix a Leak Week?

Because minor water leaks account for more than 1 trillion gallons of water wasted each year in U.S. homes, the U.S. Environmental Protection Agency (USEPA) declared Fix a Leak Week each March beginning in 2009 (U.S. Environmental Protection Agency, 2012, p. 2-11). Fix a Leak Week is an annual reminder to Americans to check household plumbing fixtures and irrigation systems for leaks. Fix a Leak Week is part of the USEPA WaterSense "We're for Water" campaign. Download information describing what Fix a Leak Week is all about from *http://www.epa.gov/WaterSense/pubs/fixleak.html*.

About USEPA's WaterSense Program

WaterSense, a partnership program sponsored by USEPA, seeks to protect the future of our Nation's water supply by offering people a simple way to use less water with water-efficient products, new homes, and services. Since the program's inception in 2006, WaterSense has helped consumers save 125 billion gallons of water and $2 billion in water and energy bills.

For more information, visit *www.epa.gov/watersense*.

[U.S. Environmental Protection Agency, 2011, USEPA WaterSense Fix a Leak Week, March 12–18, 2012, accessed August 8, 2012, at *http://www.epa.gov/WaterSense/pubs/fixleak.html*]

III.B.3.b Exterior Areas

The following water conservation measures can be applied to maintaining the areas outside of a facility.

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Reduce the frequency of washing vehicles and machinery. Wash only for health and safety reasons.
- □ Discontinue using water to clean sidewalks, driveways, loading docks, tennis courts, pool decks, and parking lots. Consider using brooms or motorized sweepers.

The information in this section was obtained from the following references.

- Pennsylvania Department of Environmental Protection, 2010a, p. 2.
- U.S. Environmental Protection Agency, 2012, p. 5–6.

Photograph courtesy of Peter deVries, U.S.Geological Survey

III.B.4. Landscape Irrigation

Some outdoor water use will occur for facilities that own or maintain the landscape surrounding the facility. The amount of outdoor water use at a facility is affected by the size and design of the surrounding landscape, local climate, facility type, and need for supplemental irrigation (U.S. Environmental Protection Agency, 2012, p. 5–2). Combining efficient irrigation practices with efficient technologies can be the key to realizing water savings in this area (U.S. Environmental Protection Agency, 2012, p. 5–13). The following water conservation measures can be applied to maintaining the landscape surrounding a facility:

- ◻ Maintaining the landscape around a facility can be a water-intensive process. Water should be applied as efficiently as possible, and it should be applied only in locations and at times when it is necessary.
- ◻ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- ◻ Design the landscape surrounding a facility to minimize the need for outdoor water use. Designs can be implemented to minimize the need for supplemental irrigation by selecting regionally appropriate plants, use appropriately sized turf areas, use healthy soils with the appropriate grading to reduce stormwater runoff, include shaded areas, and limit the use of high water-using plants such as turfgrass.
- ◻ Educate personnel responsible for designing and maintaining the landscape around a facility in water-efficient and climate-appropriate landscaping techniques.
- ◻ Train personnel working in and around landscaped areas to identify and report problems in irrigation systems.
- ◻ Avoid installing small strips of grass—also known as strip grass—between the sidewalk and street. These small areas are difficult to water efficiently and are hard to maintain.
- ◻ Inventory outdoor water use for landscaped areas.
- ◻ Water landscaped areas only when needed.
- ◻ Water thoroughly and less often, instead of lightly more frequently, in areas where the soil type is acceptable for this type of watering schedule. This watering schedule encourages deep root growth.
- ◻ Avoid watering on windy or rainy days. Install and maintain wetness sensors to prevent unnecessary watering by automated sprinkler systems.
- ◻ Time watering, when possible, to occur in the early morning or evening when evaporation and transpiration are lowest.
- ◻ Have an inspection and maintenance plan for any irrigation system and document that it is being followed. Have a full audit of the irrigation system done every 3 years by a qualified irrigation auditor, such as a professional certified by a WaterSense labeled program. Review all landscape service and maintenance agreements periodically to see if they meet efficiency and performance standards. Consider installing a separate meter to measure the amount of water applied to the landscape which may help to more quickly identify leaks.
- ◻ Adjust the lawn mower to a higher setting to promote deeper root growth and drought-resistant turf.
- ◻ Use water-efficient plants in landscapes that are drought-tolerant, native, or appropriate to the local environment Xeriscape.
- ◻ Group plants with similar water needs—a practice also known as hydrozoning—as a method of promoting efficient irrigation.
- ◻ Avoid plant fertilizing and pruning that would stimulate excessive growth.
- ◻ Remove weeds and unhealthy plants so remaining plants can benefit from the water saved.
- ◻ In many cases, older, established plants require only infrequent irrigation. Look for indications of water need, such as wilting, change of color or dry soils.
- ◻ Install soil moisture overrides or timers on sprinkler systems.
- ◻ Make sure irrigation equipment applies water uniformly.
- ◻ Consider installing drip irrigation systems which direct water to plant roots at a low flow rate, reducing water losses due to wind or runoff.
- ◻ Consider installing WaterSense labeled weather-based irrigation controllers to reduce over watering plants.
- ◻ Mulch around plants to reduce evaporation and deter weeds.

□ Remove thatch and aerate turf to encourage the movement of water to the root zone.

□ Avoid runoff and make sure sprinklers cover just the lawn or garden, not sidewalks, driveways, or gutters. Do not overwater.

□ Consider installing rain-sensing technology to turn irrigation systems off when rainfall occurs.

□ Consider installing flow-rate-monitoring equipment that can detect excess flow and interrupt the irrigation process.

□ Recirculate water in water features such as ponds, waterfalls, and decorative fountains. Reduce evaporative losses by shutting off these water features when possible. Check the water recirculation systems at least annually for leaks and other damage.

□ Use properly treated wastewater for irrigation where available.

□ Use hose nozzles on hand-held hoses that automatically shut off when not in use.

The information in this section was obtained from the following references.

- New Hampshire Department of Environmental Services, 2010a, p. 3.
- New Mexico Office of the State Engineer, 1999, p. 50 and 58.
- North Carolina Department of Environment and Natural Resources, 2009, p. 72.
- U.S. Environmental Protection Agency, 2012, p. 5–3 through 5–6, 5–8 through 5–9, 5–11 through 5–12, 5–14 through 5–16, and 5–18.
- Vickers, 2001, p. 15 and 219.

Photograph courtesy of Lynn Betts, U.S. Department of Agriculture, Natural Resources Conservation Service

III.B.5. Pools

Swimming pools can be found in a variety of settings, including school and athletic buildings, public recreational facilities, hotels and motels, gyms and health clubs, health care facilities, water parks, and residential properties (Vickers, 2001). Water savings can be achieved through limiting water lost due to evaporation, leaking, splashing, and maintenance practices such as filter cleaning and mineral buildup control. Water conservation measures that can be used for swimming pools include:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.

- □ Keep pools at a temperature at or below 79 degrees Fahrenheit. This can help reduce water evaporation rates.

- □ Limit the use of features such as sprays and waterfalls.

- □ Lower the water level in the pool to several inches below the edge of the pool to reduce the amount of water that is splashed out.

- □ Limit the frequency of pool refilling, taking into account water quality, treatment needs, and other site-specific requirements.

- □ Use a pool cover to reduce evaporation rates when the pool is not in use. A pool cover can also reduce the amount of debris that enters the pool resulting in less water needed to backwash filters.

- □ Discontinue using water to clean pool decks. Consider using brooms or motorized sweepers.

- □ Channel splashed-out pool water onto adjacent landscaping.

- □ Reduce the amount of water used to clean pool filters by cleaning filter media only when the filter is no longer operating properly, for instance when the pressure has increased by 5.0 to 10.0 pounds per square inch.

- □ Keep pools and pool filters clean to minimize the frequency of filter backwashing.

- □ Check the pool for leaks on a routine basis and repair them as soon as they are identified. Leaks can occur in the pool liner, along the pool edges, or in parts of the system such as around the pump seals, pipe joints, and water distribution and return lines.

The information in this section was obtained from the following references.

- Pennsylvania Department of Environmental Protection, 2010a, p. 2.
- U.S. Environmental Protection Agency, 2012, p. 5–24 through 5–25.
- Vickers, 2001, p. 282 through 283.

III.B.6. Cooling and Heating

The following section provides information on water conservation methods for cooling and heating processes. Large amounts of water can be consumed by cooling towers, chillers, small evaporative coolers, boilers, and steam generators. These types of equipment can also use water inefficiently, so optimizing their performance can be an integral part of a water conservation plan (New Mexico Office of the State Engineer, 1999, p. 60).

Cooling water is used to take away the heat generated by building and process systems, air and vacuum pumps, compressors, large commercial freezers and refrigerators, and ice machines. Four common types of cooling systems involve the use of water: once-through cooling, cooling towers, evaporative coolers, and equipment cooling (Vickers, 2001, p. 288). The types of equipment that typically use once-through cooling (where water is moved through a piece of equipment and then disposed down the drain) include computed tomography (CT) scanners, degreasers, rectifiers, hydraulic presses, X-ray processors, condensers, air conditioners, air compressors, welding machines, vacuum pumps, and viscosity baths (New Mexico Office of the State Engineer, 1999, p. 66). Evaporative coolers work in a similar fashion to cooling towers, where air is cooled and humidified as it passes through porous pads that are kept moist by water dripped on their upper edge. Unevaporated water trickles down through the pads and collects in a pan for either discharge or recirculation. Evaporative coolers work best in arid climates, since they rely on evaporation (New Mexico Office of the State Engineer, 1999, p. 66).

A facility that requires a large amount of water for cooling purposes may use a cooling tower. A cooling tower uses evaporation as the method of removing heat. Water is circulated through the cooling tower, where the water is exposed to air, causing some of the water to evaporate. The remaining (cooler) water flows to the equipment that needs to be cooled. Heat is exchanged from the equipment to the water, which heats up the water. Once the water has been warmed, it flows back to the cooling tower, where the cooling process begins again. “The rate of evaporation from a cooling tower is typically equal to approximately 1 percent of the rate of recirculating water flow for every 10 degrees Fahrenheit in temperature drop that the cooling tower achieves” (New Mexico Office of the State Engineer, 1999, p. 60).

The volume of water circulating through a cooling tower can also be reduced by bleed-off (also known as blowdown) and drift. The water that remains after evaporation has a high concentration of suspended and dissolved solids. Each cycle of water through the cooling tower evaporates more water, which in turn continues to increase the concentration of suspended and dissolved solids. To keep the cooling system from becoming damaged from corrosion and scaling, these dissolved solids must be removed. This removal is done by discharging some of the water circulating through the system, a process known as bleed-off or blowdown. Drift occurs when the air flowing through the cooling tower also carries off water droplets and mist. Drift is considered part of bleed-off since the water droplets that are carried off contain dissolved solids. “Typically, drift can vary between 0.05 percent and 0.2 percent of the flow rate through the tower” (New Mexico Office of the State Engineer, 1999, p. 60).

The amount of water that the cooling system loses due to evaporation, drift, and bleed-off (blowdown) is called makeup water. The rate of evaporation is affected by the amount of cooling needed and, to a lesser extent, by the weather; however, these two factors may not provide opportunities for conservation practices. The bleed-off (blowdown) process then becomes the primary opportunity for conservation practices when cooling towers are used (New Mexico Office of the State Engineer, 1999, p. 60).

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.

- □ Use the minimum amount of water necessary in cooling equipment (such as air conditioners). Check information from the manufacturer to determine the minimum amount of water needed for efficient operation of the equipment.

- □ Operate air conditioning units only when they are needed and only in areas where air conditioning is required. Reducing the load on air conditioning units can reduce the amount of water used during the cooling process.

- □ Shut down the units requiring cooling when they are not being used (for example on nights and weekends). An automatic control can be installed.

- □ Retrofit once-through cooling systems into existing closed-loop cooling systems. A closed-loop system will recirculate the water instead of disposing it. For small equipment that currently uses a once-through cooling system, connecting this system to an existing recirculating loop can recycle water that is currently being disposed. Closed-loop systems may require less water withdrawal than once-through systems but often result in greater evaporative loss.

- □ Install specific conductance and flow meters on make-up and bleed-off lines. Information on the total flow, rate of flow, and specific conductance of the water in both the make-up and bleed-off lines can be used initially to ensure that equipment is operating optimally. This information can also be compared to

future measurements, identifying the amount of water savings that were realized by implementing water conservation practices.

□ Avoid excessive bleed-off (blowdown). Monitor levels of dissolved solids; bleed-off only when needed. For evaporative cooler systems, bleed-off amounts should not be more than a few gallons of water per hour. In these systems, high bleed-off amounts could be due to leaks, pumps or controls that are not functioning properly, or worn pads.

□ Operate bleed-off on a more continuous basis by setting the specific conductance level at which the bleed-off is to start to a value that is not much higher than the target specific conductance. This allows the bleed-off to occur for a shorter time period. Bleed-off for cooling towers is generally a process that is accomplished through automatic releases of large amounts of water for a given period of time or until a target, lower level of specific conductance is reached. By keeping the specific conductance consistently closer to the target, fluctuations in specific conductance are kept to a minimum, and less water is needed for the bleed-off process.

□ Avoid using spray coil units, unless humidity levels required in critical areas cannot be obtained by other methods or in areas where the spray coil units are used to reduce cooling operations.

□ Replace water-cooled equipment with air-cooled models. Compressors and vacuum pumps can be replaced with air-cooled alternative. Water-cooled equipment such as ice makers, ice cream machines, and frozen yogurt machines can also be replaced by air-cooled alternatives, which can also be more energy efficient.

□ Reuse and recycle water when possible, especially in a once-through cooling system. Examples of uses for once-through cooling water are using the water as make-up water for a boiler, vehicle washing, and landscape irrigation. Additional water reuse opportunities can also be realized by using water from another process (such as reverse osmosis or reclaimed municipal wastewater) as the source water for make-up water.

Water can be used in heating systems and for steam generation. Two common types of heating and steam systems involve the use of water: boilers and steam generators, and humidifiers. Water loss can occur in these systems, especially if the system is older and has not been properly maintained (Vickers, 2001, p. 311 and 313).

Boilers are used to generate steam, which can then be transported through a facility's distribution system and used as a heat-transfer mechanism. The amount of water a boiler system uses varies due to such factors as the system's size, how the system was designed, how much steam is used, how much water does not evaporate (also called condensate return), and how the system is maintained. Throughout the boiler system, valves, traps, pipes, insulation, and controls used to monitor the system can all be sources of water loss, especially in older systems (Vickers, 2001, p. 309).

Humidifiers use water to add moisture to the air. Some humidifiers utilize a closed-loop system, while others send water directly from a water reservoir into the sewer line. Two types of humidifiers are pan humidifiers and wetted media humidifiers. A pan humidifier uses a heat source to evaporate water from a pan within the air conduit, adding moisture to the air as the water evaporates. A wetted media humidifier uses a pad wetted by water sprayers in the air conduit, and moisture is added to the air as it travels over the wetted pad (Vickers, 2001, p. 313).

□ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.

□ Regularly inspect the heating system. This includes the boiler, the condensate system, and all steam traps and lines. Verify that all parts of the system are well maintained and are operating properly, identifying any leaks. Repairs should be made in a timely fashion, as steam that escapes from the system wastes both water and energy. Some repairs can be done by facility personnel with instructions and materials available from a system's manufacturer.

□ Shut down heating systems when they are not being used (for example on nights and weekends). An automatic control can be installed.

□ Replace older systems with models that are more water and energy efficient.

□ Ensure that steam and condensate pipes are properly insulated. This will help to conserve heat and reduce steam requirements.

□ Install specific conductance and flow meters on make-up and bleed-off lines. Information on the total flow, rate of flow, and specific conductance of the water in both the make-up and bleed-off lines can be used initially to ensure that equipment is operating optimally. This information can also be compared to future measurements, identifying the amount of water savings that were realized by implementing water conservation practices.

- □ Install heaters and boilers for specific needs, such as domestic hot water and pools. Utilize smaller units instead of a single larger unit.
- □ Return steam condensate to the boiler if there are no water-quality concerns involved. Without a condensate-return system in place, make-up water must be added since all the water used in the process of generating steam is lost. This also conserves energy, since the already hot condensate needs less heating to produce steam. “Recovering and returning steam condensate may cut operating costs by up to 70 percent” (New Mexico Office of the State Engineer, 1999, p. 68).
- □ Avoid excessive bleed-off (blowdown). Monitor levels of dissolved solids; bleed-off only when needed. Monitor both boiler and humidifier systems that continuously bleed-off water to ensure that the system is not discharging more water than is necessary.
- □ Avoid using cold water to cool blowdown, or at least check to make sure the cold water that is being used is not flowing continuously.
- □ Operate humidifiers only when necessary and only in areas where they are needed.
- □ Ensure that flow controls for humidifiers are operating correctly. Water loss can result from improperly operating flow controls.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 62, 66, and 68.
- Pennsylvania Department of Environmental Protection, 2010a, p. 1.
- Pennsylvania Department of Environmental Protection, 2010d, p. 1.
- Vickers, 2001, p. 291, 302, 306, 311, and 313.

Water Conservation Efforts by Kodak

The Eastman Kodak Company, commonly referred to as “Kodak,” manufactures imaging materials such as photographic film and paper products. Kodak’s facility in Rochester, New York, covers approximately 1300 acres and supports nearly half of Kodak’s worldwide production of imaging materials. The Kodak Park facility uses water in a variety of ways, not only for the manufacturing of photographic film and paper, but also for use in the water and wastewater treatment facilities, two power plants, fire department, and fleet of vehicles found on site.

Kodak established a goal requiring a 15-percent reduction in water usage on a production-indexed basis by the end of 2003, using 1997 as a baseline year. In order to reach this goal, Kodak utilized several water conservation methods. These methods included changing the cooling process in a large manufacturing area from a single-pass system to a closed-loop system, returning steam condensate to the power house instead of to the sewer, repairing or replacing valves, and consolidating manufacturing facilities. Through June 2001, Kodak Park consumed an average of 26.5 Mgal/d, which represented a 16.5 percent reduction from the 1997 baseline.

[Wainwright, Gary, 2002, Water conservation in a water-intensive industry, accessed August 8, 2012, at *http://www.nywea.org/clearwaters/pre02fall/313080.html*]

III.C. Water conservation Measures: by Specific Process, Industry, or Water-Use Sector

The water conservation measures described in this section apply to specific types of water use, and as such they are organized by specific process, industry, or water-use sector.

III.C.1. Agricultural Uses

Agricultural uses include activities where water is used to sustain plant growth in all agricultural and horticultural practices; where water is used for livestock watering, feedlots, dairy operations, and other on-farm needs; and where water is used for raising organisms that live in water for food, restoration, conservation, or sport (Kenny and others, 2009).

III.C.1.a. Agricultural Irrigation

Agricultural irrigation is water used by irrigation systems to grow crops. The factors that can affect agricultural water use include water availability, crop water requirements, climate, soil type, type of irrigation system, and the price of water. Limiting the amount of water lost through the agricultural irrigation process by using efficient water-management practices and improved irrigation technologies can be a primary goal of water conservation efforts in this area.

There are three general types of irrigation methods—surface, sprinkler, and microirrigation. Surface irrigation includes flood and furrow irrigation and usually involves water flowing across a field by gravity. Sprinkler irrigation is accomplished by discharging water from sprinkler heads or spray nozzles onto the crops. Microirrigation is the irrigation method that delivers water directly to the root zone of plants via drops, small spray or mist, or small streams of water.

The following water conservation measures can be implemented for irrigation:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Improve the water efficiency of surface irrigation systems. This step can be accomplished through better distribution of water along furrows and across fields, by using techniques such as furrow diking, tail-water reuse, and laser leveling.
- □ Use furrow dikes to trap irrigation water or rainwater so that it is not lost to runoff. Mounds of soil are added across a furrow at intervals, which enable water from rain or irrigation to be stored.
- □ Replace older sprinkler systems with a newer, more efficient system. For instance, older center pivot sprinkler systems can be replaced with a low energy precision application (LEPA) center pivot system.
- □ Combine the use of furrow dikes and LEPA irrigation systems to achieve a greater water efficiency.
- □ Ensure that all parts of a field receive enough water by removing high and low spots in a field. This step can be accomplished through the use of laser or precision leveling techniques.
- □ Install on-farm meters to determine the amount of water withdrawn from a source of water and the amount of water applied to a field or crop. Ensure that meters are maintained and repaired on a regular schedule.

Photograph courtesy of U.S. Department of Agriculture, Natural Resources Conservation Service

□ Avoid over-irrigation or under-irrigation by monitoring soil moisture by using a variety of methods. A soil sample taken by hand can be compared with a reference table or picture. Moisture-sensing devices can be installed at a fixed location or portable devices could be used.

□ Implement irrigation scheduling to ensure that the correct amount of water is applied to crops when it is needed.

□ Implement drip irrigations systems, when applicable. Since drip irrigation systems deliver water directly to soil close to the root zone, the amount of water lost to runoff and (or) evaporation is negligible.

□ Implement conservation tillage techniques, whereby the remains of a previous crop are left in the field to hold moisture received during the winter months. This technique helps to conserve soil and retain soil moisture.

□ Line canals and conveyance systems to reduce water losses. Materials used for lining can include concrete, bentonite clay, and materials produced with newer technologies such as plastics and fiberglass fabrics.

□ Use recycled and (or) reclaimed water. With sufficient treatment, treated wastewater can be used on crops or fields.

The information in this section was obtained from the following reference.

- Vickers, 2001, p. 337, 339, 343, 352, 354–357, 359, 365, 367, 372, 377, 386, and 389.

III.C.1.b. Livestock

Livestock water use includes water used for livestock watering, feedlots, dairy operations, and other on-farm needs. Livestock includes dairy cows and heifers, beef cattle and calves, sheep and lambs, goats, hogs and pigs, horses, and poultry. Other livestock water uses include cooling of facilities for the animals and animal products such as milk, dairy sanitation and washdown of facilities, animal waste disposal systems, and incidental water losses (Kenny and others, 2009). The following water conservation methods can be applied to livestock facilities:

- □ Water savings should not be attempted by limiting the amount of water your animals drink.
- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Fix leaks in pipes and faucets.
- □ Do not overfill watering tubs and tanks. Install automatic shut-off measures.
- □ Reuse water, where water quality allows. For instance, reuse the pre-cooler water that chills down milk, or reuse the water from a clean-in-place system to wash down other areas.
- □ Maintain the wash system to ensure that the air injection system is working properly and to verify that you are using only the amount needed for each wash cycle.
- □ Barn cooling systems, used to reduce heat stress in livestock, may not need to spray water continuously. Cycle the unit off and on in coordination with a fan system and in accordance to manufacturer's recommendations.
- □ Manually clean floors and alleys before washing them.
- □ Rinse small equipment in a sink or bucket, rather than with running water.

The information in this section was obtained from the following reference.

- Porter, 2009, p. 2.

Photograph courtesy of Robert Nichols, U.S. Department of Agriculture, Natural Resources Conservation Service

III.C.1.c. Aquaculture

Aquaculture water use includes water used for raising organisms that live in water (such as finfish and shellfish) for food, restoration, conservation, or sport. Aquaculture production occurs under controlled feeding, sanitation, and harvesting procedures primarily in ponds, flow-through raceways, and, to a lesser extent, cages, net pens, and closed-recirculation tanks. Aquaculture facilities (for example, fish hatcheries) generally use a large amount of water to maintain water levels in production tanks and raceways (Kenny and others, 2009). The following water conservation methods can be applied to aquaculture facilities:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Determine the minimum flow rate needed to maintain optimum tank/raceway conditions. Maintain these flow rates.
- □ Control flows throughout the system by using and maintaining appropriate devices, such as sealed weir boards and pipe valves.
- □ Install flow meters for proper flow measurement.
- □ Minimize the amount of water used for tank and facility washing.
- □ Conduct routine maintenance on a regular schedule.
- □ Replace older pipes and tanks with newer equipment.
- □ Employ newer recirculation technology, when possible, such as a swirl separator that removes fish wastes in conjunction with treatment and aeration.
- □ Use recycled and (or) reclaimed water, when possible.

The information in this section was obtained from the following reference.

- New Hampshire Department of Environmental Services, 2010h, p. 1–2.

Photograph courtesy of Ron Nichols, U.S. Department of Agriculture, Natural Resources Conservation Service

III.C.2. Golf Course Irrigation

Water used in the golf course industry is primarily for turf irrigation. The following water conservation measures can be used at golf course facilities:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Contact your local water supplier about holding landscape water auditor classes for your golf course managers.
- □ Know how to select and maintain irrigation equipment. Ensure that the equipment is properly installed, maintained, and managed.
- □ Hire a golf course and (or) landscape architect with water conservation and xeriscape experience.
- □ Use turf only where actually necessary, such as greens, tees, landing areas, picnic areas, and outside lunch areas.
- □ Know when and where to irrigate.
- □ Use native plants to reduce water consumption, chemical use, and labor.
- □ Increase naturalized areas to reduce water consumption, chemical use, and labor.
- □ Limit or exclude turf from roughs.
- □ Choose the right plants for buffer strips. Use only low-water-use plant material in non-turf areas.
- □ Use automatic irrigation systems monitored by moisture probes (for example, tensiometers).
- □ Design a dual watering system utilizing sprinklers for turf irrigation and low-volume irrigation for plants, trees, and shrubs. Operate the sprinkler system before sunrise and after sunset. The amount of irrigation can be determined by the evapotranspiration rate.
- □ Use properly treated wastewater for irrigation where available and where health regulations allow.
- □ Collect, cleanse, store, and reuse stormwater.
- □ Reuse greywater for irrigation of lawns and gardens where health regulations allow.

The information in this section was obtained from the following references.

- LandStudies, Inc., and the Pennsylvania Environmental Council, 2009, p. 13, 15, 23, 25, 31, 37, and 46.
- Pennsylvania Department of Environmental Protection, 2010c, p. 1.

III.C.3. Food and Beverage

Water used in the food and beverage industry is used to transport, clean, process, formulate products, and meet Federal sanitary standards (North Carolina Department of Environment and Natural Resources, 2009, p. 90). The following water conservation methods can be used in facilities in the food and beverage industry:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Use easy-to-clean conveyor belts for product transport.
- □ Reuse water in another process. For example, use rinse water for boiler make-up, filter backflush, or floor and gutter wash.
- □ Use alternative processes instead of water-intensive ones. For example, use rubber-disc scrubbing units instead of raw product cleaning and peeling, steam instead of water blanchers, or evaporative coolers instead of water-cooled systems.
- □ Use air flotation units instead of a water-based method to remove suspended debris from raw crop materials.
- □ Modify processes to consume less water. For instance, adjust pumped cooling and flushing water to the minimum required based on manufacturer specifications.
- □ Recycle water within a specific process where health regulations allow.
- □ Rechlorinate and recycle transport water where feasible.
- □ Use pneumatic conveying systems where practical.

The information in this section was obtained from the following reference.

- North Carolina Department of Environment and Natural Resources, 2009, p. 91 and 95.

III.C.4. Rinsing and Cleaning

A number of industries rely on washing and rinsing as part of their operations. The following water conservation measures are applicable to rinsing and cleaning processes at facilities:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Identify all water-using processes and determine if less water could be used. This could be accomplished through process optimization, water reuse, more efficient technologies, and (or) switching to alternative water sources.
- □ Focus on controlling water flow, increasing the efficiency of the rinse process, and reclaiming spent water.
- □ Turn off water flow whenever a process is shut down or out of service.
- □ Avoid excessive dilution.
- □ Use measured amounts of water instead of continuous streams, or at least reduce the rate of continuous streams.
- □ Use electrically operated flow control valves and monitor specific conductance or dissolved solids to adjust rinse water concentration.
- □ Install spray rinse systems directly above the process baths where possible.
- □ Use sequential rinsing, which reuses water spent for one process in another compatible process.
- □ For multitask rinsing, consider making the first tank a static (rather than continuous) rinse.
- □ Use counterflow rinsing.
- □ Eliminate flushes where not required.
- □ Batch process items, instead of rinsing one item at a time.

The information in this section was obtained from the following references.

- North Carolina Department of Environment and Natural Resources, 2009, p. 101–103, 105.
- Vickers, 2001, p. 258–262.

III.C.5. Plating and Metal Finishing

A number of industries rely on washing and rinsing as part of their operations. Plating and metal finishing facilities are examples of these water-intensive operations. Rinsing quality has a great impact on the quality of the finished product, so care must be taken to ensure that improvements in rinsing efficiency are monitored for quality control and quality assurance. The following water conservation measures can be applied to the plating and metal finishing industries:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Use wetting agents in the plating baths to reduce the amount of spent electroplating solution, also known as drag-out.
- □ Reduce the metal concentration in the plating baths.
- □ Install drain boards between the process and rinse tanks to collect drag-out and route it back to the process tank.
- □ Improve the efficiency of rinsing by agitating the tank to increase the circulation of the rinse water or letting the work piece stay in the rinse water for a longer period of time.
- □ Optimize rinse tank design to provide fast removal of chemical solutions.
- □ Reuse treated wastewater for non-critical rinsing steps, where water quality is not of concern.

The information in this section was obtained from the following reference.

- North Carolina Department of Environment and Natural Resources, 2009, p. 101–102 and 105.

III.C.6. Medical Facilities

Medical care facilities, such as hospitals, nursing homes, dental and doctor's offices, veterinary clinics, and research laboratories, can implement water conservation measures that apply not only to domestic and indoor conservation measures, but also that affect the variety of specialized equipment and processes found within their facilities. Some of the processes and equipment used in medical care facilities includes water purification, sterilization, photographic and X-ray processes, and vacuum systems (U.S. Environmental Protection Agency, 2012, p. 7–2). The following water conservation measures can be applied to medical care facilities:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Check equipment periodically to ensure that it is operating according to manufacturer specifications, the operational control schemes used promote optimum efficiency, and leaks are identified and quickly repaired. Inspect equipment.
- □ Consider replacing older medical and laboratory equipment that rely on single-pass cooling systems with newer technologies and better practices that can reduce the volume of water used.
- □ Ensure the flow rates being discharged by medical and laboratory equipment do not exceed the manufacturer's specifications.
- □ Use a water-purification system in the facility that provides an appropriate level of water quality and amount of purified water. A system that provides a higher level of purification than is needed can result in wasted water and energy.
- □ Use water purification only when necessary.
- □ Shut off the flow of water to specialized equipment whenever units are not in operation.
- □ Turn off used water for cooling in the X-ray department when not in use.
- □ Turn off vacuum pumps when not in use.
- □ Check the manufacturer specifications for vacuum pumps to ensure the device is set to operate using no more water than is necessary to remove impurities and cool the vacuum pump.
- □ Consider implementing digital imaging to eliminate the need for water in the photographic and X-ray processes.
- □ Recycle water where feasible, consistent with state and county requirements.
- □ Install flow meters in supply lines to monitor flow rates to various equipment. Adjust water flow to minimum flow rate when possible
- □ Install a pressure-reducing device on any equipment that does not require high pressure.
- □ Use full loads in sanitizer, sterilizer, dishwasher, and washing machines consistent with infection control requirements.
- □ Set the number of rinse cycles to the fewest number necessary to effectively clean equipment based on manufacturer recommendations and health and sanitary guidelines.
- □ Check manufacturer recommendations for glassware washers to verify that the washer is operating at or near the minimum flow rate.
- □ Consider replacing older glassware washers with new, more water-efficient equipment. Consider retrofitting existing glassware washer with a water-recycling

system, if the level of water quality needed allows for the use of a recycling option.

- □ Overhaul faulty steam traps on sterilizers.
- □ Consider replacing or retrofitting older steam sterilization equipment with newer equipment that reduces the amount of tempering water required.
- □ Reuse cooling water and (or) steam condensate from sterilizers and autoclaves.

The information in this section was obtained from the following references.

- New Mexico Office of the State Engineer, 1999, p. 74–75.
- Pennsylvania Department of Environmental Protection, 2010d, p. 1–2.
- U.S. Environmental Protection Agency, 2012, 7–3 through 7–4, 7–7, 7–11, 7–18, 7–24 through 7–25, 7–34, and 7–39.

Improving Water Efficiency in the Health Care Sector

Norwood Hospital in Norwood, Massachusetts, reduced its water usage by 29 percent from 1991 to 1994 by implementing water conservation measures. These measures included eliminating seal and cooling water on medical air compressors and vacuum pumps; recirculating seal and cooling water for four vacuum pumps and one medical compressor, in addition to removing an unneeded vacuum pump; replacing flush valves on toilets and urinals; installing low-consumption aerators in restrooms; and retrofitting the refrigeration system.

[Massachusetts Water Resources Authority, n.d., Water use case study: Norwood Hospital, accessed August 8, 2012, at *http://www.mwra.state.ma.us/04water/html/bullet1.htm*]

III.C.7. Textiles

Water is used extensively throughout textile processing operations. Water baths are used to apply almost all dyes to textiles. Most fabric preparation steps are accomplished by using water-based systems, and there are many washing steps in the textile manufacturing process. Washing fabric consumes greater quantities of water than dyeing (North Carolina Department of Environment and Natural Resources, 2009, p. 83).

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.
- □ Conduct a walk-through audit of water uses within the facility to determine areas where water can be saved.
- □ Reduce the time that hoses are left running unnecessarily.
- □ Repair broken or leaking valves, pipes, joints, and pumps. Replace missing valves.
- □ Reduce excessive water use in washing operations.
- □ Turn off cooling water or wash boxes when machinery is shut down.
- □ Stop the washing process at the appropriate time. Shut off water flow when the machine is stopped.
- □ Install flow controls on washers and cooling water.
- □ Investigate the feasibility of reusing wash water through methods such as countercurrent washing, reducing carryover, and reusing wash water for cleaning purposes.
- □ Use low bath-ratio dyeing equipment.

The information in this section was obtained from the following reference.

- North Carolina Department of Environment and Natural Resources, 2009, p. 83 and 85–89.

III.C.8. Mining

Water is used in the mining industry for the extraction of minerals that may be in the form of solids (such as coal, iron, sand, and gravel), liquids (such as crude petroleum), and gases (such as natural gas). Mining water use includes activities such as quarrying, milling (crushing, screening, washing, and flotation of mined minerals), reinjecting extracted water for secondary oil recovery, hydraulic fracturing, dewatering, and other beneficial uses at the facility (such as dampening roads for dust control). The following water conservation measures can be used at mining facilities:

- □ As a critical first step in water conservation, it is necessary to understand where water is being used and why. This can be done by performing a water audit. For each water-using activity, determine the quantity and purpose of water being used. Determine water sources, how water is transported throughout the facility, and frequency of use. Assess water conservation methods for each activity, including alternate sources of water and possible reuses.

- □ Develop a maintenance program. Routinely inspect all plumbing and fixtures, equipment, water lines, spray systems, and valves and pumps for leaks, clogging, worn-out parts, and faulty operation. Repair problems promptly.

- □ Minimize the amount of water used for dust control by minimizing areas designed for traffic, limiting water application to the minimum based on need for dust suppression, and utilize reclaimed wastewater (if quality allows).

- □ Focus dust control sprays for stone cutting close to the production source to increase efficiency and limit flow rates in cutting and processing operations.

- □ Incorporate dry sorting techniques into your process, such as vibrating or conveyor sorting systems.

- □ Use high-pressure, low-volume spray nozzles (flow restrictors) on valves where high volume is not necessary.

- □ Use automatic shut-off valves on equipment to optimize water-use efficiency.

- □ Consider implementing reuse and recycling systems for aggregate washing.

Photograph courtesy of Nancy Barber, U.S.Geological Survey

- □ Wash only the products that are required to be clean.

- □ Recycle water for pressurizing ledge stone cutters.

- □ Recycle water used in well hydraulic fracturing operations.

The information in this section was obtained from the following references.

- New Hampshire Department of Environmental Services, 2007, p. 1–2.

- U.S. Environmental Protection Agency, 2010a, p. 2.

III.D. Water Reuse, Reclaimed Wastewater, and Alternate Sources of Water

Many water-using processes do not require potable water. For these processes, identifying other sources of water can result in water savings. The following sections describe sources of water that can be substituted for potable water, in certain cases.

III.D.1. Water Reuse

Reusing water for a purpose other than the primary purpose for which it was utilized can provide an additional source of water for water-using processes or operations that do not require potable water.

Water reuse in urban areas can be achieved by using non-potable water in water-using sectors such as irrigation, commercial, industrial, and public use. Water-using activities in urban areas that may utilize non-potable water include irrigation of public parks, recreational areas, transportation shoulders, and medians. Other activities include landscape irrigation and maintenance at residential, commercial, and industrial establishments. Non-potable water can also be used for irrigation of golf courses, commercial uses such as vehicle-washing facilities and laundry facilities, toilet flushing in commercial and industrial facilities, dust control and production of concrete at construction sites, and fire protection (by use of reclaimed-water fire hydrants) (U.S. Environmental Protection Agency, 2004, p. 7).

Industrial water reuse can be achieved in the areas of cooling water, boiler make-up water, and industrial process water. Power-generation facilities can use non-potable water for cooling water, especially for once-through cooling systems. Certain industrial processes can utilize non-potable water, such as those used in the pulp and paper industry and the manufacturing of petroleum and coal products. Water can be reused sequentially in some industrial processes. Some industrial process water (such as rinse water) is of sufficient quality after the process is completed that it can be reused in a later process within the same facility.

Water can be reused for certain agricultural purposes when irrigation water demands require additional sources of water and the reused water meets water-quality and other system requirements.

III.D.2. Utilizing Reclaimed Wastewater

Reclaimed wastewater is another non-potable source of water. Reclaimed wastewater can be collected, treated, and reused onsite, or might come from a water utility. The use of reclaimed wastewater may depend on the proximity to the source of reclaimed wastewater or the ability to transport the reclaimed wastewater to the point of use. Sources of reclaimed wastewater include, but are not limited to, effluent generated by domestic wastewater treatment facilities and industrial process waters. Reclaimed wastewater can be especially useful for landscape irrigation (lawns, parks, medians), air conditioning and cooling towers, industrial processing, toilet flushing, dust control, construction, vehicle washing, scenic waters and fountains, and environmental and recreational purposes. Reuse of water for environmental purposes includes wetland enhancement and restoration, and wildlife habitat and refuge creation. Recreational reuse of water can include water hazards on golf courses and activities such as fishing, boating, wading, and swimming (if water of sufficient quality is available) (U.S. Environmental Protection Agency, 2004).

Reclaimed water (especially reclaimed municipal water) typically contains more salts than potable water. If high salinity is a problem, reclaimed water can be diluted with potable water to produce a source of water that meets the salinity requirements of a given process.

III.D.3. Alternate Sources of Water

When drinking-quality water is not required, alternate water sources could include reclaimed municipal water, treated process water (onsite or offsite), or collected rainwater. Indirect potable reuse of water can be accomplished through stream augmentation and groundwater recharge because water is withdrawn and later treated for potable use.

Water discharged from one application or process can be captured, treated, and utilized in another application, if the quality of the water is matched with an appropriate end use. Potential alternative water sources include discharge from a single-pass cooling system, rainwater/stormwater, treated greywater, condensate from air-conditioning equipment, cooling equipment blowdown, and reverse osmosis system reject water.

Reusing Rainwater

The Metropolitan Transit Authority (MTA) New York City Transit (NYCT) Corona Maintenance/Car Wash facility in Corona, New York, contains subway car maintenance areas, parts storage spaces, some office space, and facilities for over 310 employees. The maintenance shop roof was designed with a system to harvest rainwater and subsequently filter the rainwater and store it in a 40,000-gallon underground storage tank. This stored water is then used at the 3,000-square-foot car wash facility. Reused rainwater for the car wash facility is estimated to save 2.455 million gallons of potable water per year, and a system of pumps and filter tanks also reclaims 80 percent of the used wash water.

[New York City Department of Design and Construction, 2011, Water matters: A design manual for water conservation in buildings, Long Island City, New York, p. 266–267]

IV. Methods of Documenting Water Use and Conservation Efforts

Water conservation efforts can benefit from documentation of the current water use within a facility (water audit), water conservation measures that are possible and those that are to be implemented (water conservation plan), and dissemination of water conservation results to the public. The following sections describe aspects of documenting water use in regard to water conservation efforts.

IV.A. Water Audit

Before any water conservation measures are adopted, it is important to conduct a water audit. The process of conducting an audit of the water system will enable a facility to collect data on how much and where water enters and leaves the facility and how water is used within the facility. Another goal of a water audit is to estimate unaccounted-for water use, which includes losses through leaks, improperly functioning or inoperative system controls, and unmetered sources of water. The water audit provides a facility with a baseline against which water conservation measures can be evaluated.

The main steps for conducting a water audit include (1) preparation and information gathering, (2) conducting a facility survey, (3) preparing an audit report, and (4) determining a total water cost (New Mexico Office of the State Engineer, 1999).

Information including building schematics, location maps identifying metered and unmetered sources of water for the facility, an inventory of all water-using equipment in the facility, an inventory of plumbing fixtures, utility records (both water and sewer), records of actual water use for the facility, any prior water audits, and anticipated future water and sewer billing rates are important to acquire. Ancillary information such as the number of employees, production information, and (or) occupancy rates are also useful. These data can be used to determine the amount of water used by the facility on a monthly basis either to provide services (such as water used per patient at a hospital or water used per meal served at a restaurant) or to produce a product (such as gallons of water used per ton of product or gallons of water used per unit produced).

A physical survey of the facility is done to collect data on water-using equipment throughout the facility. For instance, checking the actual equipment against the inventory list, determining hours of operation, calibrating water meters or determining water flow amounts if permanent meters are not installed, noting discrepancies between calibrated/measured flow rates and manufacturers' listed specifications, determining the quality of the water used throughout the system, and identifying both interior and exterior water uses are all important pieces of information to obtain. A physical survey of the facility also provides the opportunity to discuss water conservation suggestions from employees who are familiar with the equipment and process used by the facility. A daily water usage amount can be calculated for each of the operations and processes within or outside the facility, and these individual amounts can be added together to obtain a water usage amount for the entire facility. The total amount obtained in this manner can then be compared to other records such as consumption figures from the water utility.

The information gathered in the first two steps is then developed into a final report that can be used as a baseline upon which water conservation efforts can be measured. Items of special use in the final report include updated facility schematics and diagrams of water flow throughout the system (interior and exterior); updated inventory of all water-using equipment, including the comparison of manufacturers' specifications to actual water use measured; operational schedules for all water-using equipment (interior and exterior, especially landscape irrigation, if applicable); water-usage figures, including a total for the facility and amounts for each operation or process; and comments and observations obtained during the physical survey of the facility.

The information from the final report can be used to determine the total cost of the water used. The total cost of the water includes not only the utility cost but other factors such as heating, cooling, energy costs to move water throughout the system, water-treatment costs (pretreatment, chemical treatment, and predisposal treatment), and sewer discharge costs. Determine the total annual cost and calculate the cost to provide services or to produce a product. Figures of cost per unit produced, cost per customer served, and seasonal fluctuations in water costs are also useful as baselines.

Examples of how to conduct a water audit can be found in the following references.

- New Mexico Office of the State Engineer, 1999, p. 18–22.
- North Carolina Department of Environment and Natural Resources, 2009, p. 106–111.
- New Hampshire Department of Environmental Services, 2010k (industrial water use).
- Vickers, 2001, p. 20–23 (domestic water use).
- Vickers, 2001, p. 152–155 (landscape water use).
- Vickers, 2001, p. 241–243 (industrial, commercial, and institutional water uses).
- Vickers, 2001, p. 350–351 (agricultural uses).

Examples of forms to use to collect information during a water audit can be found in the following references.

- North Carolina Department of Environment and Natural Resources, 2009, p.18–26.
- Vickers, 2001, p. 410–412 (domestic indoor use).
- Vickers, 2001, p. 413–416 (landscape and irrigation use).
- Vickers, 2001, p. 417–421 (industrial, commercial, and institutional water uses).

IV.B. Water Conservation Plan

A water system audit provides a facility with information on the cost of water for that facility at a given point in time. This cost is used as a baseline for future comparison to determine the effectiveness of future water conservation measures. The next step is to form a plan of action as to what conservation measures are to be put into place and to develop these into a cohesive water conservation plan.

Areas that would produce cost-effective savings without adversely affecting production or services need to be identified and evaluated. Since the cost of water varies based on factors in addition to the utility cost, the greatest savings are generally obtained when dealing with water that has a high total cost. Possible conservation measures can be evaluated based on annual water savings (with or without treatment costs), implementation costs (including time required for implementation), operational costs, and the time it will take for the cost of implementing the conservation measure to be recouped from the savings.

Once potential water conservation measures have been evaluated, a decision needs to be made as to which measures will be implemented immediately, which measures may be implemented in the future (or need more testing/evaluation before implementation), and which measures are not cost effective. These implementation decisions can be based not only on the actual amount of savings, but on other factors such as the speed at which a particular measure can be implemented; enhancement of public image; and public, customer, and employee goodwill.

Implementation of a water conservation plan will generally begin with no-cost or low-cost, quickly implemented options and those options that have guaranteed or proven savings. These include measures such as leak detection and repair, making the public aware that only cold water is being used in restroom sinks (to reduce the amount of water wasted by letting the water run until it is hot), eliminating water usage when an alternative exists, installing timers to reduce water flow when water is not needed. Major water savings measures can be implemented next—those which will result in greater, albeit more long-term, water savings. These measures can include installation of water meters and added controls for water flow, reduction of existing water flow where the current flow is higher than manufacturer specifications, and reduction of water pressure where the current pressure exceeds that needed. Other water savings can be realized through the reuse and recirculation of water and by switching from potable to non-potable water, where potable water is not required.

Examples of how to prepare a water conservation plan can be found in the following references.

- North Carolina Department of Environment and Natural Resources, 2009, p. 18–22.
- Vickers, 2001, p. 2–3.

IV.C. Public Information and Education

Informing and educating the public (which includes facility employees and customers) is an important part of a water conservation plan. Generating positive public opinion is an intangible benefit of employing water conservation measures.

Employee awareness, education, and involvement shows a facility's commitment to water conservation. A facility can involve its employees by requesting employee support, suggestions, and feedback. If employees don't understand why it is important to conserve water and what the benefits are, they are less likely to effectively implement or participate in a water conservation plan.

The success of a facility's water conservation efforts can be publicized through internal and external communication outlets. Information shared can include the water conservation measures implemented (including realized water savings), and conservation goals set and reached. This information can also be shared by displaying the information in the facility itself or at trade shows, workshops, and other water conservation events. Contests (such as posters, slogans, or conservation ideas) for employees, faculty and students, and the public can be sponsored as a way to further water conservation awareness.

V. Appendix (Annotated Bibliography)

V.A. Books, reports, and other publications

A & N Technical Services, Inc., 2005, *BMP costs & savings study: A guide to data and methods for cost-effectiveness analysis of urban water conservation best management practices*: The California Urban Water Conservation Council, Sacramento, Calif., 142 p.
[Primarily oriented toward domestic water conservation, this report contains detailed descriptions and cost savings analysis of such water conservation measures as residential irrigation controllers, use of greywater, high efficiency washing machines, hot water recirculation on demand, universal and multi-family water metering, conservation pricing, residential plumbing retrofits, residential surveys, and ultra-low flush toilets. Also chapters on cooling and industrial processes, X-ray film processing, food service equipment, self-closing faucets, large landscape irrigation, and system audits and leak detection.]

CH2MHill, 2002, *Air Force water conservation guidebook*: Air Force Civil Engineer Support Agency, Tyndall AFB, Fla. [variously paginated].
[This report describes water conservation planning and best management practices for implementation at U.S. Air Force installations and bases. Chapters describe typical Air Force water use and the implications of Executive Order 13123, which requires the Federal government to determine a baseline for water consumption and establish water conservation goals for all Federal agencies. Best management practices that are described include establishing public information and education programs; distribution system audits; leak detection and repair; water-efficient landscaping; retrofitting with ultra-low flush toilets and low-flow faucets and showerheads; boiler and steam systems; single-pass cooling equipment; cooling tower management; water use and recycling; and miscellaneous high water-using processes such as depot activities, aircraft and ground vehicle washing systems, maintenance facilities, kitchen and food processing areas, cleaning/laundry services, laboratories, and hospitals.]

American Society of Mechanical Engineers, 2010, *ASME Water management technology best management practices and innovations for the process industries*: American Society of Civil Engineers, Washington, D.C. [variously paginated].
[The American Society of Mechanical Engineers (ASME) convened a workshop titled "Water Management Technology Best Management Practices and Innovations Workshop for the Process Industries" on May 13–14, 2009, at U.S. Environmental Protection Agency (USEPA) Headquarters in Washington D.C., as part of the follow-up to ASME's water-management technology roadmap workshop to identify roles for ASME in the development of industrial water use best management practices (BMPs). This report begins with a description of current trends and drivers associated with water management in industry to illustrate the importance of developing BMPs and furthering innovations in industrial water management. It then summarizes the structure of the workshop and the diverse group of participants that attended. The report next details the results from the workshop including pertinent information provided in presentations, as well as input received from participants during breakout group discussions. Lastly, it identifies high priority action items for ASME to pursue in the near-term.]

American Water Works Association, 2006, Water conservation programs—a planning manual: Manual of Water Supply Practices M52, American Water Works Association, 149 p.
[This AWWA manual is intended for use by water utilities that are contemplating the development of a conservation program; the manual provides information on how to develop, implement, and measure the success of a water utility conservation program. In addition, water suppliers that already have a conservation program in place can use the information in this manual for improvements to their particular program and gain the benefits of a more comprehensive approach. Chapter titles include introduction, need for efficiency and setting goals, analysis of water use and water savings, evaluation of benefits and costs, creating a formal water conservation program plan, and conservation plan development and implementation—dealing with perceptions, barriers, and obstacles to effective water conservation. There is also an appendix describing eight case studies of water conservation programs within cities of varying populations.]

Connecticut Department of Environmental Protection, 2006, *Best management practices for golf course water use*: Connecticut Department of Environmental Protection, 72 p.
[In November 2000, the Connecticut Department of Environmental Protection and the Connecticut Institute of Water Resources began collaborating on a water-management information transfer project. The focus of the project was to facilitate the development of a list of potential best management practices for golf course water use and to manage an outreach effort to include a one-day conference for industry professionals. These BMPs were developed by a work group consisting of superintendents, environmental regulators, and specialists from local engineering, scientific, and irrigation consulting groups. This report details the resulting best management practices for golf course water use including specific

BMPs for water source management, such as pond location and design, leakage and groundwater recharge from constructed ponds, pond usage and maintenance, water-level monitoring in storage ponds, environmental and regulatory permit considerations, and metering. Other BMPs include irrigation leak detection and system layout, irrigation heads and sprinklers, system maintenance, cultural practices for turfgrass and landscaping, equipment maintenance practices, irrigation requirements, water conservation, water-quality protection for riparian/wetland buffer zones, wetland and watercourse protection, stormwater management, erosion and sediment control, turf management, nutrient and integrated pest management (IPM) plans, and spill response.]

Cooley, Heather, Christian-Smith, Juliet, and Gleick, P.H., 2008, *More with less: Agricultural water conservation and efficiency in California-A special focus on the Delta*: Pacific Institute, Oakland, Calif., 69 p.
[This report outlines water conservation measures for agricultural irrigation water used in the Sacramento-San Joaquin Delta in the face of competing municipal and environmental needs. Almost half of the water used for agriculture in the state comes from water that originally flowed into the Delta, and more than half of Californians rely on water conveyed through the Delta for at least some of their water supplies. This report looks at four scenarios for increasing agricultural water-use efficiency: Modest Crop Shifting—shifting a small percentage of lower-value, water-intensive crops to higher-value, water-efficient crops; Smart Irrigation Scheduling—using irrigation scheduling information that helps farmers more precisely irrigate to meet crop water needs and boost production; Advanced Irrigation Management—applying advanced management methods that save water, such as regulated deficit irrigation; and Efficient Irrigation Technology—shifting a fraction of the crops irrigated using flood irrigation to sprinkler and drip systems.]

Cundy, Tereza, 2009, Industrial best practices for water management: A guide for industry to help reduce your water footprint: Nova Scotia, Dalhousie University Eco-Efficiency Centre, 66 p.
[This report reviews best practices for water management in industrial parks in jurisdictions across Canada and elsewhere. The document's format is modular, where the content of each module is meant to help businesses understand how best to conserve water. Case studies are provided throughout in order to demonstrate how a number of companies have reduced water consumption through more efficient practices. Topics include environmental management of industrial parks, industrial parks and water, industrial parks and integrated plans, rainwater harvesting, reuse and redistribution, on-site treatment facility, dual plumbing, stormwater management, storage controls, green roofs, pervious pavement, infiltration controls, infiltration trenches, swales, vegetated filter strips, storm and wastewater treatments, wetlands, metering, leaks, cooling and heating, cleaning, rinsing, in-process reuse, cooling towers, equipment cooling, equipment rinsing and cleaning, and greywater reuse systems.]

East Bay Municipal Utility District, 2008, *Watersmart guidebook: A water-use efficiency plan review guide for new businesses*: East Bay Municipal Utility District, 242 p.
[This guidebook provides information on water-saving technologies applicable in the commercial, industrial, and institutional sectors. The guidebook is intended for use as a resource by existing and new business; developers, and designers; planing agencies; and water providers.]

Ecology & Environment, Inc., User's manual to best management practices for gravel pits for the protection of surface water quality in Alaska: 2006, Alaska Department of Environmental Conservation, 43 p.
[This manual outlines and frames best management practices (BMPs) for gravel pit operations where stormwater runoff may impact the water quality of lakes, rivers, streams, and wetlands. It will help gravel pit owners and operators in establishing BMPs that will result in cleaner water, help fulfill obligations to a permit and take the guess work out of developing BMPs and pollution control measures for gravel pits throughout Alaska. This manual does not include BMPs for in-stream operations.]

Flack, J.E., 1982, Urban water conservation—increasing efficiency-in-use residential water demand: American Society of Civil Engineers, Water Resources Planning and Management Division, 99 p.
[This early report is an assessment of various water conservation measures aimed at reducing residential water usage. The report examines the various measures used to reduce water demand and identifies those that are applicable to residential areas. Fixtures such as water meters, recycle systems, water saving devices, and flow-reducing devices were examined. System and household leakage reduction as well as water-use restrictions were among the operational methods investigated. Social and economic methods of public education, building code modifications, horticultural changes, and pricing policy were also studied. A review of the literature to date was made to determine the water savings that each conservation measure could accomplish. The study estimates that water demand reductions of as much as 35 to 40 percent were possible though implementation of a combination of water conservation methods without incurring hardship on most water users and that demand reduction techniques could successfully be incorporated into a water utility's management program.]

Florida Department of Environmental Protection, 2002, *Florida water conservation initiative*: Florida Department of Environmental Protection, Tallahassee, Fla., 163 p. [In response to growing water demands, water supply problems, and one of the worst droughts in Florida's history, the Florida Department of Environmental Protection led a statewide Water Conservation Initiative (WCI) to find ways to improve efficiency in all categories of water use. The WCI evaluated how Floridians use water and what can be done to make significant, permanent, cost-effective improvements in water-use efficiency. Six work groups identified and investigated a variety of technological, behavioral, educational, regulatory, and economic methods of improving water-use efficiency. A total of 51 recommendations—22 high priority, 20 medium priority, and 9 low priority—are included in this report. Some of the most important include Agricultural Irrigation—such as cost share programs to implement irrigation best management practices, more use of mobile irrigation labs to evaluate irrigation efficiency, improvements in the recovery and recycling of irrigation water, and greater use of reclaimed water for irrigation. Landscape Irrigation—for watering lawns, ornamental plants, and golf courses can significantly reduce water use through more efficient irrigation system design, installation, and operation, and by reducing the amount of landscaping that requires intensive irrigation. Water Pricing measures—such as conservation and drought rate structures, informative utility billing, and other techniques to encourage water users to conserve water. Industrial, commercial, and institutional users can improve their efficiency through certification programs for businesses that implement industry-specific best management practices and through water use audits, improved equipment design and installation, and greater use of reclaimed water. Indoor Water Use—the greatest potential for conserving water in this sector is through increasing the proportion of Florida homes and businesses that use water-efficient toilets, clothes washers, showerheads, and dishwashers. Reuse of Reclaimed Water can be made more widespread and efficient by proper pricing, by more metering of its use, and by making progress on increasing reuse in southeastern Florida.]

Gleick, P.H, Haasz, Dana, Henges-Jeck, Christine, Srinivasan, Veena, Wolff, Gary, Cushing, K.K., and Mann, Amardip, 2003, *Waste not, want not: The potential for urban water conservation in California*: Pacific Institute, Oakland, Calif., 166 p. [This report, "Waste Not, Want Not," strongly indicates that California's urban water needs can be met into the foreseeable future by reducing water waste through cost-effective water-saving technologies, revised economic policies, appropriate state and local regulations, and public education. The report estimates that one-third of California's current urban water use —more than 2.3 million acre-feet (AF)—can be saved with existing technology. At least 85 percent of this (more than 2 million AF) can be saved at costs less than what it would cost to tap into new sources of supply and without the many social, environmental, and economic consequences that any major water project will bring. Major topics include conservation and efficiency in the urban sector, defining water "conservation" and "efficiency," economics of water savings, matching water need with water quality, recycled water, existing indoor residential conservation efforts and approaches, indoor residential water conservation: methods and assumptions, existing outdoor conservation efforts and approaches, outdoor residential water conservation: methods and assumptions, current California water use in the commercial, industrial, and institutional (CII) sectors, methods for estimating CII water use and conservation potential, estimating water use by industry and end use, recommendations for commercial, industrial, and institutional water conservation, and cost-effectiveness of water conservation and efficiency improvements.]

Golf Course Superintendents Association of America, 2009, *Golf course environmental profile: Volume II water use and conservation practices on U.S. golf courses*: Golf Course Superintendents Association of America, 49 p. [This volume provides the most accurate portrayal of water use and conservation practices on golf courses in the United States. It establishes a definitive baseline that will be compared to data from future surveys to identify change over time. The report gives the results of a survey of water-use practices at 2,548 golf courses across 6 agronomic regions of the United States on such factors as irrigated turfgrass acres, irrigation water use, irrigation water use across agronomic regions, monthly irrigation water use, irrigation water sources, irrigation systems, irrigation water expenditures, recycled water use, irrigation water quality, irrigation water treatments and products delivered through the irrigation system, irrigation water management and conservation, and drought management plans.]

Great Lakes–St. Lawrence River Water Resources Regional Body, 2011, Water conservation and efficiency program assessments, Great Lakes–St. Lawrence River Water Resources Regional Body: individual State and Canadian Province reports, accessed February 6, 2012, at *http://www.glslregionalbody.org/Resolutions.aspx*. [This report gives individual state reports on current and planned water conservation programs within Illinois, Indiana, Minnesota, Michigan, Wisconsin, Ohio, Pennsylvania, and New York, as well as Ontario and Quebec Provinces. Each state and province report covers such topics as ongoing water conservation programs within each state or province, current regulations that govern water

use and reporting, as well as water conservation and reuse, and planned water conservation and reuse programs.]

Green, Deborah, 2010, Water conservation for small and medium-sized utilities: American Water Works Association, 167 p.
[This AWWA publication is a revision of a previous 1993 guide published by AWWA. This revision was written for the small- and medium-sized water utility considering the implementation of a water conservation program because they are facing water shortage issues. The USEPA defines a small-sized utility as one with fewer than 10,000 service connections and a medium-sized utility as one with between 10,000 and 100,000 connections. The report covers such utility-oriented topics as factors determining future water demand, determining current water usage, characterizing the service population, system audit, leak detection and repair, metering, pricing, funding a water conservation program, training a water conservation coordinator, and public information. The report reviews such customer conservation measures as indoor residential measures; outdoor residential measures; xeriscaping; irrigation systems; promotions and incentives; alternative water sources; commercial, institutional, and industrial measures; commercial landscape measures; and industrial conservation measures. The report also has chapters devoted to designing a conservation program and implementing a conservation program, and includes worksheets to estimate potential water savings.]

Kaminski, Laura E., 2004, *Public sector water conservation: Technology and practices outside the Great Lakes–St. Lawrence region*: Great Lakes Commission, 144 p.
[This document is one of three reports developed through the project titled “Developing a Water Conservation ‘Tool Kit’ for the Great Lakes–St. Lawrence Region,” supported by the Great Lakes Protection Fund and authored by the Great Lakes Commission. The objective of the report is to assess the best available technologies and options for water conservation in the public sector outside of the Great Lakes–St. Lawrence region. The report highlights seven successful comprehensive water conservation programs from across the United States, Canada, and around the world, ranging in size from a water conservation strategy for a single city to one for an entire country. These programs have been selected based on their use of efficient technology and other conservation measures to achieve greater water efficiency and increased sustainability within their jurisdictions. These strategies include a variety of water conservation initiatives, such as public education and media campaigns, water meters, water rates, water audits, leak detection programs, performance contracting, outdoor watering restrictions, outdoor irrigation retrofit programs, water efficient plant selection and other landscaping plans, rainwater collection, community recognition programs, financial incentives or disincentives, and ordinances and resolutions.]

Kenny, J.F., Barber, N.L., Huson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, *Estimated use of water in the United States in 2005*: U.S. Geological Survey Circular 1344, 52 p.
[This report is the twelfth in a series of reports that includes estimates of water withdrawals by state, source of water, and category of use.]

Lameka, Rebecca, 2004, *Briefing paper: Summary of current water conservation practices in the public water supply sector of the Great Lakes–St. Lawrence region*: Great Lakes Commission, Briefing Paper, 66 p.
[This briefing paper is one of three products developed through the project titled “Developing Water Conservation ‘Tool Kit’ in the Great Lakes Region,” supported by the Great Lakes Protection Fund and authored by the Great Lakes Commission. The objective was to assess the state of water conservation practices in the public water supply sector in the Great Lakes region. To evaluate the state of water conservation efforts in the region, a survey of public water suppliers was developed and administered in March 2003. A randomly selected group of 525 municipal water supply facilities was surveyed from a larger set of 1,828 facilities. Surveys were mailed to the selected facilities to gather information about water conservation practices implemented in their service areas. Topics covered by the survey included water conservation activities, formal conservation plans, financial incentives, guidelines, regulations, future trends in conservation activities, and education. A few trends in the responses to the survey are worth noting. (1) Meter calibration and replacement and leak detection and repair are among the most practiced conservation activities by water systems surveyed in the Great Lakes region. (2) The least practiced conservation activities include subsidizing low-flow plumbing fixtures and the application of inverted pricing blocks for water rates. (3) Almost two-thirds (65 percent) of the facilities that responded do not operate under any formal conservation plan. (4) Education programs exist within less than half of the facilities (48 percent) responding. Bill inserts seem to be the preferred approach to consumer education.]

Lameka, Rebecca, 2004, Regional case studies: Best practices for water conservation in the Great Lakes–St. Lawrence region: Great Lakes Commission, 42 p.
[This paper is one of several products being developed by the Great Lakes Commission under a project titled “Developing Water Conservation ‘Tool Kit’ in the Great Lakes Region.” The purpose of this paper is to present in greater detail examples of the best water conservation practices in the public water supply sector in the Great Lakes region through a case study approach. There were two case studies selected, one each from the United States and Canada. The first case study is the city of Chicago, Illinois, and the second is the region of Waterloo, Ontario. The city of Chicago and the region of Waterloo were chosen as case studies of best water conservation practices because

of their comprehensive approach to water-management planning. These plans include a variety of water conservation activities such as financial incentives and disincentives, water audits, public education and outreach, and storm-water management. This report presents each case study in a detailed summary. General characteristics of each locale are described including geographic area, water supply, population trends, and other influential characteristics on water management. Then, water conservation practices are summarized in topical categories. Finally, the best water conservation practices for application to regional water management in the Great Lakes–St. Lawrence River region are highlighted.]

LandStudies, Inc., and the Pennsylvania Environmental Council, 2009, *Golf course water resources handbook of best management practices*: Pennsylvania Department of Environmental Protection, 55 p.
[The Golf Course Water Resources Handbook of Best Management Practices provides a concise overview of 18 best management practices (BMPs) to help improve and protect water resources. For each of the 18 BMPs the report provides a summary of the BMP, a list of benefits the user can realize from implementing the BMP, information about a golf course that has already implemented the BMP (including the person to contact), and a brief list of references one can use to find extensive and more detailed information about a given BMP. Some water conservation BMPs that are listed include selection and maintenance of irrigation equipment, when and where to irrigate, stormwater collection and storage, stormwater reuse, wetlands restoration, greywater reuse, and wastewater reuse.]

Maryland Department of the Environment, 2003, *Developing and implementing a water conservation plan: Guidance for Maryland public water systems on best management practices for improving water conservation and water use efficiency*: Maryland Department of the Environment, Water Supply Program, 32 p.
[Drought conditions experienced in Maryland in both 1999 and 2002 impacted some water systems' ability to meet their customers' needs and prompted the state to consider measures that might improve water systems' water-use efficiency. In January 2000, the Governor formed the Maryland Technical Advisory Committee on Water Supply Infrastructure. The Committee looked at water systems' capacity to meet demands during drought periods, high levels of unaccounted water as a result of leaking distribution systems, and the issue of inadequate funding for necessary water system improvements, and made recommendations to the Governor regarding community water system infrastructure deficiencies and needed improvements in Maryland. It was recommended at that time that the state focus water conservation efforts on water systems that serve more than 10,000 people and have high per capita usage. This report gives guidance on developing a water conservation plan for any Maryland municipal water provider, and contains the following appendices: MDE Water Audit Guidance, MDE Water Audit Instructions and Worksheet, MDE Annual Water Audit Summary, USEPA Water Accounting and Loss Control, USEPA Preliminary Water Demand Forecast Worksheet, USEPA Cost of Supply-Side Facilities Worksheet, USEPA Analysis of Each Conservation Measure Worksheet, Water Conservation Public Education, and Case Studies.]

Moreau, D.H., 1991, *Water conservation in Durham—economic and financial impacts of selected programs*: Water Resources Research Institute of the University of North Carolina, 116 p.
[This study explores water conservation options for the City of Durham, North Carolina, which was facing a possible expenditure, in 1991, of $100 million for expansions to its water and wastewater facilities. The report tries to answer the question as to whether water conservation measures can reduce the city's wastewater stream so that the capacity of receiving streams would not be exceeded. The author details the current (1991) water use in Durham for residential, institutional, commercial, and industrial users; the current (1991) wastewater flows in Durham; performs an economic evaluation of the result of instituting standard residential conservation measures; discusses the impacts of conservation measures on city revenues and expenditures; and makes recommendations to institute aggressive water conservation measures, develop models of water use and wastewater generation to help gage water demand and the effects of water conservation, adopt stricter plumbing codes, adopt and odd-even lawn watering schedule, and develop a special peak daily water pricing for large volume users.]

New England Interstate Water Pollution Control Commission, 1996, Water conservation best management practices for quarries and sand and gravel operations: MRI Water Conservation Technical Bulletin #11, New England Interstate Water Pollution Control Commission, Wilmington, Mass.

New Hampshire Department of Agriculture, Markets, and Food, 1998, *Irrigation—Best management practices for agriculture in New Hampshire*: New Hampshire Department of Agriculture, Markets, and Food, 18 p.
[This report presents accepted BMPs for reduction of water use in growing various crops. Major topics include irrigation scheduling, methods to measure soil moisture, soil water holding capacity, crop moisture extraction depth, comparison of irrigation methods, micro and drip irrigation, managing for water conservation, and managing to conserve soil water.]

New Hampshire Department of Environmental Services, 2007, *Water efficiency practices for quarries and sand and gravel operations*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-8, 3 p. [Washing and sorting aggregates is a water-intensive process. Considerable water is lost to evaporation and product incorporation. Employing water-efficiency practices reduces this water loss and saves money, protecting surface-water and groundwater supplies. This fact sheet enumerates water-efficiency practices and procedures to minimize process water use in four categories: general water-efficiency practices, water recycling systems, dust control, and stone cutting.]

New Hampshire Department of Environmental Services, 2010a, Water efficiency practices for outdoor water use: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-3, 4 p. [This fact sheet is aimed at homeowners and details ways that they can reduce their outdoor water use for such tasks as lawn sprinkling, irrigation, and car washing. Outdoor water uses increase water consumption during spring and summer by an average of 50 percent. Landscape watering and car washing are the two main outdoor water uses responsible for this demand for water. Areas where water use can be reduced include landscape and garden irrigation, establishing turf grass, swimming pools, driveway cleaning, and car washing. This is one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation.]

New Hampshire Department of Environmental Services, 2010b, *Water efficiency practices for agricultural irrigation*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-5, 4 p. [Agricultural irrigation uses considerable volumes of water and is one of the largest groups of consumptive water uses in the state. The water-efficiency practices listed in this fact sheet describe how to reduce excess water use through implementation of efficient irrigation technology, effective irrigation scheduling, and soil moisture determination and retention. These practices are designed to minimize water losses from evaporation, deep percolation, and runoff. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as irrigation technology and methods; micro-irrigation; sprinkler irrigation; water-efficiency practices for field and orchard grown crops; irrigation management for water efficiency; additional practices for irrigation water efficiency; and water conservation for greenhouse, nursery stock, and potted plant irrigation.]

New Hampshire Department of Environmental Services, 2010c, *Water efficiency practices for golf courses*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-6, 4 p. [Irrigation of turf grass is a water-intensive practice, but conservation techniques can help reduce demands on surface-water and groundwater supplies used for irrigation. Irrigation water-efficiency practices use techniques that minimize water losses while satisfying turf grass water needs. Water losses typically include evaporation, deep percolation, and runoff. The water conservation practices listed in this fact sheet help control losses through implementation of efficient irrigation technology, effective irrigation scheduling, soil moisture determination and retention, low-flow plumbing, and other water-saving practices. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as general water-efficiency practices, irrigation efficiency, domestic/sanitation water-efficiency practices, and kitchen/cafeteria water-efficiency practices.]

New Hampshire Department of Environmental Services, 2010d, *Water efficiency practices for industrial water users*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-7, 5 p. [Many industrial processes are water intensive including washing and rinsing, heating and cooling, shop clean-up and outdoor water use. The water-efficiency practices in this fact sheet address these industrial water uses. Employing these methods saves considerable water and water-related costs. Though seemingly costly to implement, investment payback on most water-efficiency methods can be relatively short. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as general water-efficiency practices, rinsing and cleaning water-efficiency practices, non-contact cooling water-efficiency practices, hot water and steam systems water-efficiency practices, and outdoor water-efficiency practices.]

New Hampshire Department of Environmental Services, 2010e, Implementing a water efficiency and conservation program for public water utilities: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-WSEB-26-9, 7 p. [The goal of an effective water demand management program should be to allow water users to maintain the benefits of their water needs while at the same time not causing damage to the environment or jeopardizing the sustainability of water to other existing or future users. Traditionally, water utilities have focused on developing additional supplies to satisfy increasing demands associated with population growth and economic development. Increasingly, however, water utilities throughout New Hampshire are recognizing that water conservation programs can reduce current and future water demands to benefit the customer, the utility, and the environment. This fact sheet describes how a water utility can manage the demand of water from its customers through the

implementation of water-efficiency practices. Topics covered include why a utility would want to promote water conservation, water conservation approaches, public education, outreach, and technical assistance, water fixture retrofitting and replacement, system metering and improvements, and water conservation incentives through rate structuring.]

New Hampshire Department of Environmental Services, 2010f, *Water efficiency practices for laundry facilities*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-10, 2 p. [Laundry facilities range in size from industrial operations to self-service machine businesses. Laundry operations can use the water-efficiency practices in this fact sheet to save water and decrease the costs associated with water supply and wastewater discharge. A large amount of energy goes into heating water for washing. Reducing the amount of water used in laundry operations will also save on energy costs. A comprehensive audit should be performed to assess the facility's water system and identify locations where these practices can be employed to conserve water. This fact sheet is one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation.]

New Hampshire Department of Environmental Services, 2010g, *Water efficiency practices for snowmaking*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-11, 2 p. [Most snow making water conservation efforts focus on efficient water-to-snow conversion and accurate snow placement, minimizing evaporative and runoff losses. This fact sheet lists management practices that address effective snow application to prevent water losses. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as efficient snowmaking practices, snow pack management practices, and snowmaking system designs.]

New Hampshire Department of Environmental Services, 2010h, *Water efficiency practices for aquaculture*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-12, 2 p. [Aquaculture is the practice of raising fish in hatcheries and farms for food, sport, or release to the wild. Aquaculture operations generally use large quantities of water to maintain water levels in production tanks and raceways. The various requirements associated with different fish species and ages affect water reuse throughout the rearing system. For example, adult fish can better survive somewhat degraded water-quality conditions than young fish, so recycling is more feasible in tanks containing older fish. Since large volumes of water are required to maintain aquaculture systems, water-efficiency practices are important to reduce the demands on source water. The water-efficiency practices in this fact sheet involve active monitoring and control of source water supplies and the application of these practices throughout the facility. A comprehensive audit can be performed to assess the facility's water system and identify locations where these practices can be employed to conserve water.]

New Hampshire Department of Environmental Services, 2010i, *Water efficiency practices for institutions*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-13, 3 p. [Schools, colleges, universities, and other institutions that provide room and board can realize significant water and cost savings by implementing the water-efficiency practices discussed in this fact sheet. These practices address water use outdoors and in living areas, classrooms, cafeterias, and laundries. A comprehensive audit should be performed to assess the facility's water system and identify locations where these practices can be employed to conserve water. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as general water-efficiency practices, domestic/sanitary water-efficiency practices, kitchen/cafeteria water-efficiency practices, and outdoor water-efficiency practices.]

New Hampshire Department of Environmental Services, 2010j, *Water efficiency practices for health care facilities*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-14, 4 p. [Health care facilities with steam sterilizers, autoclaves, x-ray equipment, and in-house laundries or kitchens can be significant water consumers, using as much as 30,000 gallons of water per day. The water-efficiency practices discussed in this fact sheet can save considerable water and reduce water-related costs. A comprehensive audit should be performed to assess the facility's water system and identify locations where these practices can be employed to conserve water. As one of a series of 16 fact sheets published by the New Hampshire Department of Environmental Services concerning water conservation, this fact sheet covers such topics as domestic/sanitary water-efficiency practices, sterilizing equipment water-efficiency practices, X-ray equipment water-efficiency practices, kitchen/cafeteria water-efficiency practices, and outdoor water-efficiency practices.]

New Hampshire Department of Environmental Services, 2010k, *Performing a business or industry water use and conservation audit*: New Hampshire Department of Environmental Services Environmental Fact Sheet WD-DWGB-26-16, 3 p. [Performing a water audit of the facility is the first step in designing an effective water conservation plan. A water audit surveys all water-using or conveying fixtures, plumbing, equipment, and practices at a business or manufacturing facility to determine the present water uses,

losses, and conservation practices, and to recommend improvements. A water audit serves as the starting point for identifying losses and implementing useful water-efficiency practices. An audit for a large facility that uses vast quantities of water is a significant undertaking, and may require the auditor receive help from a consultant or the water utility. The fact sheet lists the following steps as a general guide to the water audit process: identify your source, gather all existing information, quantify your water use from each source, perform the audit, analyze the audit results, develop a forecast of future water use, prepare a benefit/cost analysis of potential water conservation measures, and develop a long-range water conservation plan.]

New Mexico Office of the State Engineer, 1999, *A water conservation guide for commercial, institutional and industrial users*: New Mexico Office of the State Engineer, prepared by Schultz Communications, Albuquerque, N. Mex., 107 p.
[An excellent water conservation guide for commercial, institutional, and industrial users published by the New Mexico Office of the State Engineer. Chapter topics covered include how to create a successful water conservation program; water conservation guidelines for indoor/domestic use; water conservation guidelines for landscaping; water conservation guidelines for cooling and heating; water conservation measures for specific processes and industries; and case studies in commercial, institutional, and industrial water conservation.]

New York State Department of Environmental Conservation, 1989, *Water conservation manual: For development of a water conservation plan*: New York State Department of Environmental Conservation Division of Water, 62 p.
[This water conservation manual, developed by NYSDEC, focuses on municipal water conservation methods and is intended to help local water supply systems to comply with state legislation that requires a water conservation program as a part of any new application to NYSDEC for a Public Water Supply Permit. The manual is a “how to” guide that addresses a large number of water conservation measures such as water metering, the conduct of a system water audit, the detailed study of water demand, reduction in system water loss, and reduction in system water demands. The report contains two main sections, “Information Requirements” and “Water Conservation Methods.” The Information Requirements section describes the various types of water meters that are currently in use and how water metering fits into a water conservation program. It also outlines how to prepare a water supply audit and a water demand forecast. The Water Conservation Methods section outlines common water conservation methods currently in use including leak detection and repair, system pressure controls, water pricing and water rate structure, retrofitting of domestic water fixtures with flow-reducing devices, and landscape water conservation. The report provides many sample worksheets to aid in implementing a municipal water conservation program.]

North Carolina Department of Environment and Natural Resources, 2009, *Water efficiency manual for commercial, industrial and institutional facilities*: North Carolina Department of Environmental and Natural Resources, 149 p.
[A comprehensive document that outlines the best management practices for water conservation for commercial and institutional facilities, as well as processes for the textile, food and beverage, and metal finishing industries. It gives case studies to illustrate most BMPs. Chapter topics include reasons for water-efficiency efforts; sound principles of water management; conducting a successful water-efficiency program; water-management options for sanitary/domestic uses, cooling and heating, boilers, kitchen and food preparation, commercial laundries, cleaning, rinsing and in-process reuse, reuse and reclamation, and landscaping; industry-specific processes for textiles, food and beverage, and metal finishing industries; auditing methodology and tools; and drought contingency planning for facility managers.]

Pekelney, D.M., Chesnutt, T.W., and Hanemann, W.M., 1996, *Guidelines to conduct cost-effectiveness analysis of best management practices for urban water conservation*: California Urban Water Conservation Council, Sacramento, Calif., 112 p.
[The California Urban Water Conservation Council (CUWCC) and signatory organizations face the challenge of deciding which BMPs to implement. The Memorandum of Understanding Regarding Urban Water Conservation in California (MOU) states that cost-effectiveness is a fundamental criterion for making such decisions. There is no single correct way to apply cost-effectiveness analysis (CEA), and there is valid controversy on several key issues needed for CEA of BMPs—water savings, discount rates, project life spans, and appropriate cost accounting. Differences in method and assumptions can make large differences in results of a CEA. Hence, to implement the MOU, guidelines are needed to conduct and evaluate CEA studies. This report was written to help the Council and its signatory organizations develop reliable estimates of the costs and benefits of BMPs. Since suppliers may face differing circumstances, the guidelines do not prescribe a single method or set of parameter values to conduct CEAs. Instead, these guidelines suggest ways to choose methods and parameter values and to set reasonable bounds. These guidelines do not attempt to resolve long-running debates surrounding the theory and practice of cost-effectiveness analysis. Rather, they provide defensible criteria for conducting and evaluating CEAs. Chapter topics include the MOU process and the role of CEA, general guidelines for BMP cost effectiveness analysis, CEA

guidelines for specific BMPs and PBMPs, and illustrative examples—ultra-low flush toilet replacements and large landscape audits.]

Pennsylvania Department of Environmental Protection, 2010a, *Water conservation ideas for schools and colleges*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1819, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for schools and colleges are listed under the categories of general suggestions, building maintenance, kitchen and laundry areas, pool, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2010b, *Water conservation ideas for restaurants*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1821, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for restaurants are listed under the categories of general suggestions, building maintenance, kitchen area, bar, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2010c, *Water conservation ideas for golf courses and industrial landscapes*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1822, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for golf courses and industrial landscapes are listed under the following categories: start a water conservation program, survey the facility, interior area, maintenance procedures, design and maintenance criteria for turf and landscape areas, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2010d, *Water conservation ideas for health care facilities*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1823, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for health care facilities are listed under the categories of general suggestions, building maintenance, cafeteria and kitchen areas, laundry facilities, operations, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2010e, *Water conservation ideas for hotels and motels*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1824, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for hotels and motels are listed under the following categories: general suggestions, building maintenance, pools, kitchen area, bar, laundry, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2010f, *Water conservation ideas for laundries and linen suppliers*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP1825, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection. Water-saving suggestions for laundries and linen suppliers are listed under the following categories: general suggestions, building maintenance, operations, and exterior areas.]

Pennsylvania Department of Environmental Protection, 2011, *Drop by drop: Use water wisely*: Pennsylvania Department of Environmental Protection, Bureau of Watershed Management, Division of Water Use Planning, Fact Sheet 3920-FS-DEP2631, 2 p.
[This two-page fact sheet is one of a series of water conservation fact sheets published by the Pennsylvania Department of Environmental Protection and is aimed at the home owner. Water-saving suggestions for home owners are listed under the following categories: be aware of your average daily water use, water saving fixtures and appliances, leak repair, and tips to change your water-use habits both indoors and outdoors.]

Porter, John C., 2009, Water conservation and use on dairy and livestock farms: University of New Hampshire Cooperative Extension, Fact Sheet, 2 p.
[This two-page fact sheet describes water-use activities on dairy and livestock farms, including coefficients of water needs by animal and water use by on-farm activity. Also included are water conservation methods applicable to livestock farming facilities.]

Seneviratne, Mohan, 2007, A practical approach to water conservation for commercial and industrial facilities: Elsevier, Ltd, 380 p.
[Report based on industrial and commercial water conservation efforts in Australia. Contains detailed chapters devoted to measuring flow and consumption, alternatives to cooling towers, steam system conservation methods, industrial water reuse technologies, estimating the dollar cost savings associated with conservation measures, water conservation for hotels and restaurants, water conservation in commercial and institutional buildings and hospitals,

swimming pool conservation measures, water conservation in the food processing and beverage industries, water use and conservation in oil refining, and water conservation in commercial and institutional laundries.]

Sharpe, W.E., and Fletcher, P.W.,1977, The impact of water saving device installation programs on resource conservation: Institute for Research on Land and Water Resources, Pennsylvania State University, Research Publication 98, 44 p.
[The water conservation programs of the Washington Suburban Sanitary Commission (WSSC) in Washington, D.C., were evaluated and found to have been effective in reducing customer water use. The study found that shower-flow controls in college dormitories produced savings in water use of up to 60 percent, and if a similar program were adopted by Pennsylvania State University, annual cost savings would be approximately $100,000. Retrofit "bottle kits" used to displace water in existing toilet tanks were found to be very effective in reducing residential water use after 300,000 bottle kits were distributed to all of the 200,000 single-family homes in the WSSC service area.]

Sheikh, Bahman, 2010, *White paper on graywater*: American Water Works Association, 61 p.
[This white paper is sponsored jointly by the WateReuse Association (WRA), Water Environment Federation (WEF), and American Water Works Association (AWWA) and was intended to help the Board of Directors of the WateReuse Association adopt policies regarding greywater use that are logical, fair, and consistent with the mission of the AWWA. The paper (1) characterizes the most important issues in greywater and identifies the policy implications of each, (2) assesses the potential impacts of rising trends in greywater use on the water recycling industry, and (3) develops a regulatory and policy framework that will allow the industry to take appropriate actions to protect the integrity of the recycled water product and brand. Major topics include recycled water industry concerns about greywater, sources and characteristics of greywater, volume of greywater intercepted, motivation for greywater reuse, historical evolution of greywater reuse, permitted vs. unregulated greywater systems, the greywater industry and practices in the United States, key legislative models, regulations, standards, guidelines, future trends in greywater systems and reuse, infrastructure, economic aspects of greywater, public health considerations, impacts of individual greywater reuse on municipal water recycling, policy and planning approach for water recycling industry, greywater within the municipal water recycling framework, and appendices including a summary of states' greywater regulations.]

Shelton, T.B, and Lance, S.E, 1993, *Designing a water conservation program: An annotated bibliography of source materials*: U.S. Environmental Protection Agency, Washington, D.C., 92 p.
[This work represents an exhaustive survey of the available literature on the water conservation topics listed in the contents. The bibliography was compiled from major electronic databases including AGRICOLA, CRIS, Environline, Environmental Bibliography, Water Resources Abstracts, Wanternet, Government Documents, ProSearch, Biological and Agricultural Index, Colorado Alliance of Research Libraries, Pennsylvania State University, and many more. In addition, information was sought from books in print, government manuals, pamphlets, research reports, and conference proceedings. The bibliography covers publications from 1980 through January 1993, and it builds upon "An Annotated Bibliography on Water Conservation" produced for the U.S. Army Corps of Engineers Institute for Water Resources Planning (1979). The bibliography includes some of the major works prior to 1980 and selects the most important work on a variety of topics. Major topics covered include the following: public education programs for water conservation, community water conservation programs, reducing water losses in distribution systems, economics of water conservation, agricultural water conservation, miscellaneous publications on water conservation, water conservation devices and products, listing of companies selling water conservation products, and bibliographic search methodology.]

Shiklomanov, I.A., 1993, World freshwater resources, *in* Gleick, P.H., Water in crisis—a guide to the world's freshwater resources: Oxford University Press, 473 p.

Texas Water Development Board, 2004, *Water conservation best management practices guide*: Texas Water Development Board, Water Conservation Implementation Task Force Report 362, 266 p.
[This document is the result of the work of the Texas Water Conservation Implementation Task Force, a volunteer group of Texas citizens with experience in, and commitment to, using Texas water more efficiently. The Task Force was created by the 78th Texas Legislature under Senate Bill 1094. The legislature charged the Task Force with reviewing, evaluating, and recommending optimum levels of water-use efficiency and conservation for the state. The BMPs and the cost effectiveness tools in this guide are offered to the state's regional water planning groups, water providers, and water users as a tool for planning and designing effective conservation programs. The guide is organized into three sections—for municipal, industrial, and agricultural water-user groups—and contains a total of 55 BMPs. At the end of each section is a chapter giving guidance on cost effectiveness evaluation for the specific BMPs in the section. Best management practices contained in the BMP guide are voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified time frame. BMPs discussed for municipal water users include the following: system water audit and water loss; water conservation pricing; prohibition on wasting water;

showerhead, aerator, and toilet flapper retrofit; residential toilet replacement programs; residential clothes washer incentive program; school education; water survey for single-family and multi-family customers; landscape irrigation conservation and incentives; water-wise landscape design and conversion programs; athletic field conservation; golf course conservation; park conservation; metering of all new connections and retrofit of existing connections; water reuse; public information; rainwater harvesting and condensate reuse; new construction greywater; conservation programs for industrial, commercial, and institutional accounts; and cost-effectiveness analysis for municipal water users. BMPs discussed for industrial water users include industrial water audit, industrial water waste reduction, industrial submetering, cooling towers, cooling systems (other than cooling towers), industrial alternative sources and reuse of process water, rinsing/cleaning, water treatment, boiler and steam systems, refrigeration (including chilled water), once-through cooling, management and employee programs, industrial landscape, industrial site-specific conservation, and cost effectiveness for industrial water users. BMPs discussed for agricultural water users include agricultural irrigation water-use management, irrigation scheduling, volumetric measurement of irrigation water use, crop residue management and conservation tillage, on-farm irrigation audit, land management systems such as furrow dikes, land leveling, contour farming, conversion of supplemental irrigated farmland to dry-land farmland, brush control/management, lining of on-farm irrigation ditches, replacement of on-farm irrigation ditches with pipelines, low pressure center pivot sprinkler irrigation systems, drip/micro-irrigation systems, gated and flexible pipes for field water distribution systems, surge flow irrigation for field water distribution systems, linear move sprinkler irrigation systems, tailwater recovery and reuse systems, nursery production systems, and cost effectiveness for agricultural water users.]

Texas Water Development Board, 2005, Water conservation best management practices (BMP) guide for agriculture in Texas: Texas Water Development Board, Water Conservation Implementation Task Force Report 362, 84 p.
[The information contained in the publication was made available by the Texas Water Development Board and was first published in November 2004 as Report 362 (see above listing). This publication contains only those Best Management Practices (BMPs) applicable to conservation of water used by agriculture, whereas Report 362 also contained BMPs applicable to municipal and industrial sectors. The language regarding Agricultural BMPs in this report is identical to that in Report 362.]

U.S. Army Corps of Engineers, 1983, The state of the states in water supply/conservation planning and management programs—a record of the June 2–3, 1982, State Workshop: U.S. Army Corps of Engineers and Bureau of Water Resources Management, Commonwealth of Pennsylvania, 86 p.
[This report is a result of a joint effort by the U.S. Army Corps of Engineers Institute for Water Resources and the Pennsylvania Bureau of Water Resources Management to appraise states' long-term capabilities in water supply and conservation planning and management. This report summarized a 2-day conference whose objectives were to inventory various states' water supply and conservation programs, and to conduct a roundtable discussion of pertinent issues by a select group of water-resource professionals from state and local agencies. Water supply issues that are discussed include water quality, financial assistance, resource development and allocation, land and water-use conflicts, and water distribution system rehabilitation. Some water conservation issues for the 1980s that are discussed include integrating water conservation into water supply planning, evaluating conservation methods and strategies, drought management, and allocation and permitting of uses. The report lacks specific information on these topics and is simply a summary of the workshop proceedings.]

U.S. Department of Defense, 1997, *Military handbook of water conservation*: U.S. Department of Defense, MIL-HDBK-1165, 136 p.
[This military handbook provides numerous methods to increase water efficiency and details the requirements of Executive Order 12902 as it relates to water conservation within the Department of Defense. It is designed to provide guidance to the installation energy or facilities manager and project designers in the area of water conservation. This handbook is intended to assist military installations in reducing their water consumption and thereby assist in complying with the provisions of Executive Order 12902. It is essentially a compendium of water conservation Best Management Practices (BMPs) that are geared towards the specific water use needs of military installations; however, many of these needs are common to civilian industrial and institutional facilities. Some specific BMPs that are listed include water usage in the Federal government; typical water abuses; developing a water conservation plan; the facility water audit; drought management plan; water wells and treatment plants; leak detection programs; metering; pressure reduction; retrofit or replacement of water fixtures; water-efficient laundries; washrack cleaning facilities; water recycling, reclamation, and reuse; cooling towers, evaporative coolers, and once-through cooling systems; boilers and steam generators; medical facilities; irrigation and landscaping; xeriscape; subsurface irrigation; greywater; rainwater catchment; and swimming pools and spas.]

U.S. Department of Energy, 2011, *Cooling towers—Understanding key components of cooling towers and how to improve water efficiency*: U.S. Department of Energy Federal Energy Management Program, Fact Sheet DOE/PNNL-SA-75820, February 2011, 9 p.

[Federal laws and regulations require Federal agencies to reduce water use and improve water efficiency. Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance requires an annual 2-percent reduction of water-use intensity (water use per square foot of building space) for agency potable water consumption as well as a 2-percent reduction of water use for industrial, landscaping, and agricultural applications. Cooling towers can be a significant source of water use for both of these categories of water use at Federal facilities. To realize potential savings it is essential for Federal agencies understand the key components of cooling towers and how to improve water efficiency of the system as a part of a comprehensive approach to water management. This fact sheet gives an overview of how cooling towers operate, their structure, basic cooling tower terminology, physical and chemical properties of water that affect cooling tower operation, system calculations, factors that limit cycles of concentration, system concerns, and treatment options.]

U.S. Department of Energy, 2011, *Guidelines for estimating unmetered industrial water use*: U.S. Department of Energy Federal Energy Management Program, Report PNNL – 19730, 33 p.
[Executive Order 13514 requires Federal agencies to develop a baseline for industrial, landscaping, and agricultural water use in fiscal year 2010. Measuring actual water use through flow meters is the best method to develop this baseline. But there are instances where Federal sites do not meter these applications, so developing a baseline will be problematic. Therefore, the intent of this document is to assist Federal agencies in the baseline development by providing a methodology to calculate unmetered sources of industrial water use utilizing engineering estimates. The document lays out a systematic approach to estimate industrial water use in evaporative cooling systems, steam boiler systems, and facility wash applications. Chapter titles include estimating evaporative cooling system water use, estimating steam heating system water use, and washing applications water use.]

U.S. Department of Energy, 2011, *Guidelines for estimating unmetered landscaping water use*: Department of Energy Federal Energy Management Program Report PNNL-19498, 34 p.
[Executive Order 13514 requires Federal agencies to develop a baseline for industrial, landscaping, and agricultural water use in fiscal year 2010. Measuring actual water use through flow meters is the best method to develop this baseline. But there are instances where Federal sites do not meter these applications, so developing a baseline will be problematic. Therefore the intent of this document is to assist Federal agencies in the baseline development by providing a methodology to calculate unmetered sources of landscaping water use utilizing engineering estimates. The document lays out step by step instructions to estimate landscaping water by using two alternative approaches: the evapotranspiration method and irrigation audit method. The evapotranspiration method option calculates the amount of water needed to maintain a healthy turf or landscaped area for a given location based on the amount of water transpired and evaporated from the plants. The evapotranspiration method offers a relatively easy "one-stop-shop" for Federal agencies to develop an initial estimate of annual landscape water use. The document presents annual irrigation factors for 36 cities across the United States and presents the gallons of irrigation required per square foot for distinct landscape types. By following the steps outlined in the document, the reader can choose a location that is a close match to the desired/intended location and landscape type to provide a rough estimate of annual irrigation needs without the need to research specific data on that site. The second option presented in the document is the irrigation audit method, which is the physical measurement of water applied to landscaped areas through irrigation equipment. Steps to perform an irrigation audit are outlined in the document. An irrigation audit requires some knowledge of the specific procedures to accurately estimate how much water is being consumed by the irrigation equipment.]

U.S. Department of Energy, 2011, *Microelectronics plant water efficiency improvements at Sandia National Laboratories—Best management practice case study #13— Other water use*: U.S. Department of Energy Federal Energy Management Program Fact Sheet DOE/GO-102009-2905, August 2009, 2 p.
[Sandia National Laboratories has developed extensive water-efficiency improvements at its Microsystems and Engineering Sciences Applications (MESA) complex in Albuquerque, New Mexico. The MESA complex houses research in microelectronics, including designing and prototyping microsystem-based components. The complex consumes about 28 percent of the total water used at Sandia. The processes used to create microelectronics systems require high-purity water for cleaning. Over the last several years, Sandia has initiated projects that have saved 80 million gallons annually, which represents 18 percent of the current water use at the laboratory. These savings were achieved by increasing the efficiency of the system, recycling higher-quality spent rinse water, and reclaiming water to use for acid waste scrubbers and cooling towers.]

U.S. Department of the Interior, 1978, Technical assistance for water conservation in water-short areas: U.S. Department of the Interior, draft report to the Secretary of the Interior, 38 p.
[This report was prepared in response to President Carter's directive of July 12, 1978, that the Departments of the Interior, Agriculture, and Housing and Urban Development prepare plans for identifying and providing increased water conservation technical assistance to qualified water-short areas using existing assistance programs. The report lists the programs that can provide technical assistance to water-short areas of the United States (primarily the Western United States) from the U.S. Geological Survey,

the Fish and Wildlife Service, the Bureau of Indian Affairs, the Bureau of Land Management, and the Bureau of Reclamation.]

U.S. Environmental Protection Agency, 1997, Study of potential water efficiency improvements in commercial businesses—Final report: U.S. Environmental Protection Agency, 48 p.
[This report summarizes the results of a study of water use by 22 categories of commercial businesses in California and was a joint effort by the USEPA and the California Department of Water Resources. The objectives of the study were to quantify the water consumption of commercial water users in 12 cities around the United States, quantify the potential cost-effective water savings achievable in various categories of commercial water users, and estimate the volume of water potentially saved for each of the commercial water user categories in each of the selected metropolitan areas. The potential water savings for each commercial water user category, in percent, was estimated by applying the average water use saving for each category, in percent, as derived from actual on-site audits of water use at 741 various commercial sites within California, Arizona, and Massachusetts, obtained from water-use databases. The report does not detail by what mechanisms these water use savings were realized.]

U.S. Environmental Protection Agency, 1998, Water conservation plan guidelines: U.S. Environmental Protection Agency, 208 p.
[The 1996 Amendments to the Safe Drinking Water Act (SDWA) recognized the potential value of water conservation in infrastructure funding programs such as the Drinking Water State Revolving Fund (SRF). The SDWA requires the USEPA to publish conservation plan guidelines within 2 years of the Act's passage. The guidelines must take into account system size, water availability, and climate. This document contains the USEPA water conservation guidelines for municipal water systems, as required by the SDWA of 1996. The SDWA provides that states may require public water systems applying for SRF loans to submit a conservation plan consistent with the guidelines; there are no statutory mandates for states or municipalities in this section of the SDWA. The SDWA makes clear that using the conservation guidelines is at the discretion of the states. The states may decide whether to use the guidelines at all, whether to use the guidelines in conjunction with their SRF programs, and whether or not to tailor the guidelines to specific state needs or goals. Guidelines are presented for three categories of municipal water systems, classified by population served—less than 3,300 people, 3,300 to 10,000 people, and more than 10,000 people. Major topics include the role of water conservation in infrastructure planning, water conservation planning criteria, capacity-development approach, state roles, and state conservation programs. Guidelines common to all three categories include specify conservation planning goals, develop a water system profile, prepare a demand forecast, describe planned facilities, identify and evaluate conservation measures, analyze benefits and costs, and present implementation strategy.]

U.S. Environmental Protection Agency, 1999, *Getting up to speed: The water cycle and water conservation*: U.S. Environmental Protection Agency, 70 p.
[This grade 7–12 curriculum includes basic concepts on the water cycle, water distribution, treatment, and stewardship. It was developed in cooperation with the New England Interstate Water Pollution Control Commission.]

U.S. Environmental Protection Agency, 2002, Cases in water conservation—How efficiency programs help water utilities save water and avoid costs: U.S. Environmental Protection Agency Office of Water, Report No. EPA832-B-02-003, 48 p.
[Water utilities across the United States and elsewhere in North America are saving substantial amounts of water through strategic water-efficiency programs. These savings often translate into capital and operating savings, which allow systems to defer or avoid significant expenditures for water supply facilities and wastewater facilities. These case studies feature the efforts and achievements of 17 water systems. These systems range in size from small to very large, and their efficiency programs incorporate a wide range of techniques for achieving various water-management goals.]

U.S. Environmental Protection Agency, 2004, Guidelines for water reuse: U.S. Environmental Protection Agency, Municipal Support Division, Office of Wastewater Management, Office of Water Washington, D.C., EPA Report No. EPA/625/R-04/108, 450 p.
[The 2004 "Guidelines for Water Reuse" examines opportunities for substituting reclaimed water for potable water supplies where potable water quality is not required. The report presents and summarizes recommended water reuse guidelines, along with supporting information, as guidance for the benefit of the water and wastewater utilities and regulatory agencies, particularly in the United States. Chapters are devoted to urban reuse; industrial reuse, including cooling water, boiler make-up water, industrial process water in the pulp and paper, chemical, textile, and petroleum and coal industries; agricultural reuse; environmental and recreational reuse; artificial groundwater recharge; augmentation of potable supplies; and selected case studies. There are also chapters that describe technical issues in planning water reuse systems, water reuse regulations and guidelines in the United States, legal and institutional water use and reuse issues, funding water reuse systems, public involvement programs, and water reuse outside of the United States.]

U.S. Environmental Protection Agency, 2009, Water efficiency in the commercial and institutional sector: Considerations

for a WaterSense program: U.S. Environmental Protection Agency, 55 p.
[To help American consumers and businesses use water more efficiently, in 2006, U.S. Environmental Protection Agency (USEPA) launched WaterSense, a voluntary partnership program that aims to protect the future of the nation's water supply. While to date WaterSense has focused on the residential sector, USEPA is considering adding a program to promote water efficiency in the commercial and institutional (CI) sector as well. As a first step, USEPA has written this white paper to summarize information gathered to date on the CI sector and to discuss all potential facets of the program. The purpose of this paper is to solicit input from partners, stakeholders, and the general public that WaterSense can use as a foundation for developing a CI sector program. This paper gives an overview of the commercial and institutional sector, details existing commercial and institutional efficiency programs, defines key stakeholder groups, and gives design options for a WaterSense commercial and institutional program. Included are appendices, which list CI water use by subsector and data on end-use application of water by subsector.]

U.S. Environmental Protection Agency, 2009, Comments on the August 2009 "Water Efficiency in the Commercial and Institutional Sector: Considerations for a WaterSense® Program" White Paper: U.S. Environmental Protection Agency, 138 p.
[Comments pertaining to the WaterSense white paper from 26 interested individuals.]

U.S. Environmental Protection Agency, 2010a, *Hydraulic fracturing research study*: U.S. Environmental Protection Agency EPA/600/F-10/002, June 2010, 2 p.
[This document describes how water is used for hydraulic fracturing.]

U.S. Environmental Protection Agency, 2010b, *New York water fact sheet*: U.S. Environmental Protection Agency WaterSense Program, EPA 832-F-10-014, 2 p.
[A fact sheet summarizing the water conservation efforts by NYSDEC, New York City Department of Environmental Protection (NYCDEP), and New York State Environmental Facilities Corporation.]

U.S. Environmental Protection Agency, 2012, *WaterSense at work—Best management practices for commercial and institutional facilities*: U.S. Environmental Protection Agency WaterSense Program, EPA 832-F-12-034, 308 p.
[This publication is a compilation of water-efficiency best management practices for use by commercial and institutional facility owners and managers to better understand and manage water use at their facilities. The publication describes how to assess water use at a facility; establish a water-management plan; effectively communicate and achieve water-management goals; reduce water loss from leaks; increase the efficiency of water-using fixtures, equipment, systems, and processes; and identify alternative onsite water sources. Water-efficiency best management practices applicable to multiple commercial and institutional sectors are provided.]

U.S. General Services Administration, 2000, *Water management—A comprehensive approach for facilities managers*: U.S. General Services Administration, 140 p.
[This handbook explains the new water conservation requirements under Executive Order 13123, "Greening the Government through Efficient Energy Management," signed by President Clinton on June 3, 1999. It also provides comprehensive guidance on how to meet these requirements, from detailed descriptions of water-conserving technologies and principles to how to measure water use and develop a water-management plan to economic analysis and innovative financing options. Chapter 1 explains the benefits of water management and includes a comprehensive overview of the new Executive order. Chapter 2 explains the general principles of water management, including three major water-conserving areas, and buildings and uses characteristics that affect water consumption. Chapter 3 outlines the steps in developing a water-management plan. Chapter 4 provides a brief primer on developing a drought management plan and water-reduction measures that can be implemented during periods of drought. Chapter 5 details the wide variety of water-conserving technologies that are available to the Federal facilities manager. These technologies are grouped into three general categories: plumbing products, heating and cooling products, and landscaping/irrigation products. Chapter 6 covers onsite wastewater recycling, reclaimed water, and rainwater harvesting. Chapter 7 provides useful information on financing options, a description of the Federal Energy Management Program, a listing of valuable Internet resources, a description of energy-savings performance contracts, and tips on selecting a contractor. Finally, the appendices supplement the steps to water-management plan with sample energy survey worksheets, discuss selected regulations affecting conservation programs, and provide a glossary of terms relating to water-efficiency programs.]

Vickers, Amy, 2001, Handbook of water use and conservation: WaterPlow Press, Amherst, Mass., 446 p.
[This handbook by a recognized leader in the water conservation field outlines 10 key steps for a successful conservation program; describes water-use characteristics of major customer sectors; provides water audit steps for homes, landscapes, businesses, factories, and farms; supplies the latest detailed information on more than 100 water-efficiency measures for long-term demand reductions and drought response; presents estimated water savings, benefits, and costs for efficiency measures; includes energy conservation benefits from water-

efficiency measures; contains hundreds of fact-filled tables, illustrations, and case studies; and lists online links to conservation organizations, agencies, businesses, product suppliers, and relevant information sources. It also describes the water-efficiency requirements for plumbing fixtures as specified under the U.S. Energy Policy Act as well as dozens of examples of local and state policies and ordinances on conservation requirements for the residential, landscape, commercial, industrial, governmental, and agricultural water sectors. Chapter titles include the following: Planning a Successful Water Conservation Program; Residential and Domestic Water Use and Efficiency Measures; Landscape Water Use and Efficiency Measures; Industrial, Commercial, and Institutional Water Use and Efficiency Measures; Agricultural Water Use and Efficiency Measures; and The Water Conservation Network.]

V.B. Relevant Web sites

1. Alliance for Water Efficiency
    - *http://www.allianceforwaterefficiency.org/*
    - *http://www.allianceforwaterefficiency.org/Water_Conservation_Programs_Library_Content_Listing.aspx*
    - *http://allianceforwaterefficiency.org/Tracking-Tool.aspx*
2. Association of Metropolitan Water Agencies
    - *http://www.amwa.net/*
3. American Water Works Association
    - *http://www.awwa.org/*
4. Bureau of Land Management, U.S. Department of the Interior
    - *http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/technical_information.html*
5. Bureau of Reclamation, U.S. Department of the Interior
    - *http://www.usbr.gov/waterconservation/publications.html*
6. Federal Energy Management Program
    - *http://www1.eere.energy.gov/femp/program/waterefficiency_bmp14.html*
    - *http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html*
    - *http://www1.eere.energy.gov/femp/program/waterefficiency_resources.html*
    - *http://water-management-toolbox.com/holding-area/general-water conservation-bmps*
7. New Hampshire Department of Environmental Services
    - *http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm*
8. Pacific Institute
    - *http://www.pacinst.org/*
9. U.S. Department of Agriculture
    - *http://wqic.nal.usda.gov/water-availability/water conservation*
10. U.S Environmental Protection Agency
    - *http://www.epa.gov/WaterSense/commercial/index.html*
    - *http://www.epa.gov/oaintrnt/water/best_practices.htm*
    - *http://www.epa.gov/watersense/pubs/guide.html*
    - *http://water.epa.gov/infrastructure/sustain/resources_wp.cfm*
    - *http://water.epa.gov/infrastructure/sustain/wec_wp.cfm*
11. Water Systems Council
    - *http://www.watersystemscouncil.org/*
12. Water Conservation Advisory Council – Save Texas Water
    - *http://www.savetexaswater.org/bmp/*