Public Sector Water Conservation:
Technology and Practices outside the Great Lakes - St. Lawrence Region

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Preface

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. In so doing, it informs the work of the Great Lakes states and provinces in implementing the 2001 Annex of the Great Lakes Charter of 1985. This project particularly addresses the Annex provision to establish a decisionmaking standard based on the principle of "preventing or minimizing Basin water loss through return flow and implementation of environmentally sound and economically feasible water conservation measures."

The Commission's involvement in this project reflects its long-term interest in Great Lakes water resources management activities, consistent with its mandate to "promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes basin" (Article I, Great Lakes Basin Compact). The principle author of this report is Laura E. Kaminski, Program Specialist, Great Lakes Commission. Ongoing project consultation and oversight has been provided by a Project Advisory Committee comprised of representatives from federal, state and provincial governments, and other interested groups. This report has benefited from the significant input and collaboration of the members of this group, whose membership list is provided in Appendix A.

The Commission also extends its appreciation to the Council of Great Lakes Governors and its Annex 2001 Working Group; the staff of the Great Lakes Protection Fund; the city of Albuquerque, N.M.; the Southwest Florida Water Management District; and the city of Calgary, Alberta, Canada, for their guidance, input, and support throughout the project.

Abbreviations and Acronyms

AMR: Automatic Meter Reading

ASR: Aquifer Storage and Recovery

AUD: Australian Dollars (currency)

BAT: Best Available Technology

BMP: Best Management Practice

BPT: Best Practical Technology

CAD: Canadian Dollars (currency)

CDWR: California Department of Water Resources

CUWCC: California Urban Water Conservation Council

DIR: Demand-Initiated Regenerating

ERT: Encoder-Receiver-Transmitter

ET: Evapotranspiration

ET_0: Reference Evapotranspiration

EWA: Environmental Water Account

gcpd: Gallons per capita per day

gpf: Gallons per flush

gpl: Gallons per load

HDPE: High Density Polyethylene

ICI: Industrial, Commercial, and Institutional

IRWD: Irvine Ranch Water District (California)

lcpd: Liters per capita per day

mgd: Million gallons per day

ML: Million Liters

PT: Pressurized Ttank

PVC: Polyvinyl Chloride

SWEEP: Save Water and Energy Education Program (Oregon)

SWP: State Water Project (California)

SWUCA: Southern Water Use Caution Area (Florida)

UAW: Unaccounted-for Water

ULFT: Ultra-Low-Flow Toilet

USD: United States Dollars (currency)

U.S. DOE: U.S. Department of Energy

U.S. DOI: U.S. Department of the Interior

U.S. EPA: U.S. Environmental Protection Agency

UV: Ultraviolet

VOC: Volatile Organic Chemical

WRC: Water and Rivers Commission (Western Australia)

Executive Summary

As the demand for freshwater continues to increase, governments around the world are beginning to feel the effects of reduced water availability and the challenge of balancing needs for public water supply, agriculture, and other water uses. In many regions of the world, this natural resource is being used at a rate faster than sources of freshwater can be replenished. In the coming decades, water experts are predicting more than half the world's population will experience acute water scarcity, making the effect of water loss a global issue. In order to avoid such a catastrophe, new habits and innovative technologies will be called upon to help the world's population conserve and reuse existing sources of water.

This concept is often described in terms such as sustainable water use, conservation, water-use efficiency, demand management, water productivity, best management practices, and so on. Regardless of the term used, the common objective is for society to function and meet specific goals with less water. Other positive results of improving water efficiency include ecosystem benefits from taking less water from rivers, lakes, and aquifers; lower wastewater treatment costs resulting from using and polluting less water; and reductions in greenhouse gas emissions and energy costs resulting from using less energy.

This report is one of several products being developed by the Great Lakes Commission under a project titled *Developing a Water Conservation "Tool Kit" for the Great Lakes – St. Lawrence Region*. The project is one of a suite of projects supported by the Great Lakes Protection Fund to guide and inform the Great Lakes states and provinces as they begin to implement the provisions of the 2001 Annex of the Great Lakes Charter of 1985.

The purpose of this report is to present an assessment of best available technologies and practices for water conservation in the public water sector outside of the Great Lakes – St. Lawrence region. The first major section of the report, following an introduction and background discussion of water resources management and sustainability, 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.

Each case study is presented in a detailed summary. General characteristics of each locale are described, including geographic area, water supply, population trends, and other factors which influence water management. Water conservation practices are also summarized in topical categories and can be cross-referenced with the section on best available and emerging technologies to learn more about specific products or methods. Where possible, contact information has been provided for obtaining additional information for each case study. The table below summarizes the conservation initiatives and programs presented in the case studies section of the report.

Water Conservation Strategies	City of Albuquerque, New Mexico	SW Florida Water Management District	State of California	City of Calgary, Canada	Fukuoka City, Japan	State of Western Australia	Israel
Comprehensive Management Plan	X	X	X		X	X	X
Public Education or Media Campaigns	X	X	X	X		X	X
Water Meters	X	X	X	X			X
Water Conserving Rate Structures	X	X	X		X	X	X
Water Audits or Leak Detection Programs	X	X	X	X			
Indoor Retrofit Programs	X	X	X	X	X	X	X
Performance Contracting		X				X	
Outdoor Watering Restrictions	X	X	X	X		X	X
Outdoor Irrigation Retrofit Programs	X	X	X	X		X	X
Plant Selection or Other Landscaping Plans	X		X				X
Rainwater Collection	X			X		X	
Community Recognition Programs		X		X			
Financial Incentives (Rebate Programs)	X	X	X	X		X	
Ordinances and Resolutions	X	X	X	X			

Following the analysis of case studies from varying regions throughout the world, the second section of the report focuses on best available and emerging technologies. In this section, technological advances are discussed in greater detail, including those in public water distribution systems; water meters and automatic meter reading; water-efficient home appliances and plumbing fixtures; leak detection and repair; water softeners; water heaters; landscape irrigation; soil moisture sensors and probes; landscape design; rainwater collection; and reuse and recycling systems. These technologies and conservation practices can, in most cases, be cross-referenced to the specific case study in which the practice or technology is first discussed within the report by using the index provided at the end of the report.

The third section of the report is dedicated to emerging issues in water supply. Topics such as water purification techniques, canal lining, water banks, and aquifer storage and recovery technologies are presented in this section.

To assist decisionmakers within the Great Lakes-St. Lawrence River basin, the final section of this report summarizes the information provided within the report and provides an assessment of the practices and technologies that have been successful outside of the region and could benefit the Great Lakes-St. Lawrence River basin with respect to water conservation and sustainability. Several water use and conservation ordinances and resolutions are included as appendices to this report. As the Great Lakes governors and premiers continue to develop and refine a decisionmaking standard through the Great Lakes Charter Annex implementation process, the methods of conservation described in these case studies, their approaches toward implementing conservation strategies and initiatives, and the variety of best available and emerging technologies discussed in this report should be considered.

Introduction

The water we use for drinking, cleaning, and other personal use is often taken for granted. Few of us question where our water comes from or whether it will always be available to meet our needs. However, the Earth's freshwater is not an infinitely renewable resource. In fact, even though approximately 70 percent of the Earth's surface is covered by water, more than 97 percent of that water is too salty to use for drinking or irrigation. Of the remaining 3 percent, more than three-quarters is frozen as ice or glaciers, leaving less than 1 percent as unfrozen freshwater. Unfortunately, since much of this water is inaccessible (usually because it is buried too deep underground), less than 0.5 percent of the world's water is available for drinking, irrigation, and industry. This water is pumped from groundwater sources found in aquifers below the Earth's surface or withdrawn from surface waters such as lakes and rivers. (McDonald and Jehl, 2003)

The world's natural supply of freshwater is constantly cycled between the Earth's atmosphere and surface. However, as demand continues to increase, this natural resource is used at a rate faster than it can be replenished by precipitation. By 2025, the United Nations expects more than half the world's population will lack sufficient water to cover basic needs (McDonald and Jehl, 2003). This makes the effect of water loss a global issue. Avoiding such a catastrophe will require people to change their habits by conserving and reusing available freshwater resources through sustainable water-use practices.

Background

Around the world, many existing sources of water are being depleted and stressed by withdrawals from aquifers and diversions from lakes, rivers, and reservoirs. With greater than six billion people living on the Earth today, more and more people are vying for less and less water. From China to India to the United States and Canada, water supplies are under strain as never before to meet the accelerating demands of fast-growing cities, agriculture, and industry (McDonald and Jehl, 2003). Today 31 countries, accounting for approximately 8 percent of the world's population, face chronic freshwater shortages. By the year 2025, 2.8 billion people (or 35 percent of the world's projected population) are expected to face shortages. Among countries likely to run short of water in the next 25 years are Ethiopia, India, Kenya, Nigeria, and Peru (see Appendix B). (Hinrichsen, et al., 1998)

Parts of other large countries, such as China, already face chronic water problems (see Fig. 1). As the population of China continues to grow, water tables are falling by 2-3 meters (approximately 6-10 feet) per year, springs are drying up, rivers are running dry, and lakes are disappearing. This is most evident in the northern half of the country, where overpumping has largely depleted the shallow aquifer under the North China Plain. Three rivers that flow eastward into the North China Plain – the Hai, the Yellow, and the Huai – often run dry during the dry season, sometimes for extended periods of time, due to excessive demands on their water sources. Hebei Province once had 1,052 lakes. As of 2001, only 83 remained. The desperate quest for water in China is clear, as well drillers chase the water table downward; wells around Beijing now have to reach 1,000 meters (more than half a mile) to tap water from the region's deep aquifer, adding dramatically to the cost of supply. With 22 percent of the world's population and only 7 percent of all freshwater runoff, the World Bank has forecast "catastrophic consequences for future generations." (Brown, 2001)

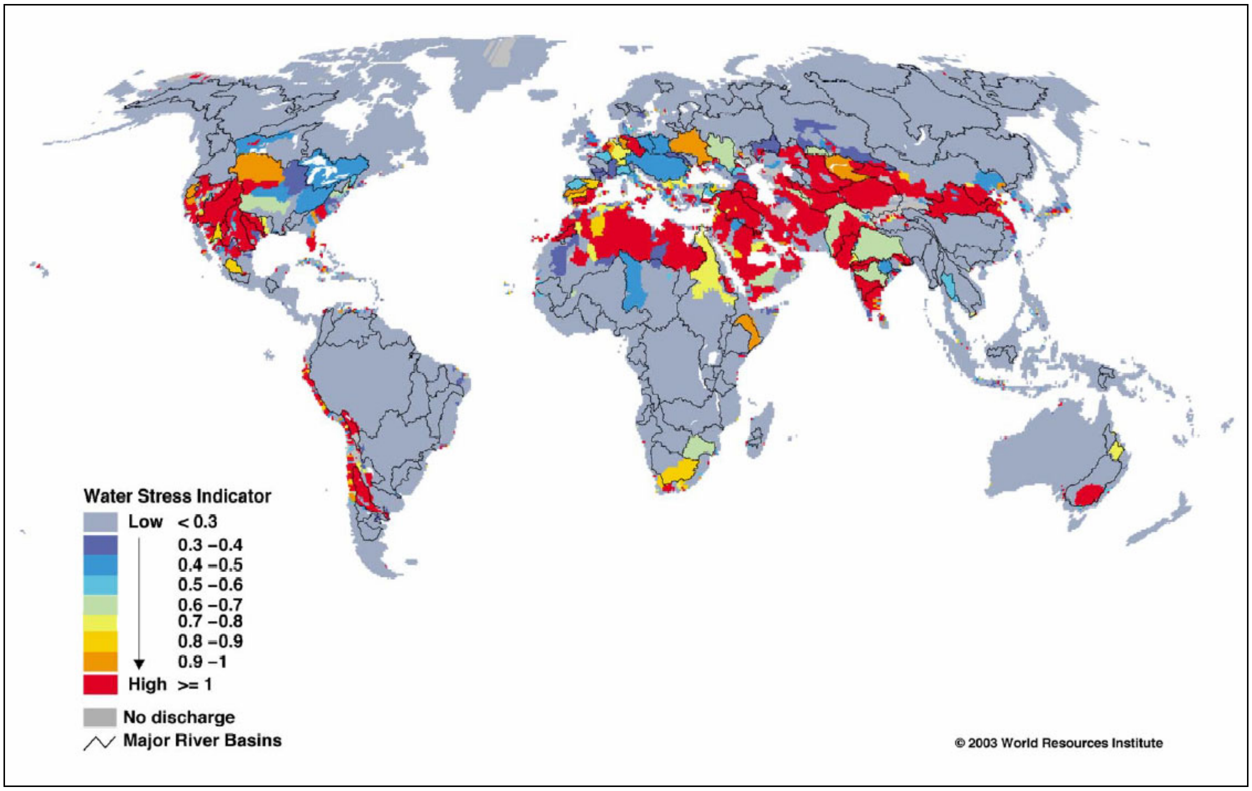

Fig. 1. Global Environmental Water Scarcity Map. (World Resources Institute)

Regional water scarcity is also seen in Rajasthan, a state in northwest India. Located in one of the most inhospitable arid zones in the world, water is a scarce commodity. Eight percent of India's population lives in Rajasthan, with only 1 percent of the country's water resources. These waters come from groundwater, limited rainfall, and a restricted share of waters that straddle state boundaries. In some parts of India, water tables are falling by 1-3 meters (approximately 3-10 feet) per year, with the rate of water extraction almost double the rate of recharge (Shah et al., 2000). As the population of India, and particularly Rajasthan, continues to grow, acute water shortages are imminent. (Population Action International, 1993)

The 20 countries of the Near East and North Africa face the worst prospects. Africa has experienced the largest population rise between 1990 and 2000 of any region, but the continent still has the lowest total water supply coverage of anywhere in the world (Great Lakes Environmental Directory, 2000). Since the early 1970s, the region has withdrawn more water from its rivers and aquifers every year than is being replenished. This is currently seen in Jordan and Yemen, where approximately 30 percent more water is withdrawn from groundwater aquifers every year than can be replenished. In Amman, Jordan, a city of one million, residents are sometimes permitted to turn on the tap only one day a week (McDonald et Jehl, 2003). Israel's annual water use already exceeds its renewable supply by 15 percent. As aquifers decline in quantity, saline and other elements penetrate them, impairing the quality of the water. (Hinrichsen et al., 1998)

Iran is yet another country facing a critical shortage of water. Following a three-year drought, the water table under the Chenaran Plain, an agriculturally rich area in northeastern Iran, fell by 8 meters (approximately 25 feet) in 2001 alone. As wells drawing from this aquifer begin to go dry, villages across eastern Iran are being abandoned, generating a swell of water refugees. (Brown, 2002)

In Mexico – home to 104 million people and growing by two million per year – the demand for water has exceeded supply in many states. Mexico City, whose population reached 15 million in 1990, is one of many cities where this has occurred. Mexico City relies on groundwater for more than 80 percent of its water supplies. But overpumping of the nearby Mexico Valley aquifer has been severe and is now restricted. Currently, the city must pump water from the Cutzamala River through a 180 kilometer (112-mile) pipeline that scales mountains hundreds of meters high. (Population Action International, 1993)

The United States and Canada, on the other hand, are fortunate. With only 4 percent of the world's population, the United States has 5 percent of its renewable freshwater (Gleick, 2001). Canada has less than 1 percent of the world's population and 7 percent of its renewable freshwater (Environment Canada, 2003). However, water sources and distribution vary considerably in both countries. Approximately 26 percent of Canadian municipalities with water supply systems have experienced shortages over the last decade, while areas such as the southwestern portion of the United States are already facing serious water shortages and increased conflict over water use. Major rivers like the Colorado no longer flow reliably to the sea due to increased demand and diversions, and large aquifers such as the Ogallala – which stretches across parts of South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas – are beginning to reflect the impacts of an increased demand on water supplies.

As one of the world's largest aquifer systems and the largest groundwater system in North America, the Ogallala Aquifer underlies about 174,000 square miles (450,658 square kilometers) of the U.S. Great Plains. The Ogallala lies close to the land surface but varies greatly in depth, saturated thickness, and water storage by region (High Plains Water District No. 1, 2003). In 1990, the Ogallala, in the eight-state area of the Great Plains, contained 1.06 quadrillion[1] gallons (4 quadrillion liters) of water (High Plains Water District No. 1, 2004). Over time, changes in climatic conditions have resulted in changes in erosion patterns, causing the Ogallala to be cut off from its original supply of water. In fact, the southern portion of the Ogallala formation in Texas and New Mexico has been completely cut off on all sides. Thousands of years of rain and snow have accounted for this collection of water, which if completely drained, would take more than 6,000 years to refill (Zwingle, 1993).

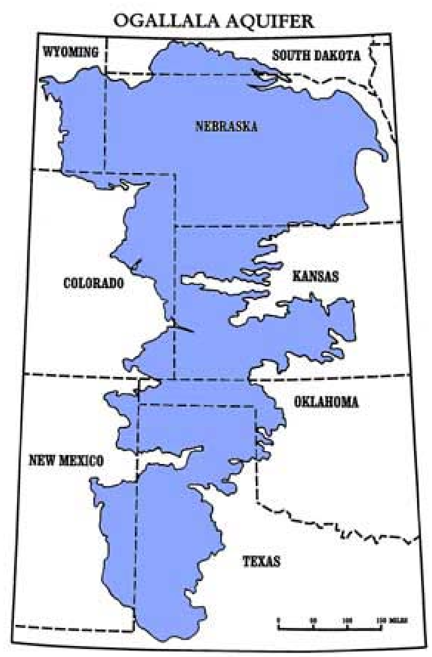

Fig. 2. Ogallala Aquifer, Central United States (High Plains Underground Water Conservation District No. 1)

[1] One quadrillion equals $1x10^{15}$

Water-level declines started to occur in the aquifer soon after extensive groundwater irrigation development began in the region in the 1940s, and have since been monitored by the U.S. Geological Survey (USGS) in cooperation with numerous federal, state, and local water-resource agencies. The water-level declines occur because of an imbalance between discharge, the largest component of which is groundwater withdrawals for irrigation, and recharge, which is primarily from precipitation. Water levels in some parts of the aquifer had declined more than 100 feet by 1980 and have continued to decline, at an accelerated rate, in recent years. At the current unsustainable rate of water use it is only a matter of time before the Ogallala's wells run dry. (McGuire, 2001)

Reflecting the scarcity of water in the western portion of the United States, the U.S. Department of the Interior (U.S. DOI) has launched a broad initiative, Water 2025: Preventing Crises and Conflict in the West, to encourage more collaboration among states and localities on water supply issues. The initiative, which was announced in 2003, focuses on facilitating a more forward-looking focus on water-starved areas of the country; stretching or increasing water supplies to satisfy growing demands and strengthen economies; providing added environmental benefits to watersheds, rivers, and streams; minimizing water crises in critical watersheds by improving the environment and addressing the effects of drought on important economies; and providing a balanced practical approach to water management for the next century.

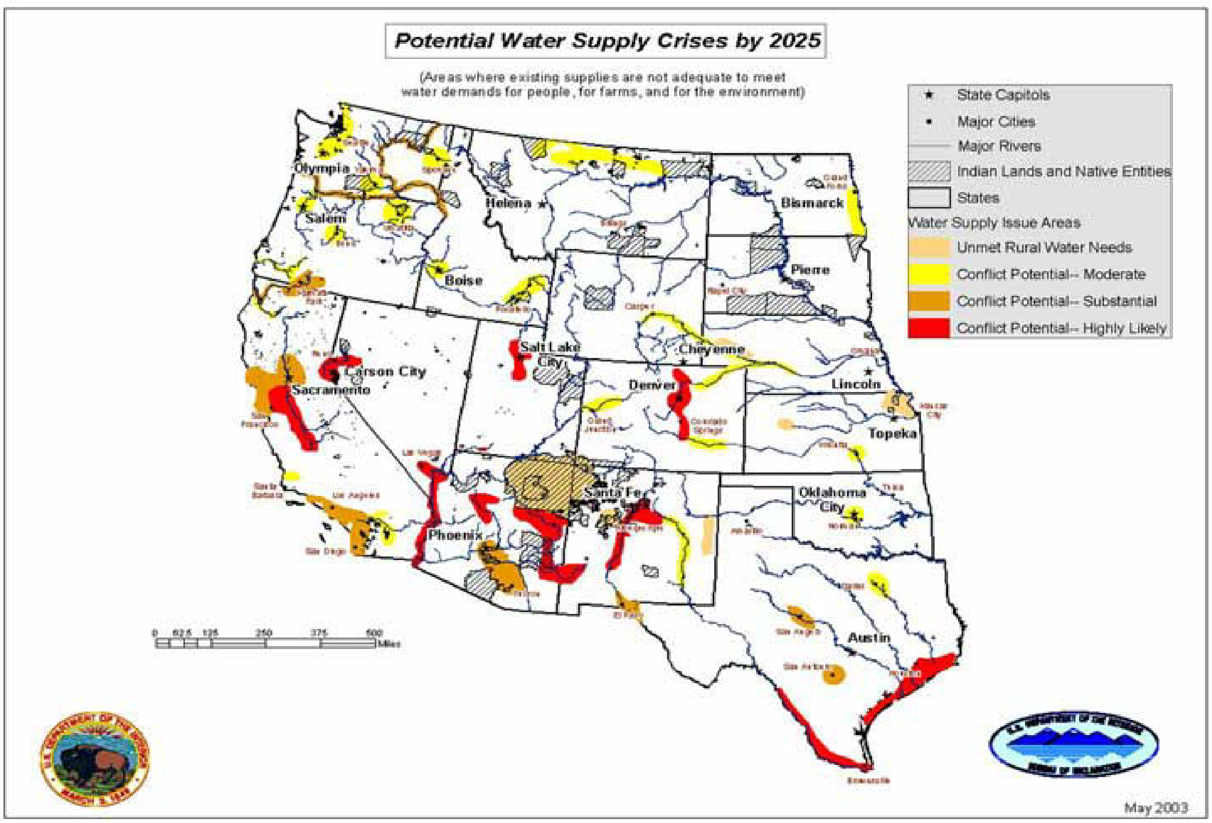

Fig. 3. Analysis of potential water supply crises and conflicts within the western United States by the year 2025. Analysis is based on a combination of technical and other factors, including population trends and potential endangered species' needs for water. (Bureau of Reclamation)

In addition, the U.S. DOI predicts that as western states continue to grow, existing water supplies are, or will be, inadequate to meet the water demands of people, cities, farms, and the environment, even under normal water supply conditions; the inevitable droughts will merely magnify the impacts of water shortages (U.S. Department of the Interior, 2003).

Water shortages in the West have demonstrated that crisis management is not an effective solution for addressing long-term, systematic water supply problems. In reality, the options for addressing shortages in water quantity are limited to increasing the efficiency of existing uses; transferring water between uses; reducing or eliminating existing water uses; developing alternative sources of water such as desalination; or by storing water in wet years for use in dry years. In some areas of the West, communities are already implementing water banks, voluntary transfers between existing users, and water conservation measures to address potential water supply crises in advance (U.S. Department of the Interior, 2003).

Severe droughts in the West during 2002 had dramatic effects:

- Rainfall in the Colorado River basin was the lowest in recorded history.
- Rio Grande flows in New Mexico were 13 percent of normal; Elephant Butte Reservoir held only 19 percent of its capacity, the lowest water level since the dam was built in the early 1900s.
- Boise, Idaho, had one of its driest calendar years on record.
- Extended drought and a reduced water supply have placed a great strain on the communities in the Lower Rio Grande basin.

(U.S. Department of the Interior, 2003)

In other areas of the United States and Canada, increased development and suburban sprawl have led to reductions in water supplies as well. As impervious surfaces such as roads, parking lots, driveways, and roofs replace natural areas, rain can no longer seep into the ground to replenish aquifers. Instead of refilling natural groundwater supplies, the water is swept away by gutters and sewer systems.

More than one-third of Americans rely upon groundwater sources for drinking water, with surface water as the source for the remaining two-thirds. Unfortunately, this pattern of increased development within U.S. and Canadian metropolitan areas adds to the reduction in capacity of existing water supplies, both directly and indirectly through surface and groundwater. To illustrate the magnitude of potential groundwater infiltration losses, a recent study by American Rivers, the Natural Resources Defense Council, and Smart Growth America compares the level of imperviousness in 1982 to 1997, and estimates the loss of groundwater infiltration in areas of extensive development. These figures are available in Appendix C. (American Rivers, Natural Resources Defense Council, and Smart Growth America, 2002)

Responsible water management, smart application of existing technology, active stakeholder participation in decisionmaking, and the efforts of innovative communities and businesses will be key to achieving the type of water conservation that will be required in coming years. As a global community, we are slowly coming to the realization that our use of water is highly inefficient and wasteful. Rethinking our needs for water and how we meet those needs could go a long way toward reducing the pressure on a decreasing water supply. (Gleick et al., 2003)

This concept of responsible water management is often described as sustainable water use, conservation, water-use efficiency, demand management, water productivity, best management practices (BMPs), and so on. Whatever the term, the common objective is for society to function and meet specific goals with less water. Other positive results of improving water efficiency include ecosystem benefits from taking less water from rivers, lakes, and aquifers; lower wastewater treatment costs resulting from using and polluting less water; and reductions in greenhouse gas emissions and energy costs resulting from using less energy. (Gleick et al., 2003)

Fortunately, some regions across North America and around the world are beginning to incorporate strategic water-efficiency programs and technologies to achieve specific water management goals. The following discussion highlights seven successful comprehensive water conservation programs that have implemented the use of efficient technology and other conservation measures, and range in size from large regional and national programs to conservation within a single municipality.