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PLANNERS AND WATER

William Cesanek, AICP, Vicki Elmer, PHD, and Jennifer Graeff, AICP

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EXECUTIVE SUMMARY

Water is essential for human life. From the beginning of civilization, human beings have devised ways to ensure that water is available when and where it is needed, as well as ways of addressing wastewater and of dealing with storms and flooding.

Historically, the work of land-use planners has not extended to water resource management. We have relied upon water utilities, public water departments, and the engineering community to deliver and manage the supply of water for cities and towns and to provide wastewater collection and treatment. While planners have become more involved in floodplain management and green infrastructure provision in recent years, most planners do not routinely work with water service or utility professionals. For these reasons, land-use planners have not needed to know much about water science, water infrastructure, and water resource management.

Water resource issues are now recognized to be highly interrelated with land development. Population and employment growth have placed increased demands on often scarce water supplies. Pollution and waste disposal practices have diminished the quality and availability of water. There is greater recognition of the need to preserve water for ecological purposes. And drinking water regulations require that cleaner water be delivered to customers even as the quality of many sources declines. In addition, emerging issues such as climate change, urban population growth, and the challenges posed by our aging industrial-era water service systems have given rise to the demand for new solutions for urban water services.

Water professionals are beginning to realize that planning water services should be better integrated with all levels of land-use planning. Many forward-thinking land-use planners, urban designers, and architects are developing new planning practices in concert with local utilities, water engineers, and landscape architects. This means that planners must be prepared to work more often, and more closely, with professionals in the local water supply, wastewater, stormwater, and disaster preparedness fields. Now more than ever, planners must consider how water needs are integrated into their current and future comprehensive plans, zoning ordinances, subdivision regulations, and capital improvements programs. There are many connections between urban planning and water.

The American Planning Association (APA) has recognized the need for a dedicated focus on water to help guide, support, and educate its members. This Planning Advisory Service report is one step among several that APA is taking to meet its members' needs. This report (1) describes the integrated approach to planning and water resource management known as the One Water approach, (2) provides foundational concepts that are commonplace in water disciplines, (3) lays out water issues and challenges facing planners, and (4) presents best practices, case studies, and practical information that planners can apply and integrate into their work.

ONE WATER

Planners and water professionals are developing a postindustrial paradigm to replace the top-down, highly engineered, siloed water service systems of the industrial past and our legacy infrastructure. One Water is based upon the idea that all water within a watershed is hydrologically interconnected and is most effectively and sustainably managed using an integrated approach. One Water advances the rationale for managing water supply, wastewater, and stormwater as one resource—because that is how it exists in nature. The benefits of One Water include improved resource sustainability (greater reliability, security, and resilience), conservation of natural waters and related ecosystems, and flood avoidance. One Water management is a foundational element of the American Planning Association's Policy Guide on Water.

One Water strategies highlight the natural interconnectedness of all water and present planning and management approaches that are based on integrated systems analysis. The more planners can factor the many dimensions of the natural and built environment into their evaluations and visions for the future, the greater will be the potential to realize sustainable and balanced water resource use. One Water provides the overarching structure, conveys the essential interconnectedness of the water systems, and advocates for integrated management, so that externalities are captured and practices in one water domain do not create problems in another. One Water is the structural basis of water sustainability.

By virtue of their skills in fostering collaboration and community engagement, and through their understanding of regulatory tools available to manage land use, planners have important roles to play in coordinating with the various actors involved in water resource management and water services. The planning community is now rising to this challenge, as better understanding and skill in science, engineering, and consensus building across formerly siloed agencies become part of the planner toolkit.

Professional disciplines that are engaging in One Water approaches now include planners, engineers, landscape architects, and architects; members of many science communities (e.g., environmental scientists, water chemists, hydrologists, geologists); and professionals from the fields of law, public administration, economics, and finance.

WATER BASICS

For planners to begin working on water issues in their communities, engaging with water-sector professionals, and moving toward a One Water approach, they must first understand the basics of the water cycle—the continuous movement of water above, below, and on the earth's surface—as well as the three basic types of water infrastructure systems: water supply, wastewater, and stormwater.

Water Supply

Water for human use comes from two main sources—surface water and groundwater. According to the most recent published U.S. Geological Society report, in 2010 about 355 billion gallons of water was withdrawn for use each day in the U.S. (Barber 2014). Trends show that overall per capita daily use, as well as total water withdrawals, have been steadily declining over the last few decades. Understanding water use helps to evaluate the effects of future development plans and trends, which in turn helps planners and water experts create more sustainable water use practices that can help meet future demand.

Wastewater

Wastewater or sewage is the byproduct of many uses of water, including typical household uses such as showering, dishwashing, laundry, and flushing the toilet. Additionally, industries and commercial enterprises use water for these and many other purposes, including processing products and cleaning or rinsing equipment.

Today's wastewater management systems are designed to ensure that harmful waterborne pollutants do not contaminate surface or groundwater sources. Centralized systems consist of networks of collection pipes that collect sanitary waste (and in some cases stormwater as well) and treatment plants that clean the wastewater to the extent needed to return it to water bodies. Decentralized systems provide on-site collection, treatment, and dispersal of wastewater from an individual property or small area. Wastewater is increasingly being viewed as a commodity with potential for resource recovery and reuse.

Stormwater

Stormwater is precipitation, such as rain or snowmelt, that is not absorbed into the ground but flows overland as runoff. In urbanized areas where impermeable surfaces such as streets, sidewalks, parking lots, and buildings predominate, flooding can occur when large volumes of runoff flow into streams and rivers (Konrad 2003).

Historically, stormwater infrastructure, policy, and practice were designed to address urban flooding by collecting and removing stormwater from where it fell as quickly as possible. But in the later part of the 20th century, concerns over pollution, coupled with the impacts of climate change, have pushed water professionals, planners, urban designers, and engineers to rethink traditional approaches of engineered, or gray, infrastructure. Increasingly, communities are turning to more natural approaches of green stormwater infrastructure and low-impact development designs to reduce runoff by infiltrating it on-site in more cost-effective and ecologically friendly ways.

WATER SYSTEM CHALLENGES AND FACTORS FOR CHANGE

The U.S. water system is one of the largest and most sophisticated in the world. However, increasingly complex challenges face water utilities and the natural water environment. Water system problems can be characterized in one of three ways (Sullivan 2016):

- There is not enough water.
- There is too much water.
- The quality of water is compromised for the proposed use.

These three issues translate into challenges of scarcity of water supplies, flooding, and water pollution and contamination. Aging and deteriorated infrastructure compounds these problems, which impact the environment, the economy, and society. Two factors—climate change and population change—are exacerbating existing water management challenges and creating new ones.

Emerging Drivers of Change in Water Management

A leading challenge in the water sector is climate change. The higher average surface temperatures across the continents are causing two water-related phenomena of concern. First, sea levels are rising. Second, weather patterns are becoming more volatile, extreme, and geographically distinct, with wetter areas becoming susceptible to increased floods and dryer areas to droughts (IPCC 2014). At the same time, both the frequency and intensity of extreme weather events are increasing. The many manifestations of climate change have the potential to negatively impact communities in a wide range of ways.

As the population of the world grows, competition will increase for water supplies, which are limited or diminishing in many parts of the world. In the U.S., population growth has accelerated in many water-scarce regions, such as the arid southwestern states. A national 150-year trend of population clustering in urban areas is expected to continue for the foreseeable future. Exacerbating the challenges of supplying water to growing populations are accompanying water demands for agriculture and food production, energy generation, business and industrial use, and recreation.

Challenges to Water Management

Freshwater shortages are occurring in the U.S. because of the depletion or loss of traditional natural water storage such as aquifers, diminished snowpack levels, decreased precipitation as a result of climate change in some areas, and long-term drought. Pollution of existing water sources can also contribute to water scarcity. Additional new demands on water supplies include such uses as hydraulic fracturing to extract natural gas. Overpumping of groundwater systems (aquifers) may cause land subsidence, aquifer collapse, and damage to water distribution infrastructure and facilities.

Several issues have arisen in recent years regarding contamination of the water supply by known contaminants, such as lead, as well as potential contamination by contaminants of emerging concern—potentially harmful chemical compounds that have no regulatory standard but have been recently discovered in natural aquatic environments. Despite an overall improvement in water quality since the 1970s resulting from enforcement of the federal Clean Water Act and Safe Drinking Water Act, many water bodies still suffer from pollution. Both urban and agricultural activities can pollute stormwater (U.S. EPA 2017e).

Flooding is the most common and costliest natural hazard facing the U.S. Over the last 30 years, floods have caused an average of $8 billion in damages and 82 deaths per year nationwide (AGI 2017). Flooding has many causes, including heavy rainfall, rapid snow melt, and broken dams or levees. In coastal areas, flooding can occur during hurricanes and storm surges, which cause sea levels to rise temporarily. Extreme precipitation events caused by the impacts of climate change have increased the frequency of flood events in many parts of the U.S.

The legacy water infrastructure in the U.S. dates from the late 1800s and relies on aging underground pipes and centralized treatment facilities as well as a complex and context-dependent organizational framework for managing and operating these systems. Both situations present challenges. In 2017, the American Society of Civil Engineers (ASCE) gave the nation's drinking water infrastructure a D grade while wastewater and wet weather infrastructure earned a D+. The U.S. needs to invest $150 billion in its water and wastewater infrastructure systems but has only provided $45 billion, leaving a funding gap of $105 billion (ASCE 2017).

Additional Impacts of the Changing Context for Water

The combination of climate change and urban population growth, coupled with legacy water system problems and long-term water management challenges, has wide-ranging impacts. Decisions about where to direct diminishing water resources can raise ecological and environmental issues, and the impacts of water on economic growth and environmental justice are becoming increasingly clear.

Human overuse of scarce water supplies and water pollution threaten regional biodiversity and the ecosystem services provided by plants and wildlife. Inefficiencies and failures in the functioning of U.S. water systems can diminish the attractiveness of cities, suburbs, and rural areas for investment by the private sector. Flooding can have extremely costly impacts on local economies.

Water is a universal need, but its cost can create equity challenges, especially for vulnerable low-income populations. The question of affordability can be considered from three different perspectives: the utility's cost of providing water services, the community's ability to pay for increases in water service, and the affordability of water services for individual households, especially economically challenged households. Federal requirements for water and wastewater systems can result in significant investments by communities in water treatment and distribution and higher water and sewerage fees for consumers. Legacy cities—older cities with declining populations and diminished economic conditions—are especially challenged by water system affordability and reliability.

Though average water and sewer costs together account for less than 0.8 percent of total household expenditures, these costs are rising rapidly (Beecher 2016). Further increases in water and sewer bills anticipated over the coming years raise concerns about the ability of low- and moderate-income households to pay for water.

Water challenges such as threats to safe quality of water supplies, high costs of water services, and negative impacts on water-related cultural and economic activities have a disproportionate effect upon minority and low-income communities. Flooding also presents special risks to these households, who may be less likely to receive news and heed warnings from mainstream weather services.

Access to clean, safe, and affordable water is a fundamental human right, and is essential for a healthy population, environment, and economy. Justice requires that the risks to health and public safety from water, or lack thereof, be equal across income levels and other measures of human diversity, so that all citizens share equally in the benefits, as well as the risks and efforts, of maintaining sustainable water systems.

PLANNING FOR SUSTAINABLE WATER: RECOMMENDED PRACTICES

Planners have important roles in transforming water systems and resources to advance sustainability and resiliency goals. Planning initiatives and practices are beginning to reflect the need to address increasingly severe and unpredictable water management issues. Progress is being made both at the local level, where individual initiatives are emerging in forward-thinking communities working in coordination with water utilities, as well as at the regional and national scales, where new information systems, alternatives analysis tools, and regulatory approaches are being created.

Two strategic planning frameworks can improve water planning and management by helping planners integrate water issues into planning work: APA's "five strategic points of intervention" and APA's Sustaining Places initiative.

Water and the Five Strategic Points of Intervention

Planners engage in a great many activities, but those that are central to their professional functions and positions and that hold the most promise for making a difference in most planners' basic work tasks can be boiled down to five key areas: visioning; plan making; standards, policies, and incentives; development work; and public investments (Klein 2011).

When considering how planners can improve water resource planning and management by applying improved planning practices, it is useful to consider these "strategic points of intervention." While there may be additional opportunities for strategic *intervention* as planners, opportunities for strategic *intersection* with other water professionals is emerging as an equally important planning function. For points of intervention, planners are typically the lead party. For points of intersection, planners need to collaborate on water management with a range of water professionals, as each of the many disciplines involved has much to contribute to sustainable water management.

Water in the Context of Sustaining Places

While the traditionally understood role of planning and planners is well represented by the five strategic points of intervention, planning is shifting toward a new paradigm with a goal of overarching, integrated sustainability. This can be characterized by APA's Sustaining Places initiative, which provides a fresh lens to help planners better integrate water issues into their work. The APA Comprehensive Plan Standards for Sustaining Places presents six principles, two processes, and two attributes for plan-making standards, each accompanied by multiple best-practice actions that support plan implementation. The standards can help advance more sustainable water management and suggest how planners might create additional opportunities for water management best practices.

Recommended Practices

New approaches, alliances, interdisciplinary strategies, and roles in planning for water are constantly evolving and being tested. Creative adaptation, modification, and interdisciplinary approaches can make a world of difference in improving the potential usefulness of existing practices or in creating innovative new practices. The principles of One Water management are readily adaptable to similar geographies and water resource settings. In many cases, implementation of best practices will benefit from collaboration and interaction between planners and other water professionals, such as hydrologists and hydrogeologists, civil and environmental engineers, landscape architects, environmental scientists, economists, lawyers and regulatory experts, local government officials, and others.

Water Supply Practices

There are four main roles for planners that relate to water supply: (1) to coordinate with the local water supply provider to ensure that the water utility's water management plan and its capital improvement program reflect the vision of the local government, and that the utility's water facilities and investments are consistent with the local land-use plan; (2) to ensure that the community's own long-range or comprehensive land-use plan is linked to adequate water quantity and quality and supports One Water management; (3) to ensure that local development regulations protect traditional water resources and appropriately allow for new water sources; and (4) to ensure that development proposals address adequate water supply and site-specific infrastructure and do not compromise the water environment (Johnson and Loux 2004).

City and county land-use planners can improve planning and water management by sharing data, plans, and information about their comprehensive plans and development proposals with water utilities, and the reverse is also true. Demand management and conservation strategies should be related to, and referenced in, the comprehensive plan. Planners can use zoning and subdivision regulations, which should implement water-related goals and objectives, to protect water supplies. Communities can address water shortages by enacting "water offset" policies and regulations. Planners have the responsibility to ensure that adequate water is available for new developments or large-scale changes of use; collecting information about water resource availability, competition for use of water, and situations where demand might exceed supply is essential when considering approving new development.

Wastewater Practices

At the city, county, and regional levels, planners should be part of conversations regarding the implementation of innovative wastewater infrastructure. Sewers are powerful determinants of where growth in an area will go—in shaping development, a city's choice of sewer investment can be more important than the city's land-use plan (Scott et al. 2005). Planners can help local policy makers decide where and, just as importantly, when to expand municipal wastewater service (Tabors 1979). Planners can also work with wastewater utilities to integrate their sustainability goals into comprehensive plans and development regulations.

The field of wastewater management is seeing innovative developments involving on-site and district-based nonpotable reuse of wastewater, which also contains valuable resources including water, carbon, nutrients, trace metals, and embedded energy that can be captured. Another exciting effort is the use of the energy contained in sanitary wastewater for heating and cooling.

Smaller on-site or decentralized and satellite systems are possible with new technologies such as advanced filters and intelligent monitoring systems. Natural treatment systems are of considerable interest today both in the U.S. and abroad because of the importance of wetlands in carbon sequestration and their ability to naturally treat wastewater.

Stormwater Practices

Planners can advance policies to integrate stormwater best practices into the design of the city through the comprehensive plan, the capital improvement plan, and development regulations (Novotny, Ahern, and Brown 2010). Best practices include replacing gray infrastructure conveyance systems that remove stormwater runoff from a site as quickly as possible with more decentralized green systems that seek to infiltrate and store stormwater near to where the rain lands.

Planners are using subdivision and land development regulations, as well as separate stormwater management ordinances, to promote on-site capture, infiltration, and slow release of stormwater. Designing with nature at the site level where the precipitation falls helps to protect water supplies, causes less runoff, and contributes to a more attractive and resilient urban environment. Such approaches include low-impact development and green stormwater infrastructure. Source control—preventing pollutants in urban runoff from getting into the pipe collection system—and stream and creek restoration efforts are also important strategies.

THE FINANCIAL ASPECTS OF WATER

To adapt, replace, and reinvent the aging U.S. water system is not only a technical and organizational challenge, but a financial one as well. The One Water paradigm calls for adopting integrated water-sector planning and breaking down the barriers between "silo" financing and fee structures of the separate water utility sectors. This paradigm also calls for new and creative ways of financing investment for the new vision of water.

Historically, water has been treated as a common good, available to all at a price based only on the cost of treating and delivering the water—but significant costs to society and the environment have not been incorporated into water prices or fees to the consumer. Economics posits that any item of value not assigned an appropriate price reflecting that value will be overconsumed or inefficiently managed. The price of water services is a key factor in being able to influence more efficient use of water, reduce pollution, and contribute to the use of more sustainable and equitable water technologies and systems.

Pricing and Rate Structures for Water Systems

The major actors in rate setting and spending on water are state and local governments, including water utilities. The price of water services is passed on to consumers through fee or rate structures, or user fees. Water and wastewater utilities use a combination of a fixed (base) fee—the price the customer pays to help cover costs of maintaining existing infrastructure and repaying loans and bonds used to build that infrastructure—and a variable fee for the volume of water used that reflects the costs of treating and providing that water. Several different types of rate structures can be used by water and wastewater utilities, and fees can vary among residential, commercial, and industrial users. Using conservation rate structures such as increasing block rates, seasonal rates, drought rates, or water budget-based rates can reduce water demand significantly.

Stormwater runoff has traditionally been the responsibility of city or county public works departments, funded by municipalities' general funds as part of street and sewer improvements and maintenance. Early financing for off-site municipal infrastructure investments also relied upon general funds from property taxes. The best practice today is for a locality to establish a stormwater utility (SWU) empowered to set user fees. Most SWUs today tie their fees to the amount of impervious surface of a parcel and hence to the volume of storm runoff generated by the user.

Capital Improvement Strategies

Since the 1950s, the federal government's expenditures to build dams, levees, reservoirs, and other water containment systems have declined substantially (CBO 2015). In the 1970s and 1980s the federal government made significant investments in wastewater treatment plants due to Clean Water Act requirements, but today federal capital expenditures for local water services are much reduced.

Historically, water and wastewater utilities have relied on bonds for capital investment or infrastructure and user fees for operations and maintenance. Most large-scale capital facilities for all three water sectors are paid for by funds from bonds issued by the local water utility or the local government. Today the federal Clean Water and Drinking Water State Revolving Loan funds offer seed money for states to capitalize state loan funds. These programs have issued more than 36,000 low-interest loans amounting to more than $111 billion to communities, funding water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed and estuary management (U.S. EPA 2017b).

In the 1980s, many local governments struggled to finance water and sewer infrastructure to accommodate rapid development. Accordingly, some cities and counties began to charge one-time fees during the development review process that allowed the locality to fund the cost of the new infrastructure needed to support that project (Galardi et al. 2004). There are three approaches to establishing development impact fees: a system buy-in or reimbursement approach for new development based on existing facilities and costs, a requirement that new development pays for the cost of new facilities, or a combination of these two.

Distributed and multipurpose systems—including satellite treatment plants, on-site water and nutrient reuse, and green infrastructure—have been noted by many as a way of addressing some of the problems with the industrial era system (Novotny, Ahern, and Brown 2010; Nelson 2012; Brown 2014). However, traditional governance systems and financing mechanisms are difficult to use for these innovative systems due to regulatory barriers at the state and local levels and a lack of organizational commitment and capacity by the water utilities. A shift toward distributed and small-scale systems will require changes in the financial markets as well as local and state regulations.

Water Markets and Water Rights

Water marketing can be defined as "the voluntary transfer of the right to use water from one party to another on a temporary, long-term, or permanent basis, in exchange for compensation" (Hanak and Stryjewski 2012, 7). Water markets are created by the interactions of buyers and sellers regarding quantities and quality of water. They can reallocate water rights from lower- to higher-valued uses, thereby, according to economists, making water use more efficient. They can also be used to incentivize conservation in low-cost water sectors such as agriculture to make more water available for higher-valued residential markets. Water markets are governed by water rights.

Water rights for surface water can be divided into two categories: riparian rights/reasonable use doctrine and prior appropriation. Riparian rights allow the property owner adjacent to a river to withdraw as much water as needed for use on the property as long as there is no harm to the downstream user. The doctrine of "reasonable use" to refine the unlimited use of a riparian right emerged in the later part of the 19th century with the rise of mills and other industrial uses with large water needs. Prior appropriation doctrine arose in the semi-arid west, where water needed to be moved from rivers to users, and holds that the first entity to take water from a surface water source for a "beneficial use" has the right to continue to use the same amount of water for that given use. Water rights for groundwater has been dominated by the "rule of capture" but this is now changing.

How Planners Can Get More Involved

Planners can effectively participate in the financial decisions their communities make through capital improvement plans (CIP) and budgets, fair and equitable fee structures and programs, and cost reduction measures. The water sectors' CIPs should be consistent with and integrated into the city or county's CIP and comprehensive plan. Planners have a responsibility to work with their local utilities to ensure that the procedures for setting fees and collecting revenues are fair and equitable. They should also ensure that preparation for the comprehensive plan includes an analysis of low-income households' abilities to accommodate future water price increases.

PLANNING FOR WATER: THOUGHTS FOR THE FUTURE

This report introduces a very complex subject matter—water—for which planning practices are rapidly evolving as planners seek to implement more integrated water systems. Yet more needs to be done by the planning profession, water professionals, and the engineering and architectural community to address water resource management challenges, protect our cities from climate change impacts, and transition to the next generation of One Water infrastructure.

Key Questions for the Planning Profession

As our communities grow, improved planning practices will better anticipate changing patterns of growth and resource use and provide more approaches to guiding that growth. The planner of the 21st century faces resource scarcity, increased competition over available resources, climate change variability and risk, infrastructure deficiencies, funding shortages, and local political barriers. Planners must consider a number of key questions:

1. How can planners better address key drivers and causes of water vulnerability?
2. How can planners build collaborative strategic partnerships and better operate across professions, communities, and regions?
3. What role can planning and design play?
4. What knowledge and tools should be applied? What new tools are needed?
5. How can planning address uncertainty and risk, and anticipate instability?

Partnerships and Conversations

The challenge of breaking down silos and engaging across disciplines is ever present in the planning profession. Given the interdisciplinary nature, range, and complexity of water management, it is virtually impossible for any single profession to identify all the system interactions and solutions. Planners should embrace this challenge and forge new connections with their counterparts at water-focused agencies, organizations, and departments.

There are increasing opportunities to engage in productive, inclusive conversations with a broad base of practitioners, citizens, and stakeholders who depend on sound water management. Interdisciplinary efforts have proven to be transformative by synthesizing the knowledge of different disciplines to guide decisions for improved outcomes. Planners must better define the dimensions of water resource challenges, work interactively with peer professions such as engineering and landscape architecture, and use decision support and public communications tools to support an interactive work environment. A broader vision and broader engagement helps to create more sustainable water management outcomes. Creating new conversations that lead to exchanges of information and science will help to forge new permanent partnerships that will not be limited by siloed missions.

Water Education for Planners

As planners, we have responsibilities not only to practice but to continue educating ourselves, the communities around us, and future planners. We need to improve water education for planning students so they are adequately prepared to address water challenges from the start of their planning careers. At the same time, educational opportunities must be made available for elected and appointed officials and practicing planners facing water-related challenges that require action now. APA can offer guidance, support, and perhaps most importantly, educational opportunities to prepare planners and decision makers to lead and respond effectively to emerging water challenges.

It is important to arm planners, both in the classroom and in continuing education, with more technical skills to address water issues so they have the confidence to not only facilitate the water management dialogue but also drive it.

Broadening the education of the populace about water-related principles, issues, and opportunities, as well as providing training for jobs in this emerging sector, is essential if the planning profession truly wants to integrate water management into traditional planning practice.

APA's Water and Planning Network

APA is dedicated to adding value not just to the growing network of water disciplines, but to its own members, ensuring they receive the guidance, support, and access to practical and educational opportunities they need to do their jobs well. Rising to the challenge and understanding its responsibility, in May 2017, APA launched the Water and Planning Network (WPN). The mission of the WPN is to provide a professional forum for the interdisciplinary exchange of ideas and planning methods. It will operate as a communications and information-sharing network to connect members to the most current water research, science, policy, technology, and best practices.

Conclusion

Planners play key roles in influencing land-use patterns and helping communities guide how development and redevelopment occur. Planners do this by planning at all scales, creating land-use regulations, and reviewing development projects. This provides planners with opportunities to advance more sustainable water systems. Planners can incorporate dynamic, nature-based, sustainable systems that do not rely solely on pipes, pumps, and treatment plants to solve water problems. Planners can help reconnect society to water's natural setting—and identify the complex interdependencies between water use, wastewater disposal, runoff management, surface and groundwater resources, and the natural environment—to start solving the many challenges of planning for land use and water resources.

CHAPTER 1

PLANNING FOR WATER: AN INTRODUCTION

Water is essential for human life. It is necessary to support human settlement and the built environment. Water is crucial for ecosystem functioning and the production of food and energy. Water provides important economic and aesthetic values for cities, counties, and towns. From the beginning of civilization, human beings have devised ways to ensure that water is available when and where it is needed, as well as ways of addressing wastewater and of dealing with storms and flooding.

Historically, the work of land-use planners has not extended to water resource management, although environmental planners have contributed much to the preservation of natural resources including water, watersheds, rivers, and streams. For urban water services, land-use planning professionals have relied upon water utilities, public water departments, and the engineering community to deliver and manage the supply of water for cities and towns and to provide wastewater collection and treatment. While planners have become more involved in floodplain management and green infrastructure provision in recent years, local public works departments and the U.S. Army Corps of Engineers still take the lead in addressing stormwater and flooding issues. Most planners do not routinely work with water service or utility professionals. For these reasons, land-use planners have not needed to know much about water science, water infrastructure, and water resource management.

Water resource issues are now recognized to be highly interrelated with land development. Population and employment growth have placed increased demands on often-scarce water supplies. Pollution and waste disposal practices have diminished the quality and availability of water. There is greater recognition of the need to preserve water for ecological purposes. And drinking water regulations increasingly require that cleaner water be delivered to customers even as the quality of many sources declines. In addition, emerging issues such as climate change, urban population growth, and the challenges posed by our aging industrial-era water service systems have given rise to the demand for new solutions for urban water services.

Though sustainable water management poses challenges, it also offers opportunities. The triple-bottom-line sustainability of cities is directly advanced by a visible water environment that is integrated into the urban design of a city's neighborhoods and open spaces. The benefits of better integration of water design into urban space are becoming more widely researched and demonstrated. Studies have shown, for example, that green infrastructure can reduce urban heat island health impacts, improve water quality for drinking water and stream ecology, enhance public safety, and increase property values due to its value as an urban amenity; it brings triple-bottom-line benefits to communities (PWD 2016).

Water professionals are beginning to realize that planning water services should be better integrated with all levels of land-use planning. This means that planners must be prepared to work more often, and more closely, with professionals in the local water supply, wastewater, stormwater, and disaster preparedness fields, whether they work inside city or county governments, are employed by special agencies, or are in the private sector.

Many forward-thinking land-use planners, urban designers, and architects are developing new planning practices in concert with local utilities, water engineers, and landscape architects. Yet most planners could benefit from more information about water. Water is ubiquitous to urban systems, and planners need to consider how water impacts their communities. The key information about water management often appears in scientific jargon, which can present barriers to planners. Whether it be water scarcity, stormwater management, or water quality, now more than ever, planners must consider how water needs are integrated into their current and future comprehensive plans, zoning ordinances, subdivision regulations, and capital improvements programs.

Planners, architects, landscape architects, and water professionals are now in transition from industrial-era infrastructure, often characterized as "gray infrastructure" or legacy systems, to post-industrial integrated systems, where the waste from one function serves as an input to another and where more holistic thinking about all systems occurs. Figure 1.1 summarizes some of the functions, outcomes, challenges, and innovations at play in the transition from the historic water resource management paradigm of the industrial era to new approaches required by the issues we face in the 21st century.

Chief among such issues is the need to look at the provision of water services holistically—to think about how the water supply, wastewater, and stormwater planning can be treated as an integrated unit ("One Water") instead of separate systems. In addition, streets and sewer infrastructure need to be thought of as one system, as repairs or construction of one are an opportunity to use more sustainable solutions for the other. Similarly, the connections between solid waste, wastewater, water supply, and energy for centralized water utilities, as well as decentralized systems for neighborhoods and buildings, need to be considered in land-use

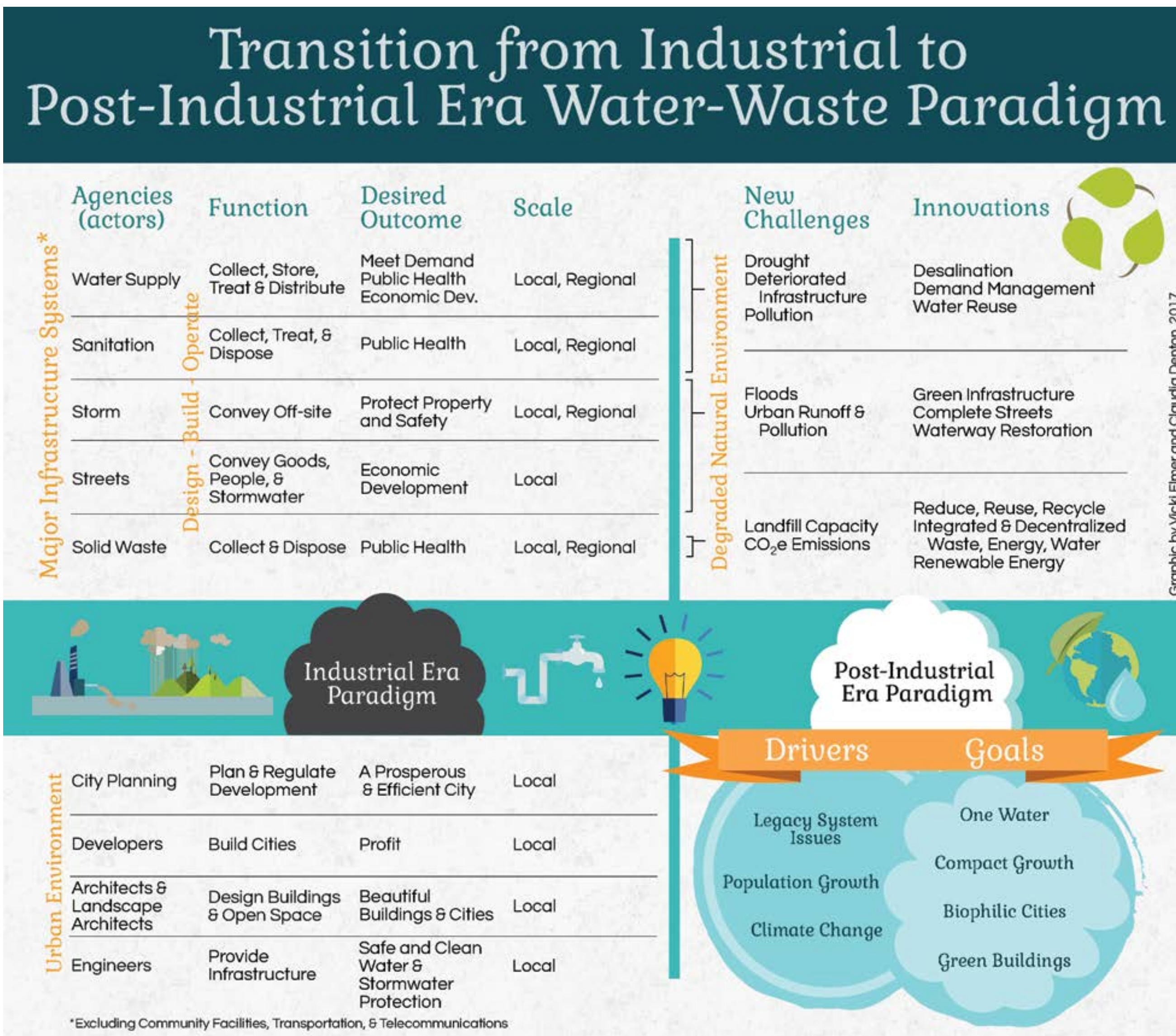


Figure 1.1. Transitioning to a new water resource management paradigm (Vicki Elmer and Claudia Denton)

THE EVOLVING ROLE OF APA IN WATER PLANNING

APA's dedicated focus on water started with the creation of APA's Water Task Force, launched by past APA president William Anderson, FAICP.

Established in January 2014, the Water Task Force analyzed the link between water management and land-use planning and offered recommendations to APA leadership for improved policy and practice. The Water Task Force convened a diverse group of experts, including planners, landscape architects, economists, policy makers, environmental scientists, and academics, to identify the essential links between water management and land-use planning.

The result was a detailed report containing 30 recommendations under six core themes and a challenge to planners to assume a lead role in breaking down existing water-planning silos. The Water Task Force report was presented to APA leadership at APA's 2015 National Planning Conference in Seattle and is available on the APA website at www.planning.org/nationalcenters/green/watergroup.

The completion and submission of the Water Task Force report signified the end of the Water Task Force. However, as a direct result of the report, APA formed the Water Working Group (WWG). The WWG was charged with determining ways in which APA and its chapters, divisions, and professionals can best implement the Water Task Force recommendations on partnerships, policy, research, education, and practice. APA staff identified and appointed a smaller group of APA members, comprising planners, engineers, and representatives from important water-focused organizations, to help advance the recommendations of the report.

Since its creation in July 2015, the WWG has identified several priority initiatives to help APA better support its members working on water issues in their communities, while also focusing on ways to implement the recommendation of the Water Task Force report. These efforts include contributing to an update to APA's Policy Guide on Water, working on partnership development, creating educational opportunities for planners, and implementing a survey of APA membership regarding water planning. These actions elevated APA's role in the water-sector world while educating its membership and developing strong networks with other organizations also dedicated to helping urban professionals address water challenges.

The WWG transitioned into the Water and Planning Network (WPN), a professional forum and information-sharing network open to all APA members, in May 2017 (for more information on the WPN, see Chapter 7).

planning. Integrating water-dependent ecological functions into the city, as well as using water as an aesthetic asset, is also important for planners to consider. There are many connections between urban planning and water.

The American Planning Association (APA) has recognized the need for a dedicated focus on water to help guide, support, and educate its members. The sidebar on p. 15 describes the evolution of APA's efforts in this area. This Planning Advisory Service report is one step among several that APA is taking to meet its members' needs.

APA SURVEY OF PLANNERS

As part of its efforts, in February 2016, APA administered a comprehensive survey about water issues to its members. An APA Water Working Group (WWG) initiative (see sidebar), the APA Survey of Planners and Related Professions on Water Issues shed light on what APA members need to help them successfully navigate the challenges posed by planning for and with water.

The survey was designed to elicit information from planning practitioners about the importance of water issues to planning, the relationship of planning and water issues in their work, specific problems, and best practices. Almost 1,000 planners responded to the survey. Their responses indicated a deep interest in water issues and planning, a desire to become more involved, and the need for APA's help in providing planning practitioners with greater support in expanding knowledge and skills about water.

Most of those who responded to the survey were APA members (92 percent). Over half were planners in state or local public planning agencies (60 percent), about 20 percent were in private consulting practice, and the remaining 10 percent were split between nonprofit organizations and water utilities. The majority of those who responded (57 percent) were from large metropolitan areas of more than one million people; 22 percent were from medium-sized metros (250,000–1 million population), and the remaining 21 percent were from planners in metropolitan areas of less than 250,000 people, micropolitan areas, areas outside the micropolitan areas, and Indian reservations.

Many of the survey respondents did not work on water issues full time, but indicated they were knowledgeable about water issues. A small group of respondents (9 percent) were water agency staff or engineers who spend between 80 and 100 percent of their time on water issues. The main findings of the survey are summarized here.

The survey identified water as one of the top 10 challenges facing the field of planning today.

Eighty percent of respondents rated water among the top 10 issues while an additional 11 percent rated it as the most important problem for planners. Stormwater management and flooding were ranked as top challenges for the field, followed by adequate water supply and water resource degradation. Concerns were also raised about climate change impacts, saltwater intrusion, equity issues, and financing.

Comprehensive plans and development regulations in the U.S. do not adequately address water issues, despite the fact that planners often deal with water utilities. Development project reviews have a better track record on integrating water issues, but it is still inadequate.

Most respondents (87 percent) indicated that they interact with staff from water, wastewater, and stormwater utilities in their work. These interactions were for project reviews (62 percent), comprehensive plan preparation (54 percent), environmental or watershed planning (45 percent), and infrastructure planning (38 percent). A smaller number cited financing (12 percent). In addition, 48 percent of a subset of the larger survey group who responded to more detailed questions about planning and water indicated that the local water supply agency is actively participating in the land-use planning process for their jurisdiction, and 44 percent felt the same way about the wastewater agency.

However, despite this involvement, more than half of survey respondents felt that neither comprehensive plans nor local development regulations adequately address water issues. Respondents were more positive about individual project reviews, but only 40 percent thought that development projects were adequately reviewed with respect to water.

Planners are not involved enough in water decisions. This is due to agency fragmentation and lack of time to engage. Planners' lack of water knowledge is also an impediment.

Three-quarters of those surveyed indicated that planners were not involved enough in water planning and decisions. Respondents do not think that planners work closely enough with water management professionals, such as those who are in charge of utility operations, engineers, architects, landscape architects, and geographers (65 percent).

Planners also overwhelmingly indicate that there is inadequate coordination of utilities' own infrastructure projects with local land-use planners. Two-thirds (67 percent) indicated that planning for these infrastructure projects are not adequately coordinated with planning departments.

The major obstacle to involvement of planners with water utility planning that was cited by respondents is the institutional separation of planning and water (86 percent). Respondents also acknowledged that too many other issues compete for planners' time (60 percent). Fragmentation of the water agencies themselves was identified as a factor by 56 percent of those surveyed, as well as lack of knowledge by planners about water (50 percent). Budget issues, lack of data, and lack of leadership were cited by 20 percent or less of the respondents as obstacles for involvement.

Plans and regulations are increasingly incorporating water-related issues and best practices, but more work is needed in this area.

The survey asked a subset of approximately 330 respondents more detailed questions about water-related provisions in local plans and regulations. These respondents are likely those planners and jurisdictions who are more advanced with respect to water issues, so the percentages reported below do not reflect what is happening in all jurisdictions, but rather what is being pioneered as best practices.

Almost 63 percent of the comprehensive plans in the jurisdictions of this subset of respondents were completed in the past five years or are currently being updated. Of these, 76 percent contain provisions for floodplain design criteria, 72 percent for stormwater management, and 68 percent for watershed protection. Smaller numbers of plans in these jurisdictions contain provisions for water supply (58 percent), water quality of receiving water bodies (55 percent), and natural resource protection and restoration (52 percent). Septic tank provisions were included in 35 percent of plans. Many states and regional entities were said to provide guidance on water planning to land-use planners.

Newer water technologies, such as water reuse by centralized facilities and water reuse at the neighborhood level, were included in 31 percent of comprehensive plans in respondents' jurisdictions, while provisions for the water-energy-waste nexus (16 percent) and the food-water-energy nexus (7 percent) are still in their infancy. However, it is encouraging that these innovations are starting to appear in local plans.

Development regulations in local communities also show progress. Ninety-one percent of this subset of respondents indicated that local planning regulations included provisions for stormwater, while 74 percent said that their regulations contained provisions for the protection of aquifers, surface waters, and riparian areas. Over two-thirds (68 percent) noted that their regulations addressed the preservation of natural water systems. Green infrastructure regulations were mentioned by 60 percent, as well as water supply development regulations (56 percent), water conservation regulations (56 percent), and efficient use of water (50 percent). Again, the more recent water recycling technologies are just starting to make headway in planning circles, with 25 percent reporting regulations that govern the use of recycled water from a centralized facility, 15 percent with graywater reuse provisions, and five percent with black water recycling provisions.

Regarding project reviews, over half of those responding to this question had been involved in processing a private-sector development where water was an issue. Stormwater was cited as the most frequent issue (76 percent), with water supply (58 percent), flooding (49 percent), and sanitary sewers (37 percent) also important. In addition, many reported that water conservation and reuse practices were typically part of new development projects in their jurisdiction.

Planners want to work more closely with water utilities. This would benefit both the planning profession and the communities that planners serve.

Respondents overwhelmingly concur that there are benefits from greater interaction between planners and the work of water professionals in other fields as well as greater understanding of water issues. Planners are also united in affirming that it would be helpful to work more closely with water agencies. Although most planners (80 percent) had not heard about One Water (see next chapter), 30 percent felt that this initiative might improve involvement.

A subsequent project is seeking additional information on water and planning. The Water Environment and Reuse Foundation (WE&RF), as part of a research project on integrating water management with urban planning and design, has leveraged the APA Survey of Planners and Water and reached out to the responders with 35 additional questions about how planners and water professionals work together. This survey focuses on the identification of best practices for urban planners and water service professionals to integrate water systems into urban design, as well as synergies and gaps that exist in current approaches to water and land-use planning activities. The products of the WE&RF research project are anticipated later in 2017.

ABOUT THIS REPORT

Planners are trained to analyze and understand the interdisciplinary nature of risks and uncertainty, but they need ad-

WATER QUESTIONS FOR PLANNERS

The American Planning Association's Water Task Force report (Cesanek and Wordlaw 2015) raises the following questions and challenges for planners:

- Knowing that the United States will grow by 90 million people in the next five decades, most of this in urban metropolitan areas, how will we plan for growth and development, guide land use, and provide infrastructure, considering growing water scarcity and the economic, social, and cultural trends toward sustainability that are occurring?
- Given the increasing industrial, agricultural, public health, and social and recreational demands for water, how will cities prioritize their needs for water and effectively and equitably price these needs while also adopting more innovative, creative methods to reclaim and reuse water?
- As water supply and quality are impacted by urbanization, how will planners work to advocate and implement more natural and less centralized solutions and celebrate water as a resource needed to sustain healthy communities and cities, resulting in One Water management of ground and surface waters?
- Given the historic separation of land-use planning and the water sectors, how can planners facilitate a process that leads to comprehensive, collaborative, interdisciplinary approaches to water planning?
- Given that water is essential to public health and safety, what tools, methods, and policies can planners use to better assist and advocate on behalf of all communities exposed to water-related challenges (including managing demand, protecting the quality of drinking water and natural streams, and protecting against storms and floods)?
- Given the need to rebuild our deteriorated water infrastructure, how can planners help elected officials and other urban professionals create policies for new economic solutions for the improvement of local and regional water systems?

ditional context and knowledge to adequately address water resources. The authors have prepared this report to assist planners in water management. Expanding on the recommendations contained in APA's Water Task Force report, this PAS report is intended to complement the work of APA's WWG and respond to the needs indicated by APA's water survey. Planners face many questions and challenges that relate to water management, a range of which were identified in the Water Task Force Report (see sidebar). This PAS report seeks to engage planners and offer them an introduction to the tools and techniques they will need to address these water issues moving forward.

This report (1) describes the integrated approach to planning and water resource management known as the One Water approach, (2) provides foundational concepts that are commonplace in water disciplines, (3) lays out water issues and challenges facing planners, and (4) presents best practices, case studies, and practical information that planners can apply and integrate into their work.

The report is designed to provide planners a snapshot of the state of planning and water as it exists in 2017. This is a field that is changing rapidly, but given the long-lasting nature of water infrastructure, it is likely that the information in this report will be helpful to planners for many years.

How to Use This Report

This report was written to allow readers to directly access and use the chapters of greatest interest. Chapters may be read sequentially, though each individual chapter can stand on its own. The structure and content of the report is described below to highlight the topics that are covered and let readers chart their own course through this information.

Chapter 2 introduces One Water, explaining and exploring this new paradigm for thinking about water management issues. One Water is a central policy of APA's approach to water management, and is an organizing principle of the current approach to water by most professional organizations and agencies involved in water planning and management.

Chapter 3 provides basic information about the water cycle and the three water systems that together make up water management: water supply, wastewater, and stormwater. Planners who are new to water systems issues can use this chapter as a primer to bring them up to speed on these systems; those who are experienced in water management may be able to expand their knowledge base by drawing on subsection topics with which they are less familiar.

Chapter 4 makes the case that the emerging global challenges of climate change and increasing urbanization and population growth are important frameworks for understanding the growing challenges of water management. It then looks at some of the specific challenges facing water supply, wastewater, and stormwater systems, and examines additional environmental, economic, and social impacts of water challenges on communities. This chapter highlights the vital issues that planners face in helping ensure that their communities are prepared for the future. This exploration of increasingly pressing water issues is a call to action for planners, and can familiarize the reader with important water resource management challenges.

Chapter 5 outlines how planners can address water issues through "five strategic points of intervention"—long-range community visioning and goal setting; plan making; standards, policies, and incentives; development work; and public investments—as well as through "points of intersection" with water management. It delves into how water resource management intersects with sustainability, exploring its integration into APA's Comprehensive Plan Standards for Sustaining Places. It then provides a more applied approach to planning and water resource management by offering recommended practices for planners. This chapter includes case study examples of exemplary initiatives and projects in the areas of water supply, wastewater treatment, and stormwater management, as well as several that represent progress toward One Water.

Chapter 6 addresses the financial aspects of water planning and management. It explains approaches to water utility financing, and will be of interest to those involved in capital project planning and financing.

Finally, Chapter 7 poses key questions and challenges for the planning profession as we look ahead at planning for water in the 21st century, and offers an agenda and recommendations for planners. As planners inherently look to the future, this chapter identifies future work and approaches that will improve the engagement of planners in water management.

CHAPTER 2

ONE WATER

In the past, planners have interacted with water utilities, which separately manage water supplies, wastewater, or stormwater outside the sphere of the planning process. Planners have typically only worked on water issues as part of development project reviews or environmental impact reviews. Planners have not been involved in planning the location, expansion, or maintenance of water systems.

Historically, water management has been focused on public health needs and economic prosperity, but we have additional goals today: compact growth, sustainable development, and livable cities. Concerns about the "perfect storm" of climate change, urban population growth, water infrastructure deterioration, and the attendant effects on public health, ecological systems, flooding, economic growth, and environmental justice, have prompted the need for a new approach to water planning and operations. Planners and water professionals are developing a postindustrial paradigm to replace the top-down, highly engineered, siloed water service systems of the industrial past and our legacy infrastructure.

This new approach is called One Water. One Water advances the rationale for managing water supply, wastewater, and stormwater as one resource—because that is how it exists in nature. A One Water approach leads to more sustainable outcomes for land development, the environment, and for our water resources.

In this section we describe the importance of a One Water approach to water resource management, especially for urban planners and other planners involved in managing water. We explore the following three questions:

- What is One Water?
- Why is One Water important to planners?
- How can planners apply One Water in their work?

WHAT IS ONE WATER?

One Water is a water management paradigm based upon the idea that all water within a watershed is hydrologically interconnected and is most effectively and sustainably managed using an integrated approach. One Water is another, simpler name for the paradigm known as Integrated Water Resource Management (IWRM).

Among water professionals there is not a consensus on a single definition for IWRM and its implementation (Bateman and Rancier 2012). For the purposes of this report, the authors offer the following definitions of One Water developed by two major water resource research foundations. According to the Water Research Foundation (WRF):

> One Water is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs. (Paulson, Broley, and Stephens 2017, 2)

The Water Environment and Reuse Foundation (WE&RF) uses the following definition:

> The One Water approach considers the urban water cycle as a single integrated system, in which all urban water flows are recognized as potential resources, and the interconnectedness of water supply, groundwater, stormwater and wastewater is optimized, and their combined impact on flooding, water quality, wetlands, watercourses, estuaries and coastal waters is recognized. (Howe and Mukheibir 2015, 3)

A complementary approach can be found in the International Water Association's (IWA) principles for "Water Wise Cities" (n.d.), based on the idea that all city dwellers should have access to safe drinking water and sanitation services. This framework is described in the sidebar on p. 22.

IWA'S 'WATER-WISE CITIES'

Discussion of One Water strategies would not be complete without referencing the framework and principles for Water Wise Cities advanced by the IWA in its "Principles for Water-Wise Cities." IWA establishes four levels of action based on the idea that all city dwellers should have access to safe drinking water and sanitation services. The principles of integration of management, water-sensitive urban design, and basin-connected cities that inform these levels directly parallel the conceptual framework of One Water, and should be interpreted as part of the same call for action.

IWA's second level of action is particularly relevant to planners (IWA n.d., 3–4):

Level B. Water Sensitive Urban Design: Seeks the integration of urban planning with the management, protection and conservation of the total urban water cycle to produce urban environments that are "sensitive" to water sustainability, resilience and liveability co-benefits. This second level of action includes four principles:

I. **Plan and implement urban design enabling regenerative water services.** Design domestic and industrial precincts and buildings in ways that provide the opportunity to enable regenerative water services. This reduces the water, energy and carbon footprint of housing, contributing to its affordability through lower monthly bills. It also leads to cleaner waterways, benefiting ecosystems and people, while also improving social and urban amenities. It implies building green infrastructure to capture and treat stormwater for a range of beneficial outcomes.

II. **Design urban spaces to reduce flood risks.** Increase resilience to flood risks by developing urban drainage solutions integrated with urban infrastructure design so that safe flooding spaces are provided and the city acts as a "sponge," limiting surges and releasing rain water as a resource. Plan vital infrastructure to enable quick disaster recovery.

III. **Enhance liveability with visible water** from road-side green infrastructure to major blue-green corridors as opportunities for recreation, inclusive public space, economic development and transportation, creating multi-purpose spaces and infrastructures. Urban water services are essential for ensuring sustainable irrigation of parks and gardens, providing adequate shade, mitigation of heat islands.

IV. **Modify and adapt urban materials to minimise their impact on water pollution**: The urban materials of roofs, walls, surfaces, roads, urban furniture ought to be carefully selected to prevent the release of pollutants when exposed to sun and rain.

The IWA further identifies 17 principles for water-wise cities, as well as the building blocks that are critical to transitioning to a One Water planning and management approach. These are illustrated in Figure 2.1.

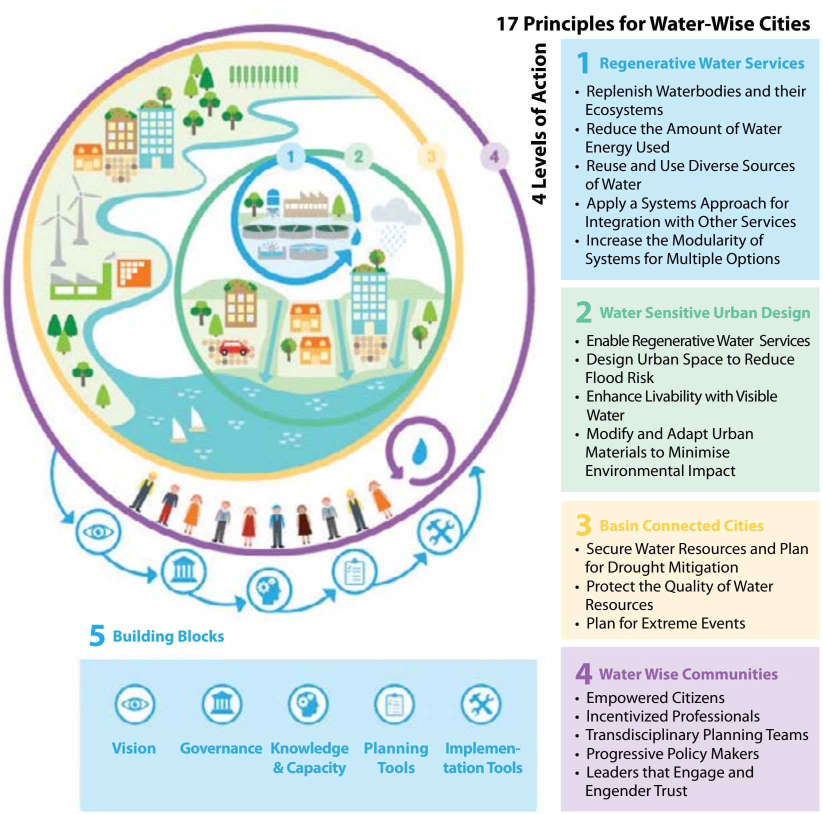


Figure 2.1. IWA's principles and building blocks for water-wise cities (International Water Association)

One Water has significant implications for the practice of urban planning. The core principles of One Water in relation to planning are:

- Water supply, wastewater, and stormwater and natural water systems should be planned, operated, and managed as one system.
- All aspects of the water system should be integrated into planning for the built environment, including the linkages with land use, energy, and transportation.
- Water is a key amenity for the city, in terms of urban design and reinvestment.
- Water planning is as important for the city as is land-use and transportation planning.
- One Water values equity, environmental justice, and respect for nature.

One Water management is a foundational element of the American Planning Association's Policy Guide on Water, which was updated and ratified by the APA Board of Directors on July 15, 2016.

> A One Water approach seeks to integrate planning and management of water supply, wastewater and stormwater systems in a way that minimizes the impact on the environment and maximizes the contribution to social and economic vitality. It also seeks to coordinate and optimize planning, development and management of water with land and other resources and infrastructure such as energy and waste. The One Water approach considers the urban water cycle as a single integrated system, in which all urban water flows are recognized as potential resources, and the interconnectedness of

TABLE 2.1. DIFFERENCES BETWEEN CONVENTIONAL AND INTEGRATED URBAN WATER MANAGEMENT

Aspect of urban water management	Conventional approach	Integrated approach
Overall approach	Integration is by accident. Water supply, wastewater, and stormwater may be managed in the same agency as a matter of historical happenstance but physically the three systems are separated.	Physical and institutional integration is by design. Linkages are made between water supply, wastewater, and stormwater as well as other areas of urban development through highly coordinated management.
Collaboration with stakeholders	Collaboration = public relations. Other agencies and the public are approached when approval of a pre-chosen solution is required.	Collaboration = engagement. Other agencies and the public search together for effective solutions.
Choice of infrastructure	Infrastructure is made of concrete, metal, or plastic.	Infrastructure can also be green including soils, vegetation, and other natural systems.
Management of stormwater	Stormwater is a constant that is conveyed away from urban areas as rapidly as possible.	Stormwater is a resource that can be harvested for water supply and retained to support aquifers, waterways, and biodiversity.
Management of human waste	Human waste is collected, treated, and disposed of to the environment.	Human waste is a resource and can be used productively for energy generation and nutrient recycling.
Management of water demand	Increased water demand is met through investment in new supply sources and infrastructure.	Options to reduce demand, harvest rainwater, and reclaim wastewater are given priority over other sources.
Provide areas for scientific study and outdoor education	Complexity is neglected and standard engineering solutions are employed to individual components of the water cycle.	Diverse solutions (technological and ecological) and new management strategies are explored that encourage coordinated decisions between water management, urban design, and landscape architecture.

Source: Table 1 in Philip 2011, adapted from Pinkham 1999

> water supply, groundwater, stormwater and wastewater is optimized, and their combined impact on flooding, water quality, wetlands, watercourses, estuaries and coastal waters is recognized.
>
> Planning, by virtue of its talent and focus on collaboration and community engagement, and its tools to manage land use, has an important role to play in coordinating the various agencies involved in water resource management and water services, resulting in a comprehensive systems-oriented approach. This includes promoting more collaborative institutional arrangements and management that result in efficiencies gained through coordinated programs. Efforts to coordinate and optimize planning, development and management of water with land and other resources and infrastructure such as energy and waste are also paramount. (APA 2016b)

Figure 2.2. Benefits of One Water management (Reprinted from WE&RF report number SIWM2T14T12a with the permission of the Water Environment & Reuse Foundation)

The need for One Water management approaches largely derives from siloed approaches to separately managing water supply, wastewater treatment, stormwater runoff, flooding, and groundwater in past decades. Recognizing the scientific interconnectedness of these components of landscape and watershed hydrology allows for identification and selection of more sustainable management practices. Table 2.1 (p. 23) summarizes the difference between conventional and integrated, or One Water, approaches to urban water management.

The benefits of One Water include improved resource sustainability (greater reliability, security, and resilience), conservation of natural waters and related ecosystems, and flood avoidance, which all derive from a better understanding of the science of the water cycle and more fully integrated resource management that derives from a better understanding of the natural environment. Figure 2.2 illustrates many of the benefits that derive from One Water approaches.

The Evolution of Modern Water Systems

Two groups of authors have provided insightful historic perspectives on the evolution of modern water utility systems. Both models are presented below. Both are needed to fully understand the historic factors that led to the roles and responsibilities of water agencies around the turn of the millennium—which are now evolving further under One Water approaches.

The first model, postulated by Vladimir Novotny and Paul Brown in their book *Cities of The Future: Towards Integrated Sustainable Water and Landscape Management* (2007), describes four historic stages of water infrastructure, and calls for a new sustainable urban water management paradigm that is holistic and systems-based, as opposed to functionally disaggregated management that is driven largely by the need to provide water where water is becoming scarce.

In the second model, Rebekah Brown et al., in the article "Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States" (2008), describe a transition framework to the "water sensitive city," which is very similar to a One Water approach. This framework describes the temporal, ideological, and technology-based phases that cities transition through as they move toward more sustainable urban water management. The authors explain the historic evolution of values and agreements among communities, governments, and businesses regarding how water should be managed, expressed through institutional arrangements, regulations, and water infrastructure.

Figure 2.3 shows the links between these two systems. Though created for different purposes, both offer a new model or paradigm of more sustainable, integrated water management. This new stage of evolved water management is what we call One Water. Understanding One Water's evolution from past siloed water management approaches and divided responsibilities is essential to understanding its innovative and integrated nature. Institutional structures are still being created to put One Water into practice.

Vladimir Novotny and Paul Brown (2007) have succinctly condensed several thousand years of water infrastructure history into four distinct stages, or paradigms as they call them.

1: Opportunistic Utilization of Available Water
This period used easily accessed surface water and shallow groundwater. Streets were the primary means for directing flows and disposing of waste. This persisted into the 17th and 18th centuries.

2: Engineered Storage and Conveyance
This stage featured engineered construction of water storage facilities, aqueducts, and drainage facilities (technologies from Roman times and earlier). Drainage meant control of stormwater runoff from rainwater and snowmelt. Drainage was contaminated with human wastes.

3: Addition of Water Treatment Technologies
Water quality degradation from growth of industrial cities in the 19th and 20th centuries drove addition of water treatment at the source of supply and wastewater treatment at the point of disposal to receiving waters, improving health and water quality.

4: Non-Point Source Pollution Control
Under the Clean Water Act, this stage sought to reduce and control the pollutants that result from stormwater runoff arriving through pipes or flowing directly into rivers and streams. it relies on streets to provide adequate drainage in a system designed to move water rapidly from where it's not wanted to elsewhere.

5: 5th Paradigm
This involves an important shift to hydrologic water/mass balance, where the components of water supply, stormwater, and wastewater are managed in a closed loop. It incorporates landscape change, less imperviousness, and more green space as filters for groundwater recharge, restoring the landscape's hydrological and ecological functions. It requires some decentralization of current centralized systems employing long-distance water and wastewater transfers.

Rebekah Brown et al. (2008), in "Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States," describe a transition framework through a typology of six city states, towards the Water Sensitive City, which is very similar to a One Water approach.

The Water Supply City (early 1800s):
The first stage is characterized by efforts to expand piped water supply to city dwellers.

The Sewered City (mid-late 1800s):
Once access to water supply is secured, emphasis moves to providing piped sewerage services to dispose of waste outside of cities.

The Drained City (mid 1900s):
This phase is dominated by efforts at ensuring flood protection.

The Waterways City (late 1900s):
In this phase the aim is to achieve social amenity and environmental protection. It is characterized by the prevalence of point and non-point source pollution management.

The Water Cycle City (2000s):
Limits on natural resources encourage a move to diverse, fit-for-purpose sources; conservation; and the promotion of waterway protection.

The Water Sensitive City (Future):
The sixth and final phase is inspired by the goals of intergenerational equity and resilience to climate change. The prevalent approach to water resources management features a combination of adaptive, multifunctional infrastructure and urban design, reinforcing water-sensitive behaviors.

Figure 2.3. Historical stages of water management transitioning to One Water (Authors; from Brown et al. 2008 and Novotny and Brown 2007)

WHY IS ONE WATER IMPORTANT TO PLANNERS?

The historic phases of water "utility" development and invention, as summarized in Figure 2.3, highlight how the construction of water supply, wastewater disposal, and flood management systems occurred in response to the needs of emerging and growing population centers—not from a comprehensive understanding of the physical, chemical, biological, microbiological, and hydrologic elements of the water environment. Further, the historic evolution of utilities focused separately and singularly on each utility element of concern (water supply, flooding, wastewater discharge, health).

In contrast, a One Water approach proceeds with a full appreciation of the hydrologic interconnections of water cycle and water system elements. New information and science calls for improved water management as a fully interdependent and integrated management system.

Land use, water, energy, and food should be considered as connected and interdependent urban systems when assessing actions to achieve more sustainable communities. Especially important for planners is understanding how land development and growth affects the demand for these resources. Planners are trained to adopt a comprehensive view of land use, resource conservation, and supporting infrastructure. From that perspective, the water environment clearly plays a critical role in determining the carrying capacity of the landscape for new growth and human uses, and it requires protection from damaging uses.

The interrelationships among water cycle elements are illustrated in Figure 2.4. The linkages are extensive. They highlight how decisions affecting one element impact the other elements. Understanding the land use–water nexus in a One Water context is critical to effective planning. It is also important to recognize that in many urban settings the natural elements of the water environment have been paved, filled, and piped, and that the focus of planners also needs to include restoration of water interrelationships when possible. For example, green stormwater infrastructure projects and coastal resiliency projects that create wetlands seek to recover lost hydrologic functions. Planners should focus on the overall resilience of the interconnected systems and how the community interacts with and benefits from water environments.

A significant obstacle to planners in advancing the methods and benefits of One Water (as identified in APA's 2016 Survey of Planners on Water; see Chapter 1) is insufficient technical understanding of how water functions in the natural landscape and in utility systems. The science of hydrology makes clear that the management of one element of the water cycle (e.g., supply) connects to and affects the other functions and characteristics of a water environment. These relationships need to be considered when planners are helping to guide the creation of sustainable comprehensive plans and land-use regulations and during development review. These planning tools guide the location, density, quantity, and design of future development. Such planning activities can guide conservation and restoration of the natural environment, potentially restoring impaired hydrology and ecosystems.

Defining the relationship between water supply and demand from future growth and development is essential to

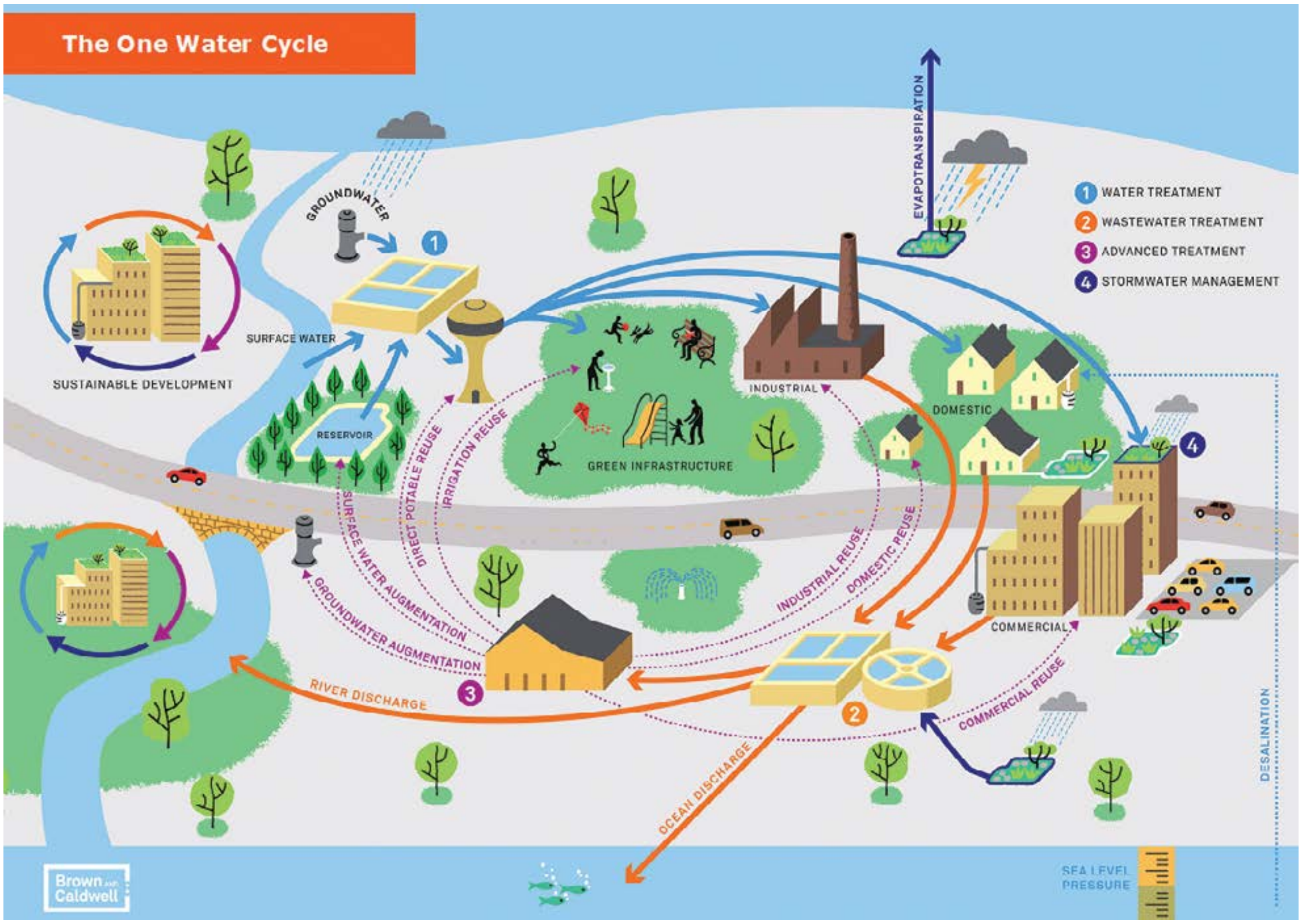


Figure 2.4. Interrelationships among elements of the One Water Cycle (Brown and Caldwell)

planners. Significant increases in population and employment are projected in the U.S., as described in Chapter 4, with major requirements for additional water supply, wastewater disposal, and stormwater management capacity.

Novotny and Brown succinctly summarize how radically different the One Water concept is from traditional approaches, and describe the challenges facing planners and water professionals:

> Progress in the direction of the fifth paradigm will require fully coordinated management of water and land in a manner that has few precedents. **Instead of a system that provides water, sewer, and drainage to individual parcels of land, we will be designing an urban landscape that utilizes integrated systems of plumbing and land use to reduce the need for more pipes, pumps, and treatment plants, as well as the imported water to fill them. More importantly, design objectives will be different as well—transitioning from the utilization of natural resources to fuel urban development towards managing urban development to preserve natural systems for growth and renewal.** When we examine the process of land-use planning and development, the prospects for this kind of radical redesign of the urban landscape present some challenges.
>
> . . . the differences between land and water when it comes to planning and development . . . are so basic that they frequently inhibit communications among individuals and institutions that share common goals and values, but work in worlds organized by these fundamentally different intellectual frameworks. (Novotny and Brown 2007; emphasis added)

It is important for planners to understand the wide-ranging and interconnected effects that urban settlement patterns and development have on the water environment. Some examples are listed below that have important long-term effects on the hydrologic system and future water supply and quality:

- Drinking water is often supplied to metropolitan areas from upstream reservoirs or rivers, used in homes and businesses, and then discharged considerably downstream into a river or an ocean or bay. This typically moves large volumes of water each day from an originating (upstream) watershed to (downstream) receiving waters through pipes rather than through travel along many miles of natural stream. It often results in interbasin transfers that can dramatically affect the natural hydrology and ecology of a river corridor.
- In many parts of the U.S., groundwater supplies have been managed and regulated completely separately from surface water supplies. However, in many locations groundwater forms the base flow of streams and rivers, and reductions in groundwater supplies can dramatically affect the drought resistance of rivers and streams.
- In much of the coastal plain locations in the U.S., impervious development and piped drainage on the surface of the land dramatically affects the ability of rainfall to penetrate the ground (infiltration) and recharge groundwater systems. Changing land development and density, as well as stormwater management practices, can dramatically affect groundwater supply (which in turn, as noted above, affects river and stream flows).
- The speed at which rainfall runs off the developed landscape directly affects flooding characteristics and receiving rivers. Development patterns and stormwater drainage piping systems tremendously accelerate the speed at which runoff from rainfall reaches rivers and exacerbates flood characteristics. In addition, the degree of imperviousness that characterizes land development affects the quantity of runoff that is transmitted to the receiving rivers.

One Water strategies are important to planners because they highlight the natural interconnectedness of all water and, more importantly, they present planning and management approaches that are based on integrated systems analysis. The more planners can factor the many dimensions of the natural and built environments into their evaluations and visions for the future, the greater will be the potential to realize sustainable and balanced water resource use. One Water provides the overarching structure, conveys the essential interconnectedness of the water systems, and advocates for integrated management, so that externalities are captured and practices in one water domain do not create problems in another. One Water is the structural basis of water sustainability.

HOW CAN PLANNERS APPLY ONE WATER IN THEIR WORK?

The APA 2016 Survey of Planners on Water identified the overwhelming interest of many planners in improved water resource management and the desire to work with a wide range of water professionals to improve the sustainability of our water environment (APA WWG 2016).

The emphasis on One Water is a function not only of the need for a paradigm shift toward more resilient and sustainable management but also the need to expand the skills of planners and improve the partnerships among the actors in water management. More than ever, because the components of the water cycle have historically been managed separately, it is critical that we leverage our knowledge and improved science to help alter and reverse past impacts as well as optimize future conditions in our cities and towns.

Planners are increasingly engaging on water-centric issues, such as:

- protecting wetlands, rivers, and lakes as habitat and cleansing systems and resilient features
- understanding the systems for the use, reuse, and disposal of water and wastes discharged to our waters, and how this affects sprawl
- recognizing the importance of water utility systems in serving development, and the importance of long-term reliability and dependability of those utility systems
- assessing how density of development both increases the efficiency of water distribution and the opportunity for reuse, while that density also serves to concentrate wastes and stormwater discharged to water bodies

Planners also recognize that integrated management of water means that planning, design, budgeting, and implementation of water utility services will require a deeper understanding of land development and land conservation processes. Planning is inherently interdisciplinary; planners often function as generalists and become the glue to bind together the many technical disciplines (e.g., engineering, science). By virtue of their skills in creating collaboration and community engagement, and through their understanding of regulatory tools available to manage land use, planners have important roles to play in coordinating with the various actors involved in water resource management and water services. Planners can be instrumental in achieving a more comprehensive systems-oriented approach to managing the land use–water nexus.

The roles of the planner include facilitating more collaborative institutional interactions and arrangements, and helping to forge management structures that result in improved water system efficiencies gained through coordinated designs and actions. Planners should play lead roles in efforts to coordinate and optimize land planning and land development with management of water and other resources along with related infrastructure, such as energy and waste. The planning community is now rising to this challenge, as better understanding and skill in science, engineering, and consensus building across formerly siloed agencies become part of the planner toolkit.

Some of the key elements of an improved One Water approach for planners include:

- recognizing that groundwater, surface water, stormwater, and natural aquatic environments are all part of one water cycle and that effects on these resources need to be considered across both longer timescales and larger geographic areas
- bringing better water science to local decision making when drafting comprehensive plans, crafting zoning ordinances and subdivision regulations, and reviewing development proposals
- shifting to performance measures and metrics related to outcomes as opposed to prescriptive rules for water management
- establishing performance goals, then facilitating interagency dialogue to move beyond standard objections to innovation
- creating innovative policies, management practices, regulations, and capital investments that allow existing water environments to be managed holistically
- applying more robust alternatives analysis and considering the effects of land-use and planning decisions on each of the components of the water environment as a routine part of the planning process
- using design competitions as a method to develop innovative proposals for physical planning
- recognizing that while a One Water approach is beneficially integrative, it is important to also recognize that local, watershed, and regional management actions must be selected based on the scales at which they are effective
- identifying mechanisms to reduce the water footprint of development and redevelopment by reducing demand, recycling used waters and runoff, and reusing waters on a "fit for use" basis
- working to help the public and decision makers understand that stormwater and wastewater should be considered potential water assets, recognizing that even the best of surface waters contain animal wastes, atmospheric deposition, and biological constituents that are removed in the drinking water treatment process
- holding ongoing workshop events to build relationships

and allowing for cross-cultural exchange on technical and social issues
- achieving greater social equity in pricing practices for water, recognizing the importance of redressing imbalances in water resource availability and quality, improving resources and infrastructure in lower-income neighborhoods that would otherwise be overlooked by new private investments, and addressing repetitive flooding

WE&RF and WRF have worked jointly and proactively to help communities understand, adopt, and implement One Water principles. Their publications on One Water include *Pathways to One Water* (Howe and Mukheibir 2015), which serves as a guide to institutional innovation for water professionals and utilities, and *Institutional Issues for Green-Gray Infrastructure Based on Integrated One Water Management* (Mukheiber, Howe, and Gallet 2015), which describes institutional challenges and actions to support a transition to a One Water resource management framework.

Water resource managers who try to apply One Water principles often face challenges that arise from outdated and siloed institutional frameworks, and planners can learn from their experiences. These challenges include lack of understanding of hydrologic relationships and power struggles over utility functions and staff. Figure 2.5 shows the range of institutional challenges that affect urban functions and options for action. Addressing these issues requires strategies to address the challenges shown in the outer circles while implementing One Water principles that connect the separate disciplines in the interior circle.

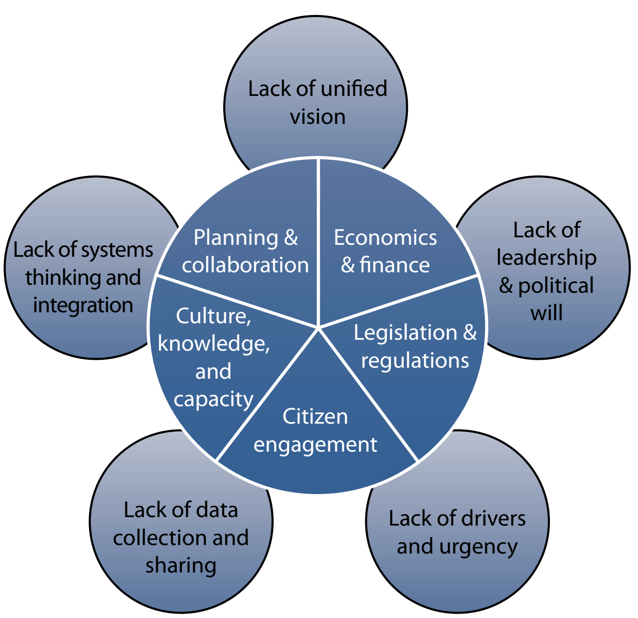


Figure 2.5. Institutional challenges to One Water (Reprinted from WE&RF report number SIWM2T14T12 with the permission of the Water Environment & Reuse Foundation)

Research projects by both WE&RF and WRF have explored how to improve and expand interdisciplinary engagement between planners and water professionals to achieve One Water management (Fedak et al., forthcoming; Stoker et al., forthcoming). It is valuable to identify local barriers to improved planner–water professional coordination and interaction. Improved One Water management can result from an identification of the planning mechanisms that can influence water management—such as comprehensive and master planning, zoning, performance requirements, and public engagement processes—and an evaluation of how to use those planning mechanisms to advance sustainable water management goals.

Examples of some specific approaches that can help achieve and formalize improved planner–water professional interactions and promote One Water management include the following:

- building cross-program (or cross-disciplinary) coordinating groups or councils
- developing memoranda of agreements between water and planning agencies that describe roles on shared management functions or projects
- evaluating consistency between planning documents and water management decision making
- appointing coordination managers or facilitators to meet and identify shared and conflicting objectives or procedures
- creating mandates for collaboration or specific water management outcomes

Figure 2.6 (p. 30) illustrates the various water planning-related roles of water service personnel and planners and highlights where overlap and opportunities for collaboration occur. Planners need to consider roles that include more proactive engagement on water issues, creating new opportunities to intersect and collaborate with professionals from water-related disciplines, such as the following groups:

- watershed management agencies
- water, wastewater, and stormwater utilities

- groundwater/aquifer recharge protection programs
- fish and wildlife agencies
- professional associations and their associated research organizations, such as the Water Environment Federation, the American Water Works Association, WE&RF, WRF, the American Water Resources Association, the American Society of Landscape Architects, the American Institute of Architects, Lincoln Institute of Land Policy, Sonoran Institute, and many others
- research agencies such as the National Oceanic and Atmospheric Administration (NOAA) as well as the U.S. Geological Survey (USGS), which monitors and models hydrologic system health and future performance, including the possible effects of climate change
- the Federal Emergency Management Agency (FEMA), which plans and responds to natural hazards such as floods and hurricanes and advances natural resiliency strategies
- other organizations, regional and watershed entities, and professional groups not included in this list

Improvements that will advance the One Water approach include new partnerships, more integrated roles in working together on land development and capital improvement planning for water utilities, professional association interactions, and informal professional interactions.

CONCLUSION

As the water sector in the U.S. begins to transition to One Water approaches, there are a number of efforts under way that can help local and regional planners better integrate these strategies into comprehensive and master plans as well as sustainable communities initiatives.

Professional disciplines that are engaging in One Water approaches now include planners, engineers, landscape architects, and architects; members of many science communities (e.g., environmental scientists, water chemists, hydrologists, geologists); and professionals from the fields of law, public administration, economics, and finance. Chapter 5 of this report provides examples of existing programs

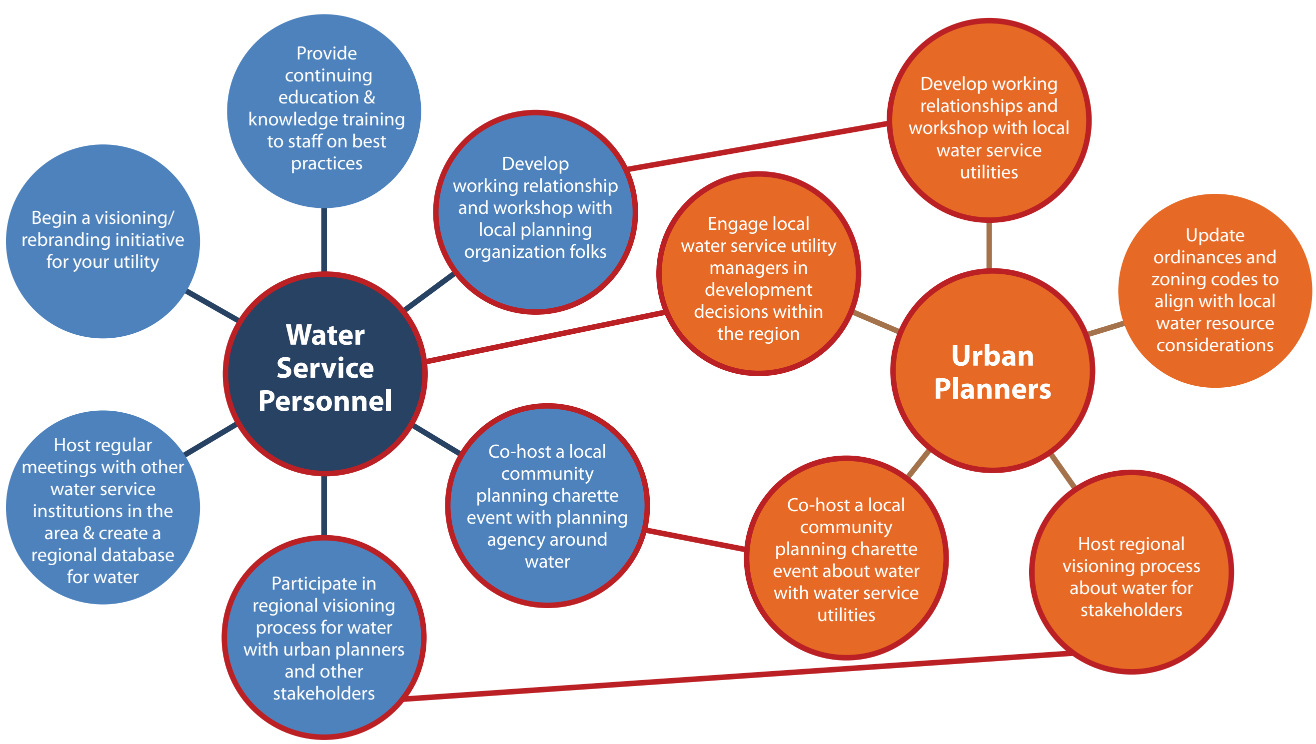


Figure 2.6. Potential interactions between urban planners and water service personnel (Reprinted from WE&RF report number SIWM2T14T12 with the permission of the Water Environment & Reuse Foundation)

and actions that can be considered illustrative recommended practices in this area.

Before planners can begin to apply One Water approaches to their work, however, they must have a solid understanding of the three main areas of water planning: water supply, wastewater, and stormwater. The next chapter provides a primer on these three topics.

CHAPTER 3

WATER BASICS

For planners to begin working on water issues in their communities, engaging with water-sector professionals, and moving toward a One Water approach, they must first understand the basics of water. This chapter provides an overview of water basics for planners. It begins with a description of the water cycle, then moves to the three basic types of water infrastructure systems: water supply, wastewater, and stormwater. It offers introductions to the system components, institutional players, and regulations relevant to all three systems.

THE WATER CYCLE

Behind all of the water-service sectors lies the natural water cycle, which describes the continuous movement of water above, below, and on the earth's surface. This cycle is also referred to as the hydrologic cycle. Hydrology is the science that encompasses the occurrence, distribution, movement, and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle.

As explained by the U.S. Geological Survey (USGS 2016), the water cycle, or hydrologic cycle, is a continuous process by which water is purified by evaporation and transported from the earth's surface (including the oceans) to the atmosphere and back to the land and oceans (Figure 3.1, p. 34). All of the physical, chemical, and biological processes involving water as it travels in the atmosphere, over and beneath the earth's surface, and through growing plants, are of interest.

There are many pathways water may take in its continuous cycle of falling as rainfall or snowfall and returning to the atmosphere. It may be captured in polar ice caps or run into rivers and flow to the sea. It may soak into the soil to be evaporated directly from the soil surface or transpired by growing plants. It may percolate through the soil to groundwater reservoirs (aquifers) to be stored, or it may flow to wells or springs or back to streams by seepage. The cycle for water may be short, or it may take millions of years.

WATER SUPPLY

Water for human use comes from two main sources—surface water and groundwater. Surface water originates from rivers, streams, lakes, or the ocean. It is replenished through precipitation, and lost through evaporation and seepage into groundwater supplies. Groundwater is obtained by drilling wells into underground basins and aquifers. Groundwater and surface water together form a watershed, which is where water drains into a common water body. Watersheds are important as they serve as the meeting point for numerous water sources, which eventually drain into other bodies of water or the ocean (Claytor 2006).

Elements of the Water Supply System

A water supply system includes multiple components: one or more water sources and storage facilities, a conveyance system that moves water from the source to a water treatment facility, storage facilities for the treated water, and a means of distribution to the end users (Figure 3.2, p. 34).

Water sources and storage: Examples of water sources include rivers, lakes, streams, aquifers, and reclaimed water. Water supply systems in metropolitan areas tend to rely on surface water supplies, while less-populated rural areas usually rely on groundwater-based systems. Water storage can be reservoirs created by major or minor dams, underground water basins, or municipal water tanks. These facilities can be controlled by the local water agency or by state or federal agencies.

Source water conveyance systems: Municipalities transport water from the water source or storage areas to the treatment plant in multiple ways, using networks of pipes, channels, and tunnels. The transportation mechanism depends on different factors including demand, topography, and cost. Often, larger metropolitan regions must seek out adequate water supplies hundreds of miles away or even in other states to meet water demands.

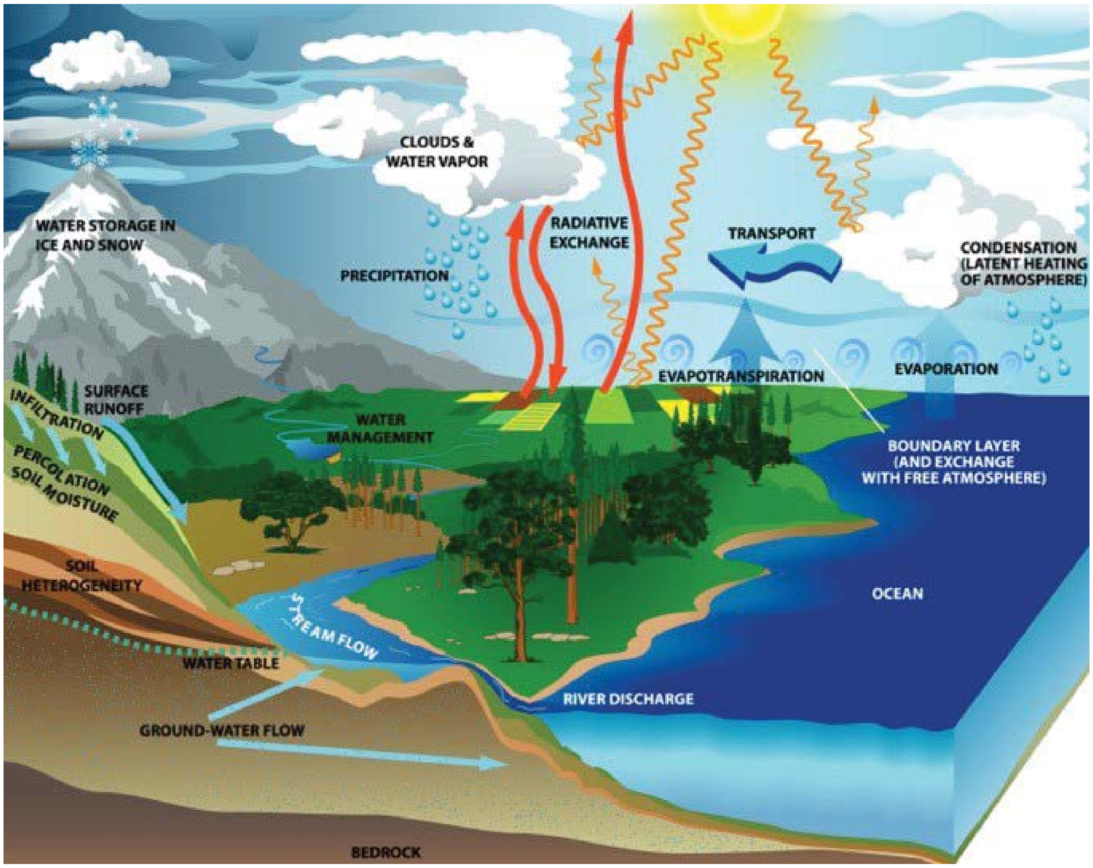


Figure 3.1. The water (hydrologic) cycle (diagramcenter.org, CC BY 2.0)

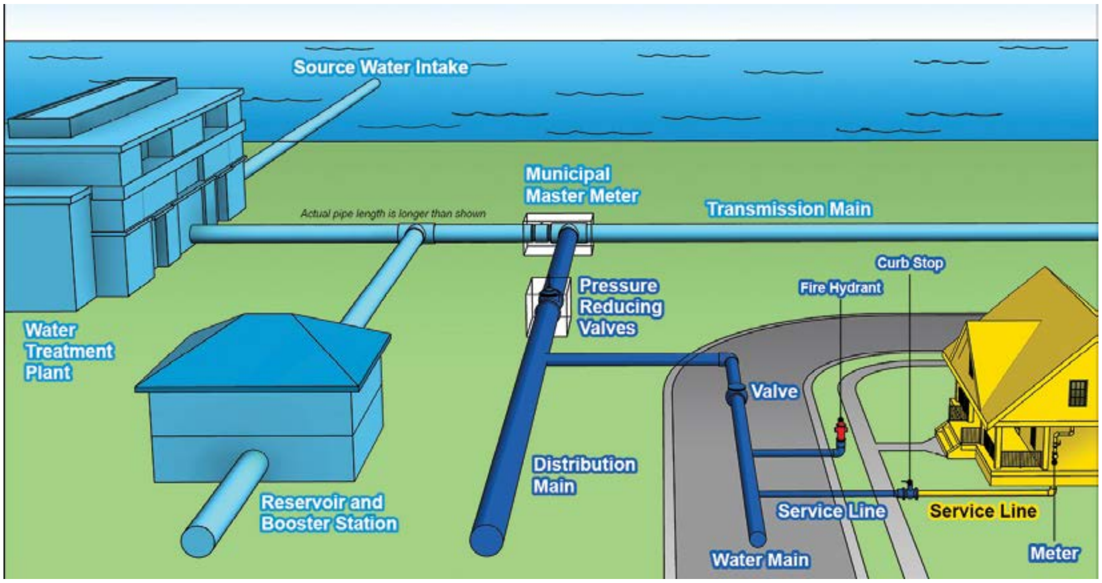


Figure 3.2. Components of the water supply and distribution system (Great Lakes Water Authority)

Water treatment: Water is treated to ensure human safety in compliance with the Safe Drinking Water Act. How the water is treated depends on the water source. Water treatment is usually conducted at a central treatment facility.

Treated water distribution: Water is distributed from a treatment plant to consumers (households, businesses, and other end users) through a network of connected pipes, pump stations, and storage tanks. The details of the distribution network reflect the area being served, taking into consideration topography, street layouts, and type of water use.

Water Use

The U.S. Geological Survey tracks the nation's water use, gathering data from local, state, and federal environmental agencies and publishing a report every five years. (At the time of publication, USGS was still compiling its 2015 report, which will present more current water usage data and a more accurate picture of national water use.) According to the most recently published USGS report, in 2010 about 355 billion gallons of water was withdrawn for use each day, a decline of 13 percent from 2005. Thermoelectric power accounted for 45 percent of total water use, followed by irrigation at 33 percent and public supply (water withdrawn by public suppliers for residential, commercial, and industrial use) at 12 percent (Figure 3.3). Surface water supplied 78 percent of all withdrawals (Barber 2014).

According to USGS, 57 percent of public supply withdrawals were for residential uses, supplying about 86 percent of the U.S. population with water for household use; the remaining 14 percent of households rely on wells or other private water sources (Barber 2014).

Trends show that overall per capita daily use, as well as total water withdrawals in the U.S., have been steadily declining over the last few decades. There are debates as to why this is happening, with possible answers linked to conservation measures by all types of users, the outsourcing of many manufacturing processes, and advancements in food production. A Water Research Foundation survey of residential water use found that from 1999 through 2016, residential end uses per single-family household declined by 22 percent, primarily because of water savings from efficient toilets, showers, and washing machines (DeOreo et al. 2016). Water conservation and demand management is one of several strategies being used to help reduce the demand for new water supplies as population continues to grow; see the sidebar on p. 36 for more information on this and other approaches.

Understanding water use helps to evaluate the effects of future development plans and trends, which in turn helps

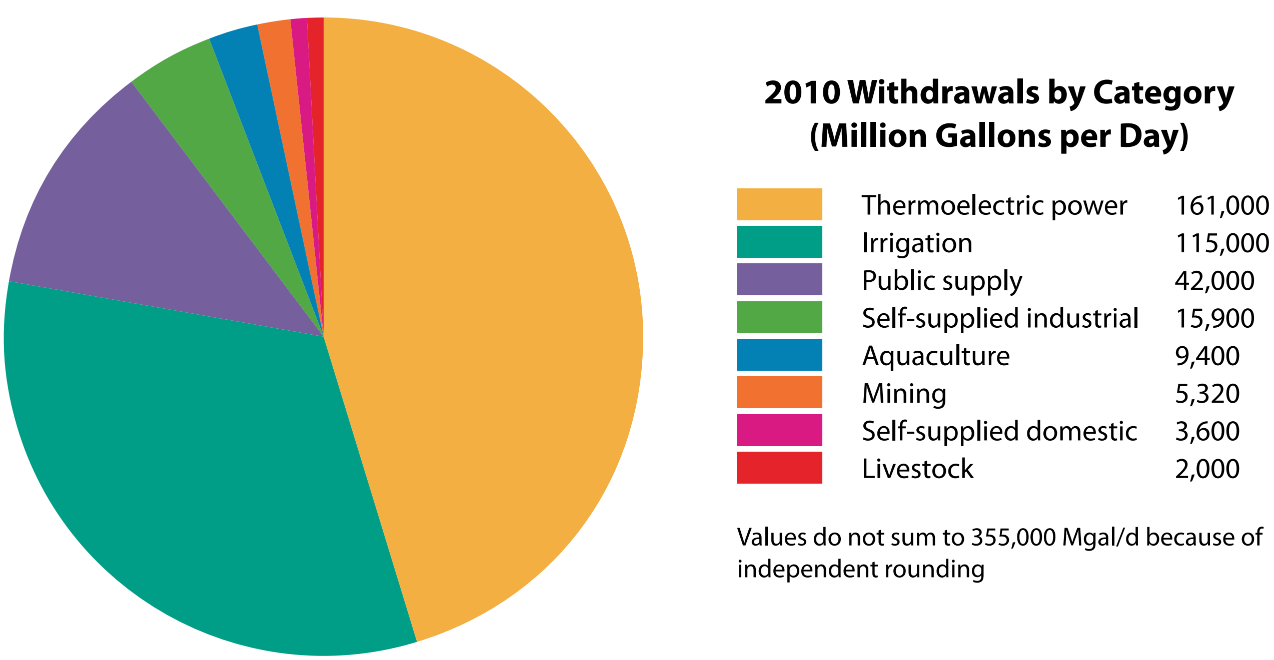


Figure 3.3. U.S. water withdrawal by use category in million gallons per day, 2010 (From Barber 2014)

INNOVATIONS IN WATER SUPPLY MANAGEMENT

As alternatives to developing new supplies of potable water, water supply utilities have turned to several strategies. The most common is conservation and demand management. These efforts may begin with a communication plan to encourage conservation among consumers (U.S. EPA OW 2016).

Many utilities use monetary incentives to encourage customers to retrofit or install water-efficient equipment. Some work with customers to detect leaks on their properties. Utilities are also working to reduce their own water leaks in distribution pipes and equipment; a recent study found that leakage from crumbling infrastructure could account for as much as 14 to 18 percent of drinking water produced each day in the U.S. (CNT 2013). Other important tools for water conservation and demand management are water meters to track water use and fee structures that increase rates for high amounts of water use (see Chapter 6 for a discussion of conservation-based fees).

Conservation is also becoming a priority for the agricultural sector and electric utilities. Farmers are beginning to use drip irrigation and other techniques to reduce the amount of water they use (Held 2016). Electric utilities are working with water utilities to reduce the amount of water they use; many recycle the water they use for cooling in the production of electricity (Young 2013).

Another strategy is desalination, the process by which fresh water is obtained from seawater. Desalination is being increasingly used in arid countries such as those in the Middle East, with 16,000 plants operating worldwide in 2012 (Olsson 2015). In the U.S., most municipal desalination plants are located in Florida, California, Texas, or North Carolina (Leven 2013). Desalination produces water that is expensive compared to other water sources. The high cost arises from the energy required to push the water through filters in the reverse osmosis process, which results in a concentrated brine containing salts, minerals, and byproducts of the desalination process. Environmental impacts of desalination plants can include the deaths of fish and other marine organisms during seawater intake and processing; questions remain about the impacts of brine discharge back into oceans (Cooley, Ajami, and Heberger 2013). Desalination technology has not been updated in several decades and is ripe for more energy-efficient approaches (Talbot 2014).

Rainwater harvesting, or the collection of rainwater in rain barrels or cisterns, is an older practice that is now coming back into vogue in some water-scarce states. Rainwater is generally not used for drinking, but is useful in offsetting the use of potable water for landscaping irrigation and other outdoor purposes (U.S. EPA 2017h). States with programs and regulations for rainwater harvesting include Texas, Ohio, Oklahoma, and Colorado. Water collected from roof runoff is not treated and may contain contaminants, including fecal matter from birds (CDC 2013). Research suggests that in addition to reducing stormwater runoff, rainwater harvesting can reduce consumption of potable water and generation of wastewater (University of Wisconsin Population Health Institute 2010).

planners and water experts create more sustainable water use practices that can help meet future demand. For more information on water use, planners can access county-level water use data from USGS (https://water.usgs.gov/watuse/index.html and https://water.usgs.gov/watuse/data/); however, the most recent data available is four to five years behind the current year. For more current data, planners may contact the state agency responsible for water allocation and management or reference a state water supply master plan (where available). The most current and most highly resolved data is usually available from local water utilities.

Water Supply Agencies and Utilities

Water supply in the U.S. typically operates under a local and fragmented system, with many public and private water utilities in each state. These agencies range in size and vary in the numbers of people served per day. More than 97 percent of the nation's 156,000 public water systems are small systems, meaning they serve 10,000 or fewer people (U.S. EPA 2016e). And while there is continued interest in privatization of water systems, most systems are still publicly owned and this will most likely remain the case. If anything, efforts to privatize water utilities will encourage public systems to improve performance (Elmer and Leigland 2014).

The full range of water supply functions usually occurs locally, in proximity to users. Typically, a source of supply (surface or ground water) is developed, treated, and distributed to local customers by one utility. However, different entities can be responsible for different steps in the supply process, often depending on geographic scale. Below are listed the sequential steps of water supply functions and possible responsible entities.

- **Source water development and management.** Federal entities, states and state authorities, large cities, consortiums of local governments, individual local governments, private water utilities, and industries all have developed sources of supply. For example, the U.S. Bureau of Reclamation, the New Jersey Water Supply Authority, New York City, and American Water Company all have been involved in water supply development.
- **Water treatment.** Source water can be treated centrally by the entity owning and operating the supply, or it can be delivered untreated to a local utility to treat and deliver.
- **Water distribution.** After water is treated to required standards (usually federal Safe Drinking Water Act standards), it can be distributed to users by a local "distribution only" utility, or by the utility that owns the source and treatment facilities. Some local utilities purchase treated water in bulk from adjacent large systems, and then take responsibility for distributing that supply to local customers.

Larger water districts are often wholesalers; the district purchases water from federal and state government suppliers and then sells it to cities, towns, and private companies. Larger water districts can also act as retailers, delivering water directly to their customers. Public water agencies can control water rights. They can also own water infrastructure such as dams, reservoirs, and aqueducts as well as canals and pipes, and can manage treatment plants and distribution systems. The agencies may also own the land that forms the watershed.

Usually, water supply agencies are governed by appointed commissions or elected boards. These bodies set the general policies. Daily operations are carried out by professional staff, comprising managers, engineers, and technicians. Some water supply agencies are housed within city or county government, while many are freestanding special districts independent of the local general-purpose government.

Planners are becoming critical staff at water agencies as land-use and growth management policy issues that intersect with water management become more common.

Water Supply Regulations

In the 1970s, the U.S. Environmental Protection Agency (EPA) took the lead in developing two major regulations for water: the Clean Water Act and the Safe Drinking Water Act. The Clean Water Act of 1972 establishes a structure for regulating discharges of pollutants into U.S. waters and regulates quality standards for surface waters. It was amended in 1987 to expand and strengthen protections. The Safe Drinking Water Act of 1974 establishes standards for the quality of drinking water in the U.S. The law targets all waters actually or potentially designed for drinking use from both surface and groundwater sources (Daniels 2014).

Enforcement of these federal regulations has been delegated to most states, and within the larger states, to counties, but the EPA plays a central role in helping to provide financial resources and technical guidance for water regulation. States generally follow the standards established by the EPA, but then have the option of adding additional standards and testing requirements (and public notification requirements in the event that standards are violated) based on local drinking water quality issues and public information needs. Water rights are regulated at the state level and are governed by state law.

WASTEWATER

Wastewater management practices in the U.S. have evolved since the 1800s, mostly in response to demands to protect public health and more recently, a growing interest in protecting the environment.

Wastewater or sewage is the byproduct of many uses of water, including typical household uses such as showering, dishwashing, laundry, and flushing the toilet. Additionally, industries and commercial enterprises use water for these and many other purposes, including processing products and cleaning or rinsing equipment. After the water has been used, it enters the wastewater stream and flows to a facility for treatment.

Prior to 1800, human waste was collected in cesspools, but wastewater management changed significantly when running water became available in private dwellings. By 1880, water closets could be found in more than one-third of urban households across the country, requiring new systems for sewage collection and disposal. Several health epidemics in Memphis, Tennessee, prompted the construction of the first separate sewer system for sanitary waste in the late 1870s, a concept soon adapted for use in other cities across the country (Melosi 2000).

Elements of the Wastewater System

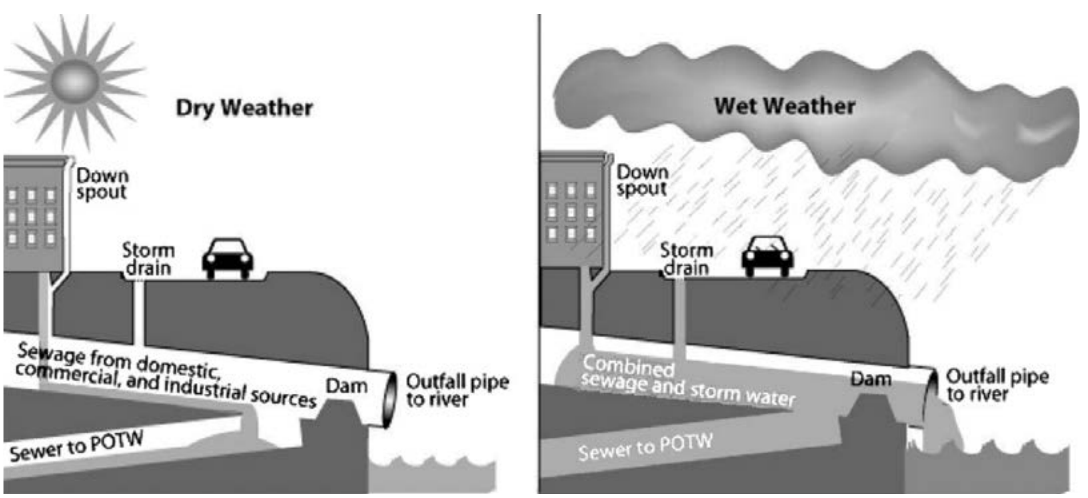
Today's wastewater management systems are designed to ensure that harmful waterborne pollutants do not contaminate surface or groundwater sources. Centralized systems consist of networks of collection pipes that collect sanitary waste (and in some cases stormwater, as well) and treatment plants that clean the wastewater to the extent needed to return it to water bodies (see Figure 3.7, p. 40). Decentralized systems provide onsite collection, treatment, and dispersal of wastewater from individual properties or small areas.

Wastewater collection systems. Most municipal wastewater systems consist of a network of underground pipes that collect sanitary waste and wastewater and carry it away to a treatment plant. Pipes from individual houses or buildings are called laterals, and connect to submains, which follow the street. The submains connect into trunk lines or interceptors, which are large pipes that terminate at the wastewater treatment plant.

In the 19th and early 20th centuries, limited financial resources led U.S. cities to install one set of wastewater collection systems (combined sewer systems, or CSSs) to convey both wastewater and stormwater to treatment plants. However, these systems are vulnerable to storm events in which increased stormwater flows overwhelm system capacity, resulting in combined sewer overflows (CSOs) that send untreated stormwater and wastewater directly into local water bodies (Figure 3.4). Storm events can also trigger overflows of sanitary sewers, called sanitary sewer overflows (SSOs). Both CSOs and SSOs may also be called wet weather overflows. Since World War II, most cities—especially those in the South and the West—have installed separate sanitary and storm sewer systems. Most of the remaining combined sewers are in the Northeast, the Great Lakes region, and the Pacific Northwest (Figure 3.5). See the sidebar on p. 40 for more information on types of sewer systems.

Treatment plants. After wastewater has been collected, it must be treated. In water reclamation plants, wastewater

Figure 3.4. Combined sewer systems convey wastewater and stormwater in the same set of pipes, leading to combined sewer overflows when storm events overwhelm the system (U.S. EPA OW 2004, Figure 2.1).



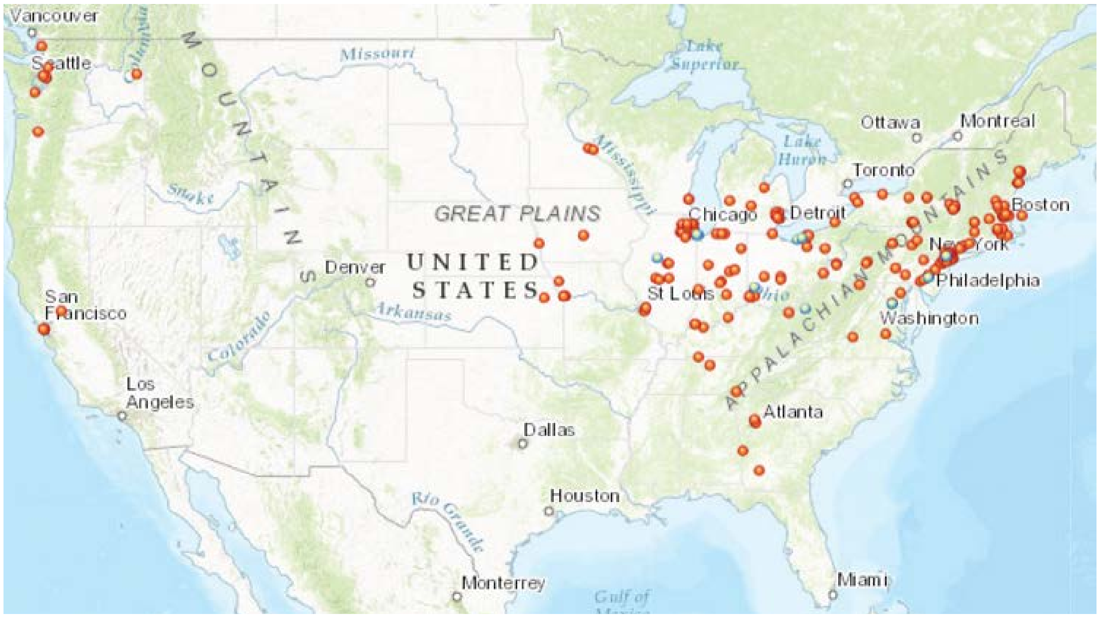


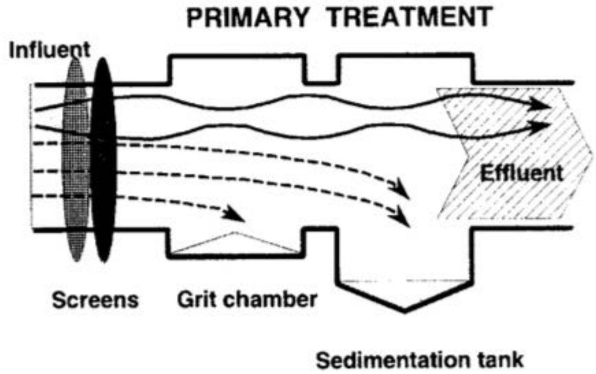
Figure 3.5. Locations of the remaining U.S. combined sewer systems (CSSs) (U.S. EPA 2016f)

undergoes primary and secondary treatment processes, and in some areas a tertiary treatment process may be required.

In primary treatment, physical debris and solids are removed from wastewater. First, the sewage passes through a screen that removes large floating objects before it moves to a grit chamber, where smaller debris like sand and pebbles will be caught. The remaining inorganic matter is removed though a sedimentation tank, where a slower speed of flow allows the solids to settle out of the wastewater (Figure 3.6).

The secondary stage of treatment further improves water quality. The main secondary techniques are the trickling filter and the activated sludge process, both of which allow the bacteria present in the wastewater to consume organic matter to help purify the water. The trickling filter is a bed of stones, or more recently plastic or other synthetic materials, that helps filter the sewage as it passes through for further treatment. The activated sludge process speeds up the process by introducing air and more bacteria-filled sludge to the sewage being treated (U.S. EPA OW 1998).

To complete secondary treatment, the wastewater is disinfected with chlorine to kill harmful bacteria. When used properly, chlorine will kill 99 percent of harmful bacteria in



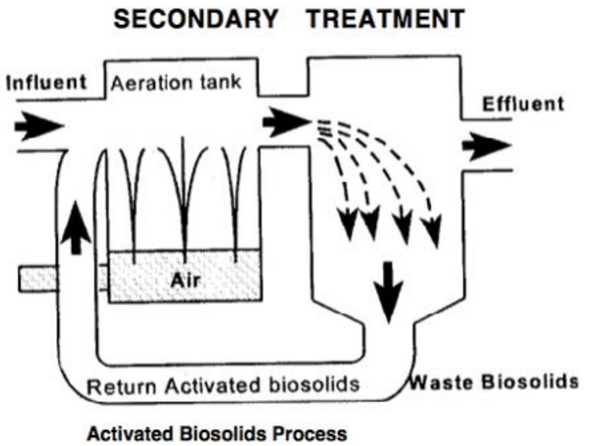


Figure 3.6. Primary and secondary wastewater treatment (US EPA OW 1998)

TYPES OF SEWERS

Combined sewer systems: These are the country's early sewers that carried both sanitary sewage and stormwater, now typically found in older communities. CSSs serve more than 860 communities and more than 40 million people in the U.S. (U.S. EPA 2016g). A CCS carries domestic, commercial, and industrial wastewater and stormwater runoff through the same set of pipes to treatment plants, where it is treated and discharged into surface water.

Separate sanitary sewer systems: These are sewers that carry only sanitary sewage from the household or business to the wastewater treatment plant. They are a more recent infrastructure system found in cities built after World War II.

Municipal separate storm sewer systems (MS4): These are publicly owned sewer systems that only carry stormwater, not sanitary sewage. These conveyances systems can include any pipe, ditch, or gully, or system of these that are owned or operated by a governmental entity and used for collecting and conveying stormwater. Local streets and curbs are an important component for stormwater collection as they direct water into the storm drains. MS4s are meant to carry five- to 10-year stormwater runoff. In locations where there are separate systems for stormwater and sewage, stormwater sewers discharge directly into surface water bodies (U.S. EPA 2017d). Because stormwater runoff is often polluted, MS4s are regulated by the EPA's National Pollutant Discharge Elimination System (NPDES) municipal stormwater program. NPDES permits must be obtained before these system operators can discharge stormwater.

Figure 3.7 shows the different types of sewer systems and the relationships between them.

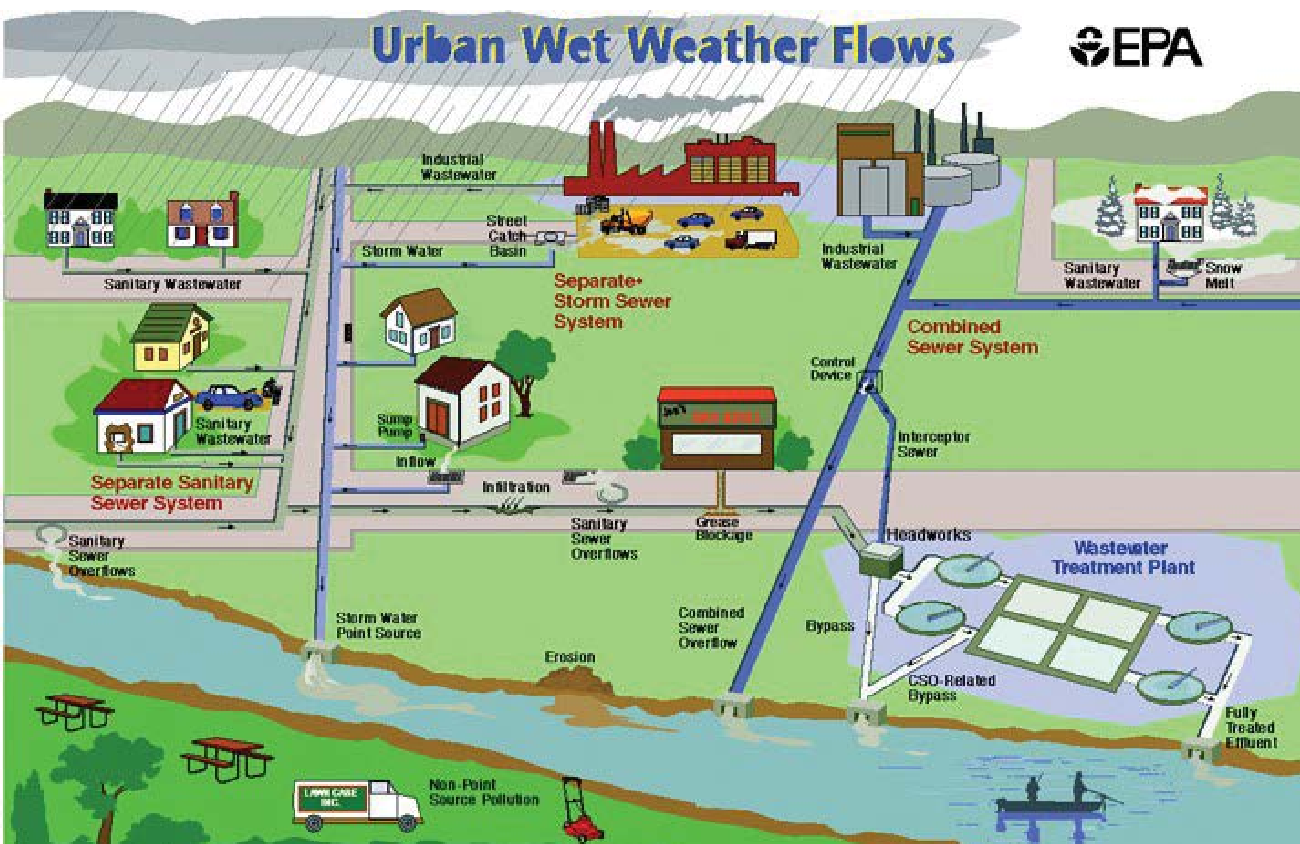


Figure 3.7. Sanitary sewers, storm sewers, and combined sewer systems (U.S. EPA)

the water (US EPA OW 1998). It is also becoming common practice to remove excess chlorine from the water before it is discharged back to the receiving bodies of water, as chlorine can be harmful to aquatic ecosystems. Ultraviolet light or ozone is also being used in lieu of chlorine to minimize impact on aquatic life.

In cases where cleaner effluent is desired, wastewater is run through additional levels of treatment. These advanced or tertiary treatments can include use of filtration membranes, ion exchange, reverse osmosis, and biological processes. They can remove more than 99 percent of impurities from sewage, leaving high-quality water, but are costly to implement. This level of treatment is often used to remove additional phosphorus and nitrogen (U.S. EPA OW/OWM 2004).

Decentralized Wastewater Treatment. Decentralized wastewater treatment systems (including septic systems, private or individual sewage treatment systems, or package plants) are defined as on-site wastewater systems used to collect, treat, and disperse or reclaim wastewater from individual dwellings, businesses, or small communities or service areas. Decentralized wastewater treatment systems serve 25 percent of U.S. homes and 33 percent of new development, and they are permanent components of our nation's wastewater infrastructure (U.S. EPA OW 2003).

The best known and most common of small systems is the septic system, which usually serves a single home in a rural area. It consists of a tank and a leach field, and responsibility for maintenance lies with the homeowner. The EPA and many states have been concerned about improperly managed septic tanks that do not provide the level of treatment necessary to adequately protect surface water and groundwater quality and public health (U.S. EPA OW 2003). Many localities and states have been working to eliminate septic tanks and to connect exurban properties to local wastewater treatment plants, but this is often not possible in rural areas.

Newer technologies for package wastewater treatment plants with a small footprint can serve small clusters of residential units. These are often called distributed systems. A study in 2010 determined that these types of systems are installed for three reasons: (1) as part of an effort to make the development environmentally friendly so as to attract buyers; (2) to preserve the character of a community that has previously been served by septic systems to prevent unwanted growth and expense associated with connecting with a centralized treatment facility; and (3) to allow wastewater utilities to serve customers outside the system of sewer pipes or smaller neighborhoods within their jurisdiction (D'Amato 2010).

While most wastewater in the U.S. is treated through traditional centralized or decentralized wastewater systems, wastewater is increasingly being viewed as a commodity with potential for resource recovery and reuse. See the sidebar on p. 42 for more information on new wastewater management possibilities.

Wastewater Institutions

The U.S. has both public and privately owned wastewater treatment facilities. Private facilities are typically used to treat wastewater from industrial plants and commercial operations. The organizational arrangements of the systems vary, reflecting the different ways and scales in which local governments address both human health and natural systems.

It is common for water supply agencies to also operate as wastewater agencies. If the wastewater agency is part of a local general-purpose government (where the planning function is located), the agency is likely responsible for the wastewater treatment plant and sanitary sewage collection system. If the wastewater agency is a special district, and operates at the county or regional level, the agency may only be responsible for the treatment plant and major interceptors (large sewer pipes that cross jurisdictions). In this case, local general-purpose governments run the wastewater collection systems (i.e., sanitary and storm sewers) in their jurisdictions that connect to the interceptors. They also play key roles in enforcing local land-use and building regulations for sewers. Private-property owners are generally responsible for the connection of their household sewage pipes to the city sewer systems in the streets.

Wastewater Management Regulations

Similar to water supply, wastewater management is overseen by the EPA and its Office of Wastewater Management, which is responsible for ensuring compliance with the 1972 Clean Water Act (CWA).

A key component of the CWA is the National Pollution Discharge Elimination System (NPDES). Under the CWA, discharge of a pollutant from a point source to U.S. waters is prohibited unless that discharge is authorized by an NPDES (Section 402) or wetlands (Section 404) permit. Point-source pollution is pollution that is discharged from a specific single source, like a wastewater treatment plant or an industrial plant. NPDES permits establish necessary technology-based and water quality-based terms, limitations, and conditions on pollutant discharges to protect public health and the environment. They must be renewed after five years.

INNOVATIONS IN WASTEWATER MANAGEMENT

Increasingly, wastewater is being viewed as a resource that contains water and energy that can be reclaimed for reuse, as well as valuable nutrients for food (phosphorus and nitrogen) and trace amounts of metals. The goal of current thinking by wastewater professionals is to transform waste management from a linear disposal-based system to a recovery- or reclamation-based system (Tarallo 2014). Indeed, the term *water resource recovery facility* is gaining traction for use in place of wastewater or sewage treatment plant and older conventional names. The name change reflects a changing paradigm in the water sector, focusing on resource recovery (Fulcher 2014).

More than 99 percent of wastewater is water by weight (WEF 2009). Wastewater reuse originated in California and Florida due to the frequency of droughts and the costs of transporting water from distant sources. Advanced technologies such as reverse osmosis and membrane bioreactors push wastewater or saltwater through semipermeable membranes to filter out pollutants, including viruses, pharmaceuticals, and other emerging contaminants. These technologies have advanced dramatically in the past 20 years and are now more cost effective and energy efficient. Constructed or natural wetlands can also be used to help purify water with little energy costs, though these systems require large land areas. Water for reuse can be produced from wastewater at centralized treatment plants as well as at district, neighborhood, or on-site scales.

Recycled water can be used for both potable and nonpotable uses. Nonpotable reuse systems deliver treated water for irrigation or other uses in separate pipes (Asano et al. 2007). Indirect potable reuse systems return water first to the natural environment; for example, by returning tertiary-treated wastewater to reservoirs or groundwater aquifers and then pumping it out for additional treatment and delivery to customers (Asano et al. 2007; Espinola 2016; Leverenz et al. 2011). In one sense, almost all water supply systems are now indirect potable reuse systems; the lake or river that provides one community's drinking water may also receive treated wastewater from another upstream community or facility.

Direct potable reuse systems, which are still uncommon, purify wastewater and introduce it directly into municipal water supply systems (Leverenz et al. 2011). There has been, and continues to be, a great deal of resistance against "toilet to tap," as it has been called by the media, but in the past 20 years water reuse has become more accepted by consumers (U.S. EPA OWM/OW 2012; Espinola 2016). While more positive approaches to reuse of wastewater have opened the door to more favorable consideration of direct potable reuse, few locations in the U.S. currently use this method, and most states lack regulations to engage in direct potable reuse.

Decentralized or on-site water reuse for individual facilities and homes has been primarily for "graywater," which includes wastewater from bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs, but not kitchen water or "blackwater" from toilets. Graywater must not be contaminated by fecal matter (U.S. EPA OWM/OW 2012). Decentralized reuse for a neighborhood or a building is still in its infancy in the U.S., though this is a widespread practice in Australia and Europe (Beatley 2010). Water professionals expect that the wastewater systems of the future will be a combination of centralized and decentralized facilities (Daigger 2009).

Energy is another resource that can be extracted from wastewater. It takes energy to run water purification plants and water resource recovery plants, and in some cases energy is needed to pump source water and wastewater between treatment plants and end users. A 2017 federal report concluded that energy consumption by drinking water and wastewater utilities accounts for 30 to 40 percent of a municipality's total energy bill (Copeland and Carter 2017). According to the EPA, there is enough thermal energy embodied in wastewater to run existing treatment plants five times over (WE&RF 2014).

Pioneering wastewater treatment plants in the U.S. are using thermal heat pumps and heat exchanges, along with biogas produced from the sludge or biosolids left over after treatment, to reduce their energy footprint. Food scraps and other organic waste can also be combined with biosolids to produce more energy than from biosolids alone. These approaches have made some U.S. utilities energy neutral (Kohl, forthcoming). Wastewater can also be used in distributed (district) heating, ventilation, and air-conditioning (HVAC) systems for residential and commercial facilities to warm them in the winter, or to cool them in the summer. Thermal heat pumps and heat exchangers are used with a pipe loop in which water in the HVAC systems, warmed by sewage, circulates. Users can take heat or put it back into the system using heat pumps. Copenhagen serves 97 percent of city buildings with wastewater-sourced heat, as do other European cities (Kohl, forthcoming). On-site loops and heat pumps for individual buildings are also possible.

In 1987, the CWA was amended to include nonpoint sources of water pollution: chemicals, sediment, bacteria, and other pollutants picked up by stormwater runoff (U.S. EPA 2017g). More than 200,000 wastewater sources are regulated under the NPDES program. The EPA has delegated responsibility for implementing the NPDES program and permits mostly to the state level, where departments of environmental quality or health typically implement this program (U.S. EPA 2017c). In many cases where pollutant levels from cities have exceeded limits set by CWA regulations and NPDES permits, the EPA has sued cities to enforce compliance. The resulting agreements, commonly known as consent decrees, commit cities to wastewater infrastructure upgrades designed to reduce future CWA violations.

Many federal and state laws and regulations specify how wastewater discharges must be managed, especially when they involve discharges into water or onto land (e.g., U.S. EPA OW 2003, Appendix B). Addressing the scope and complexity of the many wastewater regulations and programs is beyond the scope of this report, but a comprehensive summary of federal law applicable to wastewater management can be found at www.epa.gov/regulatory-information-sector/water-and-sewage-utilities-sector-naics-2213.

STORMWATER

Stormwater is precipitation, such as rain or snowmelt, that is not absorbed into the ground but flows overland as runoff (Figure 3.8). In rural and natural environments, where runoff follows the natural topography, a significant portion seeps into the ground and is absorbed by the vegetation in its path before finally discharging slowly to water sources. When the amount of precipitation exceeds the rate at which it can be absorbed into the ground—or in urbanized areas where impermeable surfaces such as streets, sidewalks, parking lots, and buildings predominate—the excess precipitation accumulates and begins to flow over the ground, becoming runoff (Novotny and Brown 2007). Flooding can occur when large volumes of runoff flow into streams and rivers (Konrad 2003).

The challenge of how to collect, control, and leverage stormwater is not new. Historically, stormwater infrastructure, policy, and practice were designed to address urban flooding by collecting and removing stormwater from where it fell as quickly as possible. But in the later part of the 20th century, concerns over pollution, coupled with the impacts of climate change, pushed water professionals, planners, urban designers, and engineers to rethink traditional approaches.

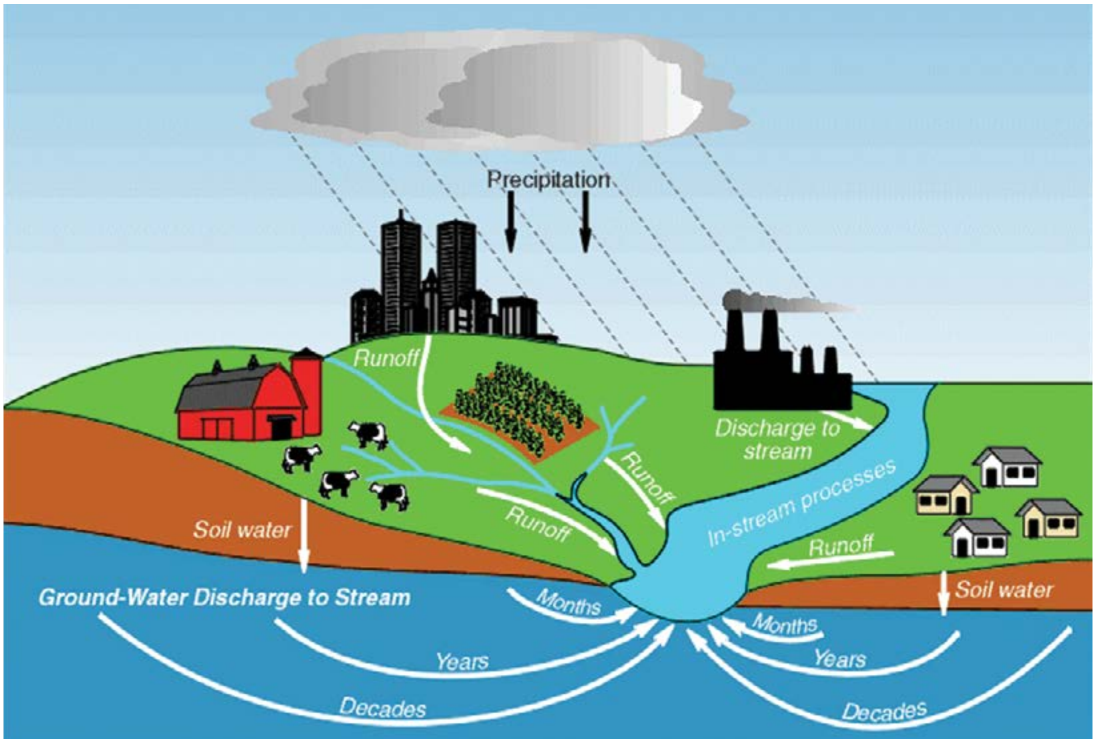


Figure 3.8. Stormwater runs off the landscape into streams and replenishes groundwater (Phillips, Focazio, and Bachman 1999, Figure 2)

The Stormwater System

Stormwater infrastructure is composed of two main subsystems: minor and major elements (Columbia County 2009). Minor elements remove stormwater from areas where people walk, bike, or drive. Examples include curbs, gutters, street inlets, underground culverts, ditches, channels, and small underground pipe systems—anything that carries water away from the site.

The major elements of a stormwater management and conveyance system serve flood needs and emergency flows. They include creeks and rivers, lakes, ponds, marshes, estuaries, and oceans that receive the bulk of the stormwater runoff, as well as the larger pipes and drainage collection systems that receive stormwater runoff from the minor system and convey it to receiving waters. Newer management approaches, designed to retain stormwater runoff on-site, include detention and retention basins.

Municipal stormwater sewers (Figure 3.9) consist of lateral connections that drain stormwater from residences and streets to either a separate storm sewer or a CSS (described in a previous section). The storm sewers lead to submains in the street, which in turn lead to trunk lines, which discharge storm water into receiving water bodies. Storm drains and catch basins both catch debris and are cleaned out periodically by public works crews who access these facilities through utility access ports (also known as manhole covers).

Stormwater management has traditionally been handled through engineered, or gray, infrastructure. Increasingly, however, communities are turning to more natural approaches of green stormwater infrastructure and low impact development designs to reduce runoff by infiltrating it on-site in more cost-effective and ecologically friendly ways. See the sidebar for a discussion of this shift in paradigms.

Stormwater Management Institutions

The responsibility for building and maintaining stormwater infrastructure falls principally on local government, with involvement by the federal government in large-scale flood control. Regulation of stormwater principally derives from the federal government, and is implemented by state and local governments.

At the federal level, the EPA and the U.S. Army Corps of Engineers (USACE) are the main actors. The EPA focuses on reducing runoff and improving water quality by initiating stormwater programs, building facilities, and overseeing regulations for state and local stormwater programs. USACE has played a significant role in providing structure protection from flooding to vulnerable structures. USACE is one of the oldest entities engaged in stormwater management and is responsible for the major systems of stormwater infrastructure. It oversees federal flood protection, builds and repairs dams and levees, keeps navigable waterways clear, and provides

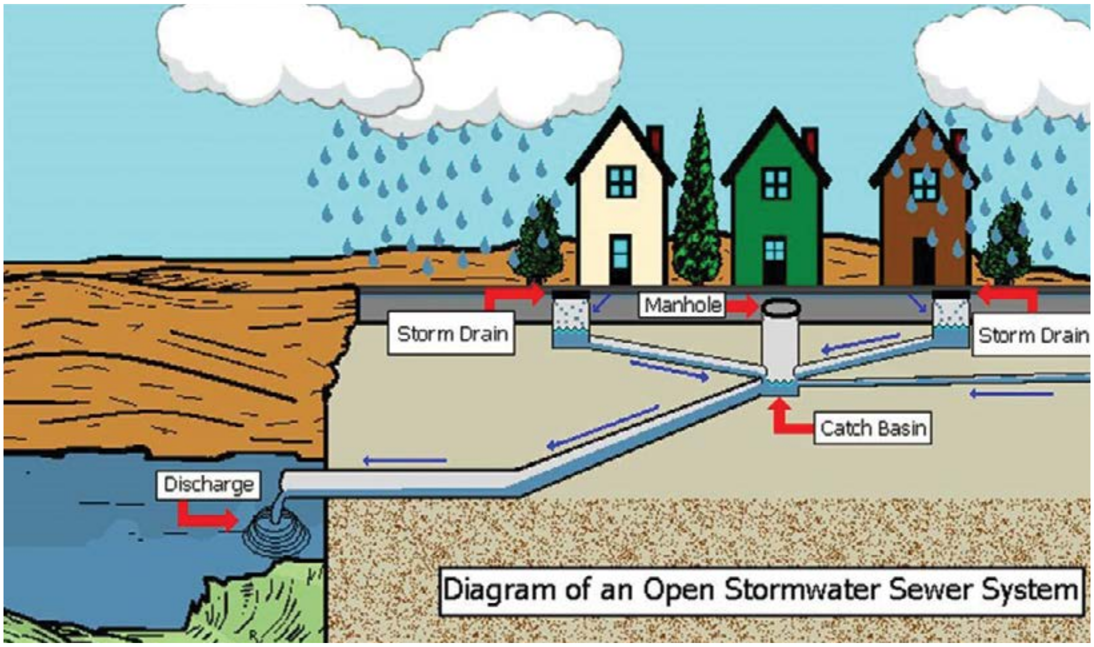


Figure 3.9. Elements of a stormwater sewer system, which collects and disposes of water from streets and sidewalks (Troy n.d.)

INNOVATIONS IN STORMWATER MANAGEMENT

Traditionally, stormwater runoff has been viewed as a nuisance and a waste product. To meet demand for new development, natural permeable surfaces such as wetlands, streams, and creeks were paved over to make room for structures, roads, and basic infrastructure needs. Development occurred in floodplains. Not surprisingly, flooding and pooling became common. To keep populations and structures safe, it became commonplace for cities to build stormwater infrastructure to remove any excess water as quickly as possible, with little thought about the consequences of how the water was moved or to where it was placed. This was done through engineering techniques, such as curb-and-gutter and piping systems that discharge runoff to the nearest receiving waterbody.

Traditional stormwater management largely relies on conveyance efficiency and end-of-pipe treatment. Although end-of-pipe treatment is still important in stormwater management, the key to effective management of stormwater runoff is to reduce the volume of stormwater generated in the first place. This is done by maintaining and working with the hydrology of a site and capturing, infiltrating, and slowly releasing stormwater at the source (Rouse and Bunster-Ossa 2015).

Today, cities are starting to view stormwater not as a nuisance, but as a valuable resource and even an opportunity, if managed wisely. To capitalize on opportunities, a more integrated approach to stormwater management and urban design is gaining momentum. With designs and practices to capture runoff, it is possible to recharge groundwater supplies, provide additional sources of nonpotable water, and to minimize or even prevent damage to public and private resources (Novotny, Ahern, and Brown 2010).

Natural floodplains and riparian zones provide stormwater management functions. Also referred to as green infrastructure or natural capital, these landscape features naturally spread out and slowly absorb floodwaters, while providing water quality benefits. The combined storage and slowing of runoff provides a high level of natural (and cost-effective) flood control, making wetland restoration and preservation of riparian zones increasingly important from both water management and ecological perspectives (Freitag et al. 2009).

Green stormwater infrastructure, also known as low-impact development, can also be defined as neighborhood- or site-scale elements, such as planter boxes, rain gardens, bioswales, permeable pavements, and green roads or alleys. They can be integrated throughout urban environments to capture and infiltrate stormwater runoff on-site (U.S. EPA 2016c; U.S. EPA 2017f).

The EPA has begun to recognize the need to approach stormwater and wastewater management in a holistic way, acknowledging that a more integrated planning approach supports better infrastructure investments. Integrated stormwater and wastewater planning should engage all stakeholders and permit sustainable and comprehensive solutions, including green infrastructure practices (Stoner and Giles 2011). The EPA offers guidance on how to implement sustainable best practices at the community level for stormwater, including information on building and managing sustainable water infrastructure and utilities and examples of how communities are successfully integrating these practices into daily routine (e.g., U.S. EPA 2016h).

support to state and local agencies working on flood management (Elmer and Leigland 2014).

Also at the federal level, over the last 50 years, the Federal Emergency Management Agency and the National Flood Insurance Program have worked together to insure structures in the floodplain, to map floodprone locations to avoid placing fill in the floodplain, and to encourage more responsible land use within the floodplain.

At the local level, stormwater agencies deal with the minor elements of stormwater infrastructure, including the elements of municipal stormwater sewer systems (MS4). Many stormwater agencies are located within the general-purpose government—specifically, the public works department—although there are some freestanding wastewater utilities that have taken over this function. Local governments are usually in control of stormwater management and flood control. In general, there is no set standard or organizational structure for local governments to follow in determining responsibility for stormwater management.

Stormwater Management Regulations

As noted earlier in this chapter, the NPDES permitting program was expanded in 1987 through amendments to the CWA to cover nonpoint source pollution such as discharges from stormwater systems, as well as construction and industrial discharges. In 1990 the EPA established Phase I of the NPDES stormwater program. It requires communities with MS4s serving populations of 100,000 or greater or sites with industrial or construction activity to implement a stormwater management program to control polluted discharges. Phase II, which took effect in 2003, extends coverage of the NPDES stormwater program to certain "small" MS4s and small construction sites (U.S. EPA OW 2003). In most states, enforcement takes place at the state level.

One result of the 1987 CWA amendments was the Section 319 grant program to states to restore impaired water bodies. In 1999 Congress authorized $200 million for the program and directed states to use half of those funds to address local water quality problems at the watershed level. A national evaluation in 2011 found that the 319 grants had resulted in the remediation of 355 impaired water bodies. Although this only represents a small portion of the impaired water bodies in the U.S., the program is significant because it demonstrates how collaboration by stakeholders can result in voluntary actions to restore local waterbodies impaired by nonpoint source pollution (U.S. EPA OWOW 2011).

As is the case with wastewater management, the number and complexity of stormwater regulatory programs is beyond the scope of this primer. See www.epa.gov/npdes/stormwater-rules-and-notices for a summary of EPA stormwater regulations.

CONCLUSION

This chapter has described the basic infrastructure, institutions, and regulations for the three legacy water service systems: water supply, wastewater, and stormwater. Readers should now have a basic understanding of these systems and are encouraged to build on their knowledge of water issues in their own regions by delving more deeply into these topics on their own, especially where regulations are concerned and local conditions diverge from this general discussion.

As noted in Chapter 2, the water industry is moving towards a more integrated One Water view of the three systems, realizing that many water management challenges affect all three, and that problems of one system can be solved with changes in the others. The next chapter examines such challenges, most of which will be exacerbated by the confounding factors of climate change and urban population growth. One Water approaches, and greater involvement of planners in water resource management, will be important parts of efforts to address these challenges.

CHAPTER 4

WATER SYSTEM CHALLENGES AND FACTORS FOR CHANGE

Safe water systems are generally regarded as one of the great achievements of the 20th century, ranking only behind electricity, the automobile, and the airplane (National Academy of Engineering 2017). At the beginning of the 20th century, death from waterborne diseases was a serious public health scourge, but by 1940 cholera, typhoid fever, and dysentery had been virtually eliminated in the U.S. in large part due to clean water treatment and sanitary sewers.

Mortality rates in urban areas dropped by 40 percent from 1900 to 1940, erasing the urban penalty for life expectancy, with half of that due to clean water treatment technologies (Cutler and Miller 2004). The water system in the U.S. has played a significant role in the doubling of life expectancy in the past 150 years.

Our water system is one of the largest and most sophisticated in the world. It has long relied upon a system of pipes and treatment plants operated by separate utilities for supply, wastewater, and stormwater. However, increasingly complex challenges face water utilities and the natural water environment. Water system problems can be characterized in one of three ways (Sullivan 2016):

- There is not enough water.
- There is too much water.
- The quality of water is compromised for the proposed use.

These three issues translate into challenges that water professionals are currently grappling with: scarcity of water supplies, flooding, and water pollution and contamination. At the same time, the current system is aging. Deteriorated infrastructure compounds these problems, which impact the environment, the economy, and society. Finally, all of these issues are further exacerbated by climate change and urban population growth.

This chapter sets the stage for understanding the future challenges and needs of water management by describing how climate change and urban population growth intersect with water systems. It then provides an overview of the several long-standing challenges that water managers and planners have faced regarding water supply, wastewater, and stormwater, as well as the problems posed by legacy water infrastructure. Finally, it discusses the impacts of water challenges in areas of particular concern to planners: ecosystem health, economic growth, and water equity and justice.

EMERGING DRIVERS OF CHANGE IN WATER MANAGEMENT

Two factors—climate change and population change—are exacerbating existing water management challenges and creating new ones. They also have economic, environmental, and social implications for communities. The interconnections of all these issues highlight the importance of a One Water approach that holistically addresses these issues in a comprehensive fashion.

Climate Change

A leading challenge in the water sector is climate change. During the past 100 years, humans have discharged increasing amounts of hydrocarbons into the atmosphere, especially from burning fossil fuels for energy. Hydrocarbons do not "rain out" of the atmosphere but stay suspended indefinitely. They block heat from leaving the planet, resulting in higher temperatures for the earth, air, and water. For the last 45 years, global surface temperatures have risen at an average rate of about 0.17°C (around 0.3° Fahrenheit) per decade—more than twice as fast as the 0.07°C per decade increase observed for the entire period of recorded observations (1880–2015). As shown in Figure 4.1 (p. 50), the 10 warmest years in the 134-year record all have occurred since 2000, with the exception of 1998 (NOAA n.d).

In North America, average temperatures have risen between 1.3°F to 1.9°F from 1985 to 2012, although the

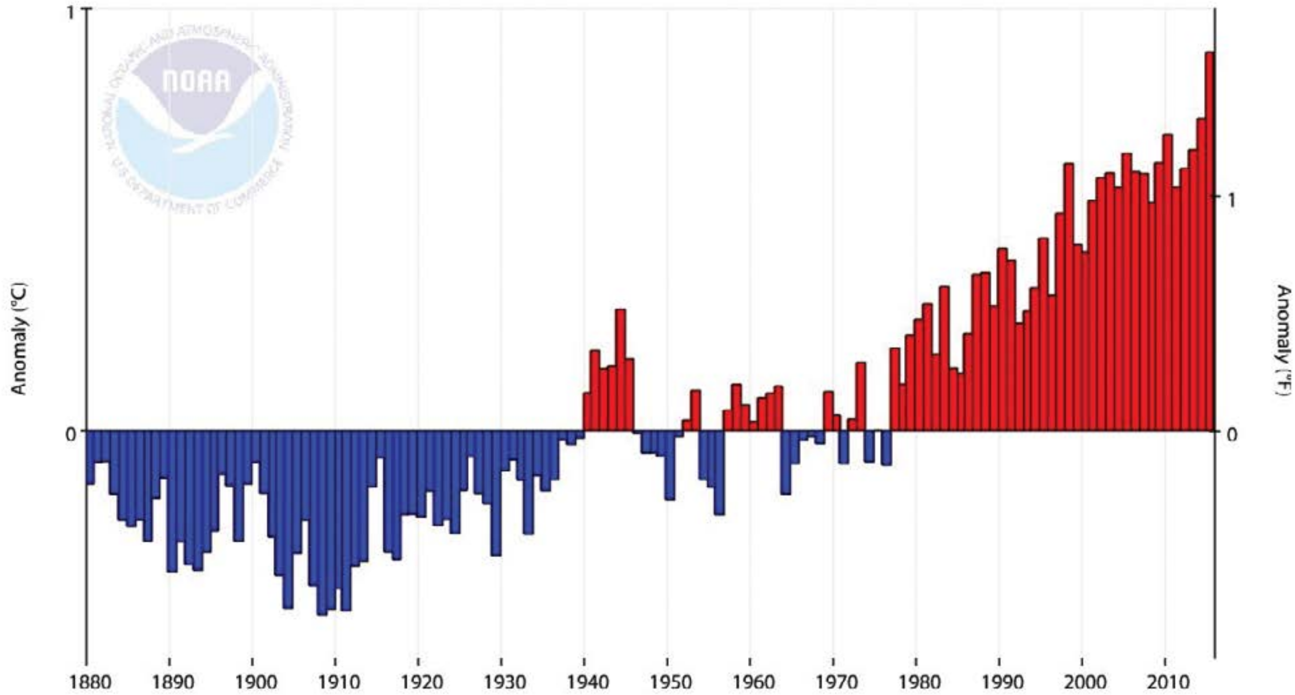


Figure 4.1. Change in global surface temperature from 1880 to 2015 relative to 1951–1980 average temperatures (NOAA n.d.)

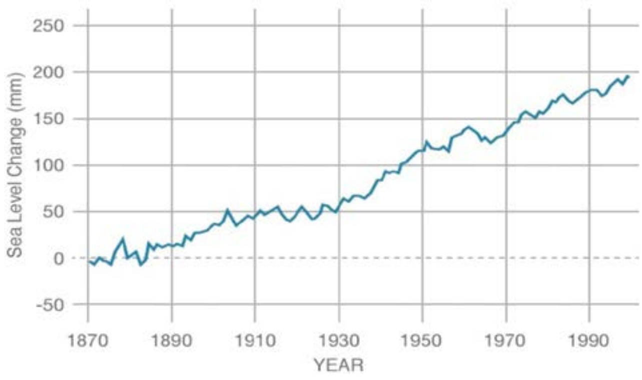


Figure 4.2. Change in sea level between 1870 and 2000 recorded by coastal tide gauge readings (Courtesy NASA/JPL-Caltech)

increase has been more pronounced in recent years. By 2100, North American temperatures are projected to rise 3°F to 5°F if carbon emissions are lowered substantially, or 5°F to 10°F for higher emissions scenarios, with the greatest increases in Alaska and the Midwest (Walsh and Wuebbles 2014).

The higher average surface temperatures across the continents are causing two water-related phenomena of concern. First, sea levels are rising. Records kept since 1870 show that the level of the oceans is rising along most of the coastal areas of the U.S. (Figure 4.2). Rising sea levels are caused by the expansion of the ocean as it warms—it absorbs more than 90 percent of the increased global temperature caused by carbon emissions—and the hastening of the melting of the glaciers and ice sheets. Analysis of both satellite measurements and tide gauge records show that in the past two decades, the annual rate of increase in sea level has doubled (Douglas 1997). Scientists anticipate that sea levels could rise by as much as 6.25 feet by 2100 if efforts to reduce greenhouse gases are not effective (Lindsey 2016).

Second, because climate change results in greater levels of energy in the atmosphere, weather patterns are more volatile, extreme, and geographically distinct, with wetter areas becoming susceptible to increased floods and dryer areas to droughts (IPCC 2014). Between 1958 and 2008, average precipitation in the U.S. increased by 5 percent. However, significant subnational variations exist, with decreases of annual precipitation in the southeastern and western regions of the country, as well as Alaska (Figure 4.3). Current predictions are for increases of precipitation in the northern U.S. and decreases in the South, especially in the Southwest (Georgakakos et al. 2014).

At the same time, there has been and will continue to be an increase in both the frequency and intensity of extreme weather events: unusual, unpredictable, severe, or unseasonal weather representing the most unusual 10 percent of a place's history (NOAA NCEI n.d). These events are caused by a combination of warmer ocean waters and more water in the atmosphere as a result of evaporation caused by hotter temperatures. From 1958 through 2008, there was a substantial increase in the heaviest 1 percent of all daily precipitation events across the U.S. The highest rate of increase, 67 percent, was in the Northeast, with the smallest in the Southwest at 9 percent (Karl et al. 2009). Figure 4.4 shows the percentage of land area in the lower 48 states where a much greater than normal portion of the total annual precipitation has come from single-day events. The bars represent individual years, while the line is a smoothed nine-year moving average.

The many manifestations of climate change have the potential to negatively impact communities in a wide range of

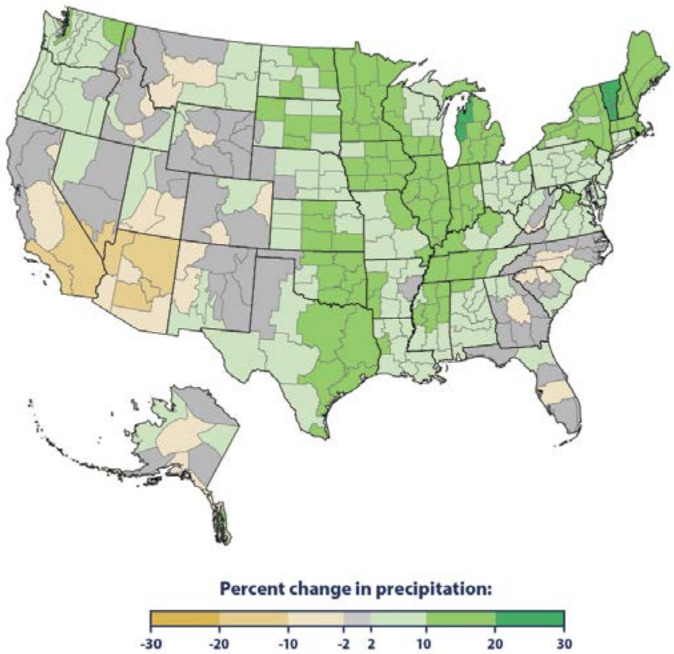


Figure 4.3. Change in annual precipitation from 1901 (Alaska from 1925) to 2015 (U.S. EPA 2016b, Figure 3)

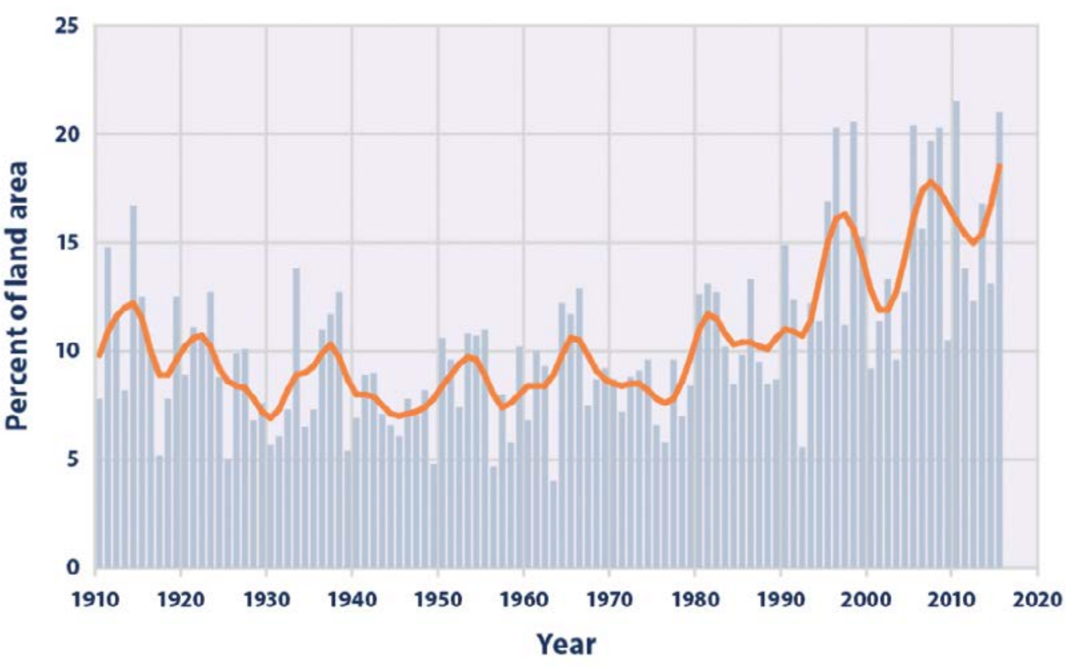


Figure 4.4. Percentage of land area in the lower 48 states between 1910 and 2015 where a much greater than normal portion of the total annual precipitation has come from single-day events (U.S. EPA 2016a, Figure 1)

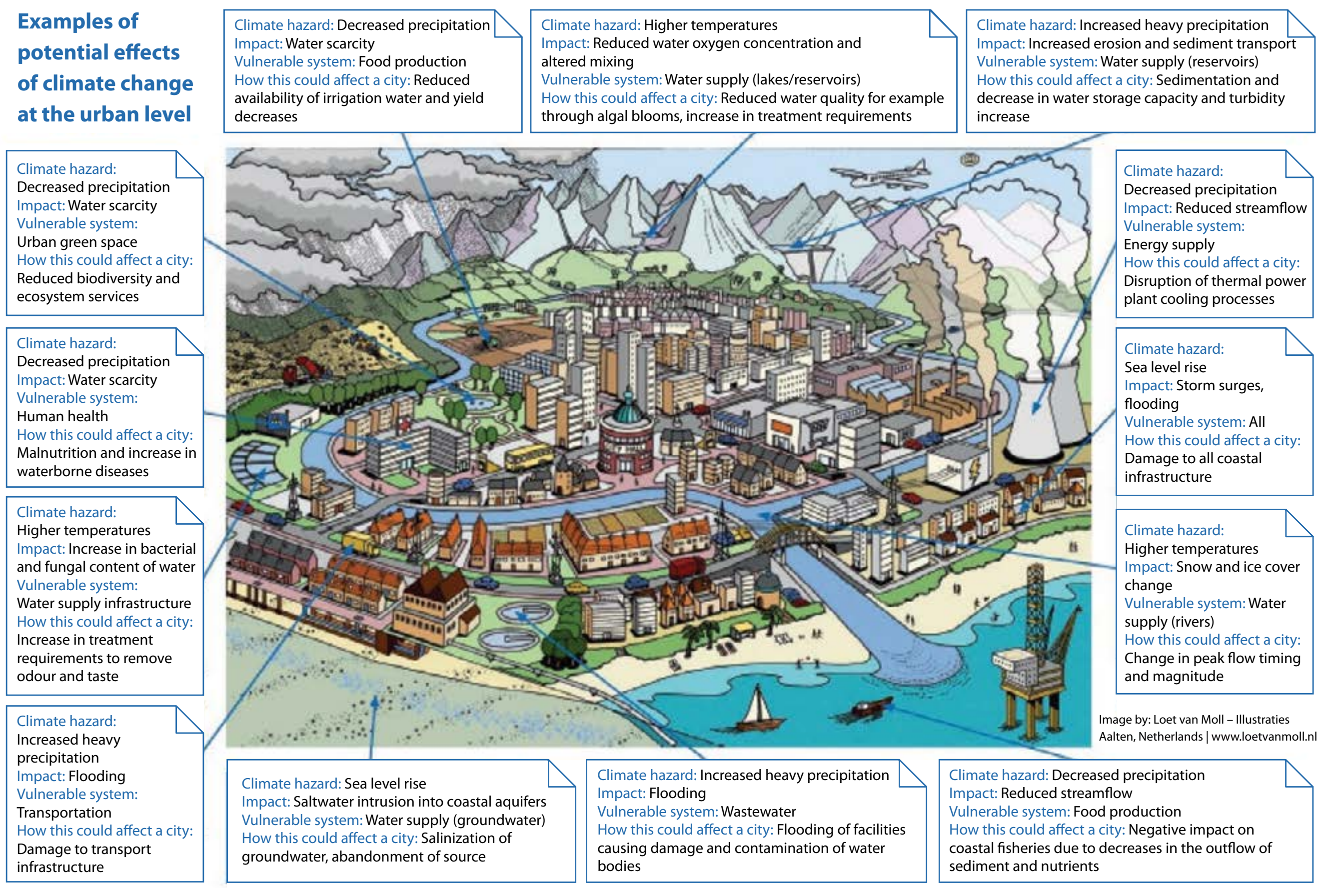


Figure 4.5. Impacts of climate change, urbanization, and legacy water system problems on water services (Loet van Moll/Illustraties, in Loftus 2011)

ways. Figure 4.5 illustrates the negative water-related impacts climate change may bring to urban and rural areas.

Population and Urbanization

As the population of the world grows, competition will increase for water supplies, which are limited or diminishing in many parts of the world. The United Nations Department of Economic and Social Affairs expects global population to increase from 7.3 billion in 2015 to 9.7 billion in 2050 and 11.2 billion by 2100, an increase of 38 percent. This is according to the "median-variant" scenario, often regarded as "most likely" based on analysis provided by the UN's Population Division (United Nations 2015).

This situation is mirrored in the U.S. Although population growth has slowed in some areas of the country, it has accelerated in many water-scarce regions. The population of the U.S. grew from 281 million in 2000 to 309 million in 2010, a 9.7 percent increase (U.S. Census Bureau 2012). Several states, all of which are water-stressed, experienced growth rates that were greater than the nation as a whole: Nevada (35 percent), Arizona (25 percent), Utah (24 percent), Idaho (21 percent), and Texas (21 percent). The five states with the greatest increases in population during that period were Texas (4.3 million), California (3.4 million), Florida (2.8 million), Georgia (1.5 million), and North Carolina (1.5 million). At the time of publication, these states were on record as suffering water supply shortages.

These trends are expected to continue in the future, furthering the demand for water services above current levels. The U.S. Census Bureau projects that the population in this country will increase by 95 million from 2014 to 2060 (from 321 million people in 2014 to 417 million in 2060), with

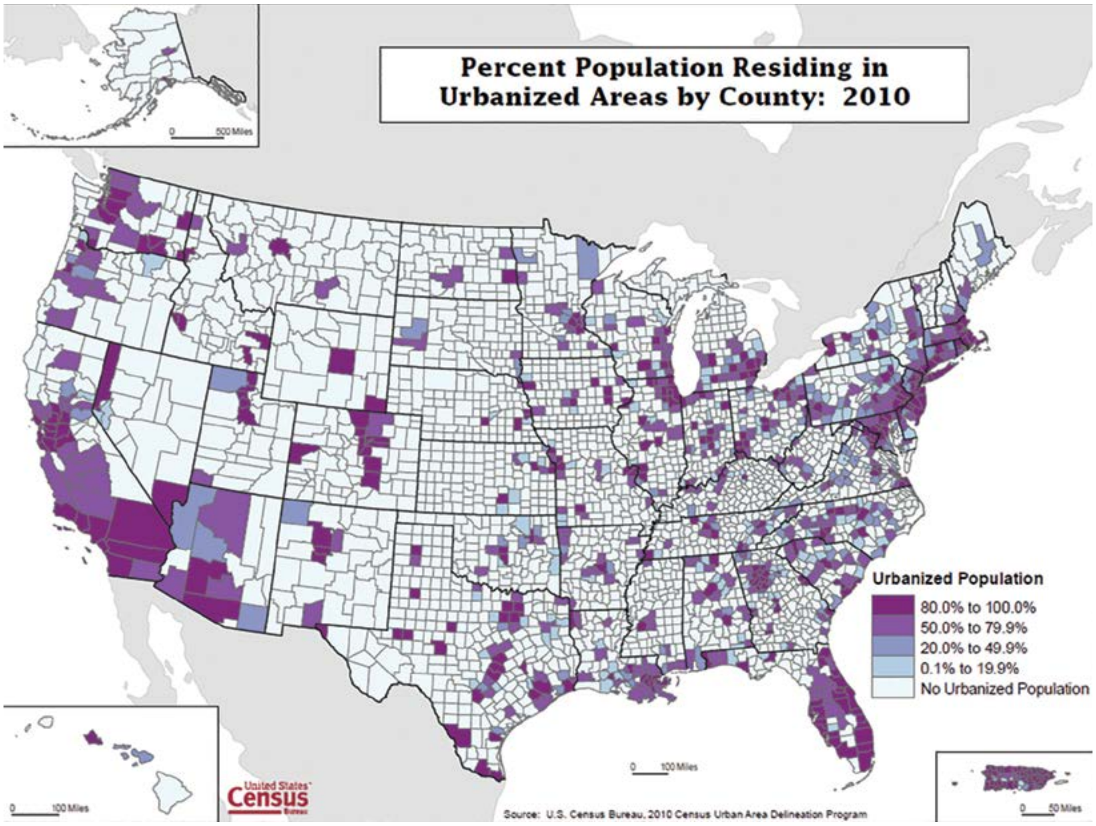


Figure 4.6. Percent of U.S. county populations living in urbanized areas (U.S. Census Bureau)

two-thirds of the growth caused by migration (U.S. Census Bureau 2014). Most of this population growth will be in the Southwest and central and southern great plains, but also notably in urban centers.

In addition, a national 150-year trend of population clustering in urban areas is expected to continue for the foreseeable future. Figure 4.6 illustrates the percent of county populations throughout the U.S. living in urbanized areas. Most recently, the urban population increased 12.1 percent from 2000 to 2010, compared to an increase of 9.7 percent during the same time period for the entire nation (U.S. Census Bureau 2012).

Urban areas typically have large water infrastructure systems in place, but they are often challenged by new demand from urban and suburban residential growth and their supply sources are often limited. Additional factors exacerbate the challenges of supplying water to growing populations, including the accompanying water demands for agriculture and food production, energy generation, business and industrial use, and recreation.

CHALLENGES TO WATER MANAGEMENT

It is important for planners to understand existing challenges to water systems as they plan for future growth and conservation of resources. The impacts of climate change and urban population growth will only worsen the impact of these issues.

Water Scarcity

Freshwater shortages are already occurring in the U.S. because of the depletion or loss of traditional natural water storage such as aquifers, diminished snowpack levels, decreased precipitation as a result of climate change in some areas, and long-term drought. Growing populations in warmer, drier areas of the country, such as the Southwest, further stress already limited water supplies. The challenges of water scarcity will be especially acute in the arid West and Southwest, where rivers and streams have highly variable flows and where prolonged droughts are increasingly common (Foti, Ramirez, and Brown 2012). Pollution of existing water sources can also contribute to water scarcity.

Additional new demands on water supplies include such uses as hydraulic fracturing to extract natural gas. The U.S. Environmental Protection Agency (EPA) has estimated that fracking may use 70 to 140 billion gallons of water each year in the U.S., roughly the equivalent of the use of 40 to 80 cities of 50,000 people or one to two cities of 2.5 million people. This process can also result in pollution to aquifers (U.S. EPA ORD 2011).

Overpumping of groundwater systems may cause land subsidence, aquifer collapse, and damage to water distribution infrastructure and facilities. Notable examples of this are depletion of aquifers in the California Inland Empire and the Ogallala Aquifer and others in the Midwest by both urban and agricultural users.

A county-level water scarcity index is shown in Figure 4.7. This scarcity index compares the cumulative water shortages over a 60-year period to the amount of rainfall in that area, with shades of red indicating scarcity and blue indicating adequacy (Columbia Water Center 2016). Note the intense red in California and in the agricultural Midwest. Areas with significant shortages of supply, without adequate rainfall to refill the streams and aquifers, are in the most precarious position with respect to reliable future supply.

In May 2014, the U.S. Government Accounting Office (GAO) updated its 2003 report addressing trends in freshwater availability and use. The report found that 40 of 50 state water managers expect water shortages in some portion of their states under average conditions in the next 10 years; see Figure 4.8 (U.S. GAO 2014).

Drinking Water Quality Concerns

The EPA's compliance report for public water systems in 2013 noted that there were 16,802 "significant violations" of its drinking water standards. Almost half included coliform violations (48 percent), followed by chemical contamination (22 percent), disinfection byproduct contamination (13 percent), and lead and copper violations (5 percent). Surface and groundwater treatment were found to be inadequate to meet requirements to control pathogens 7 percent of the time and fecal contaminants 6 percent of the time (U.S. EPA OECA 2015).

Several issues have arisen in recent years regarding both contamination of the water supply by known contaminants, such as lead, as well as potential contamination by contaminants of emerging concern. The following sections provide an overview of these drinking water quality challenges.

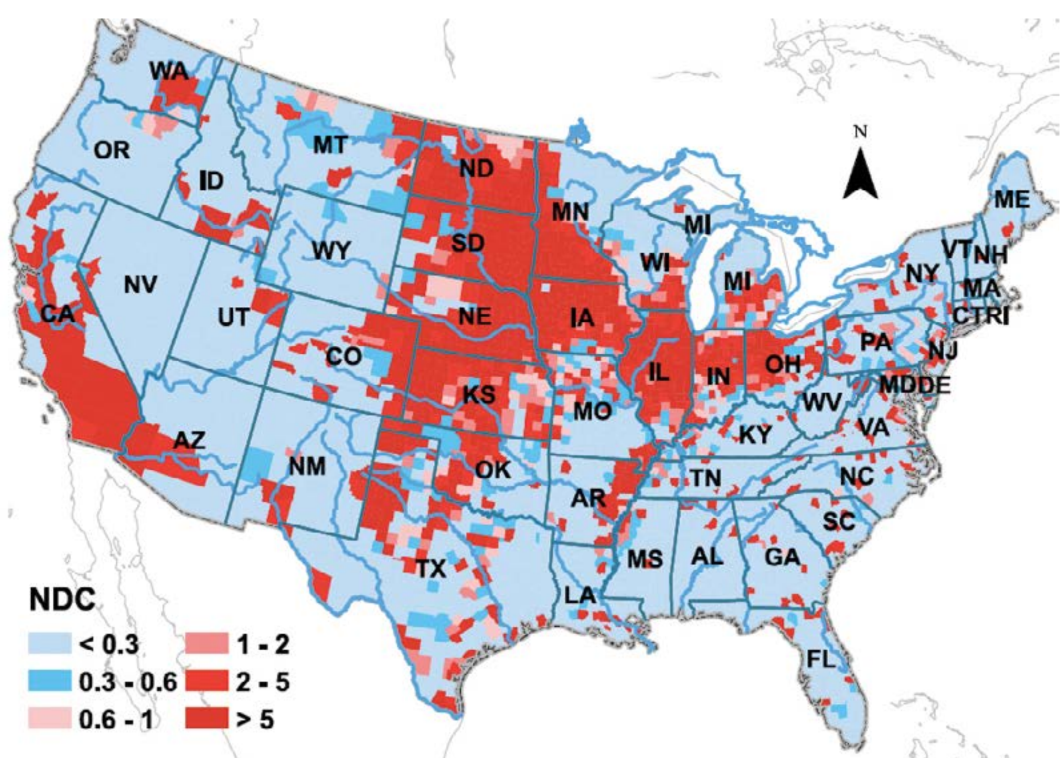


Figure 4.7. Normalized Deficit Cumulative (NDC) for U.S. counties (1948–2009) shows cumulative, multiyear water deficits; an NDC of greater than 1 represents a location where the average rainfall is less than the average use (Columbia Water Center 2016)

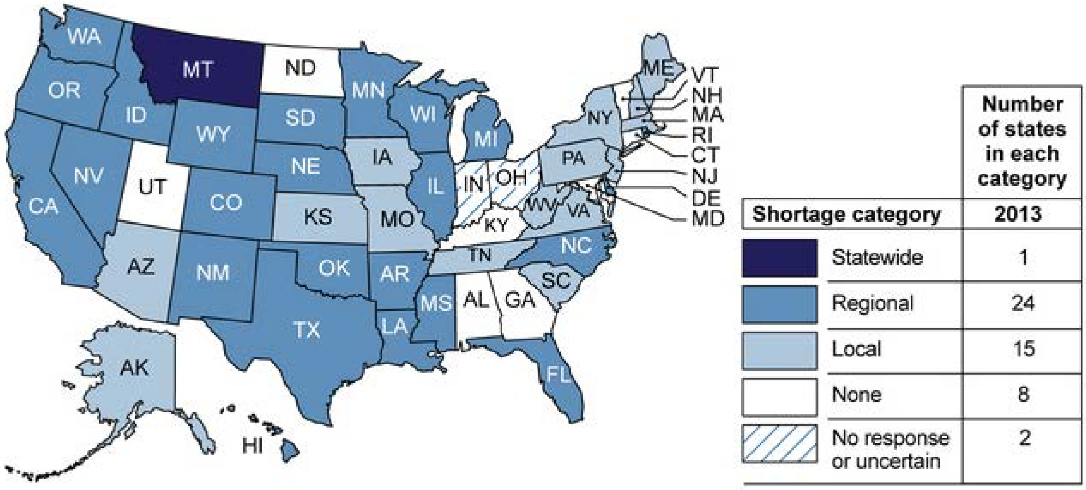


Figure 4.8. Water managers in all but 10 states expect some degree of water shortage in the next 10 years (U.S. GA0 2014)

Lead

Nationwide, risk exists in many locations for lead contamination in cases where the privately owned water service line that connects a building to the city- or county-owned water main is made of lead. If disturbed, or if the water quality changes, there may be releases of lead particles into drinking water. The replacement responsibility often lies with the private property owner.

In Chicago, when new water infrastructure was built in the public right-of-way in 2013, contaminated water was found at residential taps, even though tests by the treatment plants indicated that the water was free of lead when it left the plant. This was principally due to the disturbance of the lead service pipe (Del Toral et al. 2013). National surveys of U.S. community water systems have found that approximately 30 percent have some lead service lines in their systems (Cornwell et al. 2016). Lead contamination of the water supply in Flint, Michigan, is discussed later in this chapter.

Contaminants of Emerging Concern

A new type of pollutant, contaminants of emerging concern (CECs), are increasingly being detected at low levels in surface waters, and there is concern that these compounds may have an impact on aquatic life. Human health impacts are still being researched, but primary concern centers on prenatal exposure (Richardson and Ternes 2014).

The term "contaminant of emerging concern" has been used by the EPA to identify a variety of chemical compounds that have no regulatory standard but have been recently discovered in natural aquatic environments, principally because of improved analytical chemistry detection levels. The agency is particularly concerned about pharmacologically active chemical compounds and personal care products because they are commonly discharged at wastewater treatment plants, the effluent from which often flows to downstream water supply intakes, and some of these compounds are designed to stimulate a physiological response in humans, plants, and animals. The EPA is still researching approaches to setting criteria for CECs in water.

Many CECs act as endocrine-disrupting chemicals (EDCs). EDCs are compounds that alter the normal functions of hormones, resulting in a variety of health effects. These compounds can have reproductive impacts on aquatic organisms. Evaluating these kinds of biological effects requires new testing methodologies. Examples of emerging contaminants that the EPA is working to better understand include perchlorates, pharmaceuticals, personal care products, veterinary medicines, EDCs, and nanomaterials (U.S. EPA OW/ORD ECW 2008). The majority of CECs differ from "conventional" environmental pollutants, such as pesticides, metals, PCBs, and dioxins, because many CECs are used by typical households (AWRA 2007).

These emerging contaminants may have low immediate toxicity (principally to aquatic organisms) but may cause significant reproductive effects at very low levels of exposure. In addition, the effects of exposure of CECs to aquatic organisms during the early stages of life may not be observed until later in adulthood. In addition to surface waters, CECs have also been found in groundwater and in water supplies from drinking water treatment plants (Erickson et al. 2014; Glassmeyer et al. 2017). The EPA has proposed recommendations for better understanding the effects of these chemicals and for testing to identify possible CECs (U.S. EPA OW/ORD ECW 2008).

Water Pollution

Despite an overall improvement in water quality since the 1970s resulting from enforcement of the federal Clean Water Act and Safe Drinking Water Act (see Chapter 3), many water bodies still suffer from pollution. The EPA states that 44 percent of assessed stream miles, 64 percent of lakes, and 30 percent of bay and estuarine areas are not clean enough for fishing and swimming (Bradford 2015). Water pollution diminishes recreational and economic opportunities for communities with waterfront assets, and can cause public health crises if public water supplies for daily use are not properly treated.

Water pollution occurs when a body of water is contaminated by various physical, biological, or chemical substances that are proven to be harmful to human, plant, or animal health. Pollutants may include fertilizers and pesticides from agricultural runoff, sewage and food processing waste, lead, mercury, industrial discharges, and contamination from hazardous waste sites (NIEHS 2017). As previously noted, CECs are a new source of concern. Most municipal water supply treatment systems are currently unable to effectively remove CECs (Herman 2014).

Both urban and agricultural activities can pollute stormwater (U.S. EPA 2017e). When runoff flows through streets into storm drains, pollutants including nutrients, petrochemicals, litter, debris, bacteria, and pathogens are transported, untreated, to waterways. There are hundreds of thousands of farming operations across the U.S., and when they are not managed and regulated properly, animal waste and fertilizer can cause serious water pollution, including nutrient enrichment of surface waters, fish kills, and contaminated drinking water. Farms may not have the appropriate plans to dispose of waste, which can lead to contamination.

Polluted stormwater runoff can completely shift the way communities interact with their waterways and sources. It can result in contaminated beaches and drinking water sources, and can also contaminate fish and shellfish. This can have a devastating economic impact on communities reliant on water-based tourism and recreational opportunities (U.S. EPA OW 2015). According to the National Rivers and Streams Assessment, 46 percent of our nation's rivers and streams are in poor biological condition (U.S. EPA OW/ORD 2012). Such high levels of pollution make it difficult for these bodies to support aquatic life as well as fishing and recreational activities.

Sewer System Overflows

As described in Chapter 3, older wastewater systems in the U.S. convey both wastewater and stormwater in the same set of pipes. When the amount of wastewater moving through the sewage systems exceeds the capacity of the wastewater treatment plant or the pipe, untreated wastewater will be discharged into local surface waters (e.g., rivers, bays) as a combined or sanitary sewer overflow (CSO or SSO). During a CSO or SSO event, untreated sewage is released into water bodies and may erupt from manholes, spill onto streets and private property, and flow into local streams.

Overflows can cause water quality problems, property damage, and public health threats. They can also infiltrate and pollute drinking water resources, recreational areas, and aquatic life. There are thousands of overflow events every year in the U.S., and it will cost tens of billions of dollars, and many years, to rectify them as required under the Clean Water Act (Vallabhaneni et al. 2007).

Nutrients and Eutrophication

Fertilizers that contain the nutrients phosphorus and nitrogen have been important to feed growing populations. However, excess fertilizer can run off farmland and end up in surface water bodies. Nutrients are also byproducts of wastewater treatment plants. The presence of increased concentrations of nutrients in water is called eutrophication (Figure 4.9). These nutrients spur the growth of aquatic plant life (e.g., algal blooms), which leads to a reduction in dissolved oxygen in water bodies. This can impact the quality of surface water and result in dead zones.

Wastewater treatment plants are central players in efforts to remove phosphorus and nitrogen from wastewater. Many treatment plants are under consent decrees requiring them to reduce the discharge of these pollutants. Typical primary and secondary wastewater treatment do not remove nutrients. The cost of such removal is very high. Agricultural runoff, which is also a major source of phosphorus and nitrogen, is not regulated in the U.S., but there are now efforts to reduce these discharges voluntarily (Ribaudo 2009).

Flooding

Flooding is the most common and costliest natural hazard facing the U.S. Over the last 30 years, floods have caused an average of $8 billion in damages and 82 deaths per year nationwide (AGI 2017). Flooding has many causes, including heavy rainfall, rapid snow melt, and broken dams or levees. In coastal areas, flooding can occur during hurricanes and storm surges, which cause sea levels to rise temporarily.

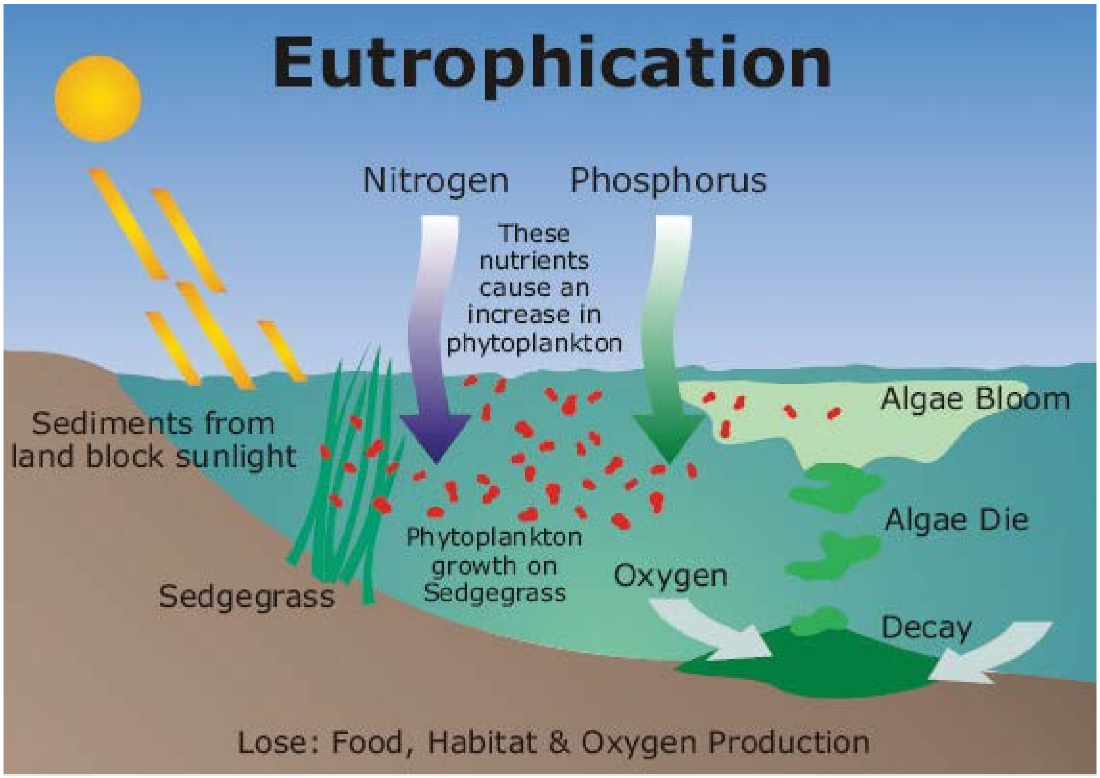


Figure 4.9. Excessive nutrient levels in water cause algal blooms, which reduces dissolved oxygen in the water (Lincoln n.d.)

This is often combined with the effects of heavy rainfall on upstream rivers, causing additional floodwater discharge along the coast.

Almost every development site is part of a larger riverine or coastal watershed. Any modifications that increase runoff or disrupt natural protective systems often increase flooding either downstream or in other parts of the watershed (Morris 1997). Development in floodplains and along rivers and streams can pose considerable risk to the safety of people and property. In addition, such development can be destructive to the environment. Environmental disturbance from land development in sensitive areas can impact wetlands and estuaries, which might be filled or channelized. Natural drainage systems are typically "recreated" with less effective man-made channels and pipes. Vegetation is often removed, and beaches and dunes are destroyed and replaced with bulkheads and seawalls.

These actions, combined with the effects of creating and expanding impervious surfaces by constructing buildings, streets, parking lots, and other surfaces that do not allow rainwater to be absorbed, increase stormwater runoff beyond the capability of the remaining undisturbed land to absorb runoff (Figure 4.10, p. 58). The two primary results of such actions are the constant threat of flooding of developed and undeveloped property, and the degradation of surface water and groundwater (Morris 1997).

As the land in a watershed develops, and greater areas of impervious surface are created, the hydrology of the watershed becomes more flood prone: the speed at which water is channeled or piped from the developed areas increases, and the receiving stream does not have capacity for the new inputs of additional flow. This insufficiency of flood carrying capacity in the stream is exacerbated by placement of fill and structures in the floodplain, which obstructs the capacity of the stream to carry away the runoff.

Extreme precipitation events caused by the impacts of climate change have increased the frequency of flood events in many parts of the U.S. In the Midwest (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin), the frequency of "largest" storms delivering three inches of rain or more in one day increased by 103 percent between 1961 and 2010. Less severe storms (ranging between two to three inches of rain in one day) have increased by 81 percent, and moderate storms (one to two inches per day) increased by 34 percent

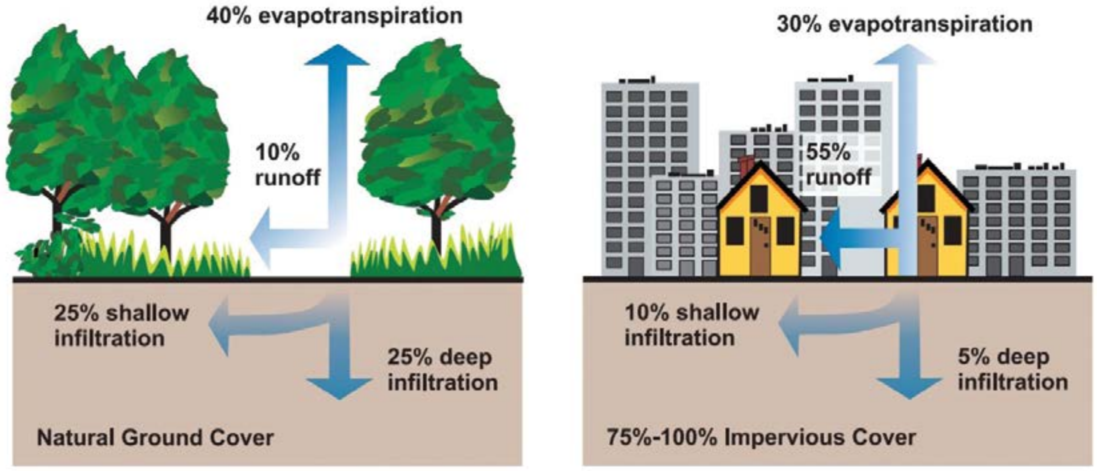


Figure 4.10. The effects of increased impervious surfaces on runoff and infiltration (U.S. EPA 2003)

(Saunders et al. 2012). Inland flooding has caused billions of dollars of property damage, hundreds of deaths, and untold damage to ecological systems (Georgakakos et al. 2014).

It is important to differentiate ocean and coastal flooding, which is usually caused by storm surges and high tides, from riverine flooding, which is exacerbated by obstructions and fill in the river floodplains. Riverine flooding is usually more extreme in terms of increased water levels, whereas ocean or coastal flooding is more extensive in terms of land area impacted. Flooding in coastal areas is also aggravated by climate change. Higher sea levels mean that storm surges push further inland than they once did, which causes more frequent nuisance flooding—minor, recurrent flooding that takes place at high tide. Because of sea-level rise, nuisance flooding in the U.S. has become a "sunny day" event not necessarily linked to storms or heavy rain (Sweet and Marra 2015). Nuisance flooding is estimated to be from 300 percent to 900 percent more frequent within U.S. coastal communities than it was just 50 years ago (NOAA NOS 2017).

As sea levels continue to rise, inconvenience and nuisance may escalate to serious questions of risk to life and safety. Not only can key community facilities be flooded, but roads can become impassable for emergency vehicles, power and communications can be interrupted, and recovery often requires significant investment of public and private resources.

In addition to riverine and coastal flooding, urban flooding caused by excessive runoff from storms also can have devastating impacts on residents. Urban flooding occurs when local rain events overwhelm drainage systems and floods property in the built environment that may be outside of floodplain areas. Homes and businesses are damaged when sewage backs up through floor drains or pipes, groundwater seeps through foundation walls and floors to flood basements, or stormwater inundates yards and public rights-of-way (Festing 2015).

Legacy Water System Challenges

The infrastructure for water supply, wastewater, and stormwater management can be called the legacy water system, because it was conceived, developed, and built in America's industrial era beginning in the late 1800s. This system enabled the construction of the great industrial cities of the U.S. and their suburbs and the westward expansion of the post-World War II construction boom.

The legacy system relies on aging underground pipes and centralized treatment for water supply, wastewater treatment, and stormwater runoff, as well as a complex and context-dependent organizational framework for managing and operating these systems. Both situations present challenges.

Aging Infrastructure

The lack of maintenance and investment in the U.S. water supply system is a huge challenge. In 2017, the American Society of Civil Engineers (ASCE) gave the nation's drinking water infrastructure a D grade, while wastewater and wet weather infrastructure earned a D+. This grade indicates the poor condition of the infrastructure (ASCE 2017). A report by the American Water Works Association found that "a large proportion of U.S. water infrastructure is approaching, or has already reached, the end of its useful life," and that replacing the system will total more than $1 trillion nationwide, assuming pipes are replaced at the end of their service lives and systems are expanded to serve growing populations (AWWA 2012). Failing physical infrastructure contributes to many of the water supply and pollution problems communities of every scale are dealing with (Gusovsky 2016).

Treatment plants for both water and wastewater are critical pieces of wastewater infrastructure requiring serious attention and resources. Most of these treatment plants were either built or renovated in the 1970s with federal funds, but many of these are coming to the ends of their useful lives or need to be upgraded to meet current regulations. Given the ever-increasing demands for improved water quality, coupled with the increased volume of wastewater and pollutants found in wastewater, the need for funds in this area is essential (Sedlak 2014).

Pipes are another critical area for expenditures. An estimated 240,000 water supply main breaks per year account for wastage of an estimated 2.1 trillion gallons of water, or 14 to 18 percent of our drinking water (CNT 2013; Schaper 2014). The EPA estimates that there are 1.2 million miles of sewers owned by public and private entities (U.S. EPA 2002). While many of today's systems were constructed after World War II, some systems were built before the Civil War. Pipe replacement is important as it prevents cracking due to wear and tear, which can lead to overflows and contamination. EPA has estimated that the percentage of U.S. wastewater pipe that will be in "poor," "very poor," or "life elapsed" (older than its predicted life span) condition will rise from 23 percent in 2000 to 45 percent in 2020 (U.S. EPA OW 2002b).

According to the ASCE 2017 infrastructure report card, the U.S. needs to invest $150 billion in its water and wastewater infrastructure systems but has only provided $45 billion, leaving a funding gap of $105 billion (ASCE 2017). While this is a hefty expense, the economic, environmental, and public health costs of delaying investment are far greater. ASCE believes that the economic impact of not investing in new water infrastructure would be substantial. In a do-nothing scenario, by 2020 $400 billion in U.S. GDP and 700,000 jobs would be endangered, as well as more than half a trillion dollars in personal income (EDRG and Downstream Strategies 2013).

Governance Issues and Institutional Divisions

In many cities and counties there are separate utilities for water supply, wastewater, and stormwater, each with their own elected or appointed board members or executive leadership. For example, in California, Bay Area water systems are managed by a complex network of special districts, city and county agencies, and private water companies. Most water suppliers provide water service directly to households and businesses and are referred to as retail water utilities. A handful of water suppliers in the region, such as the Contra Costa Water District and Sonoma County Water Agency, sell water wholesale to retail water utilities. Some utilities provide both retail and wholesale service, such as the San Francisco Public Utilities Commission, which sells water directly to households and businesses in the city and county of San Francisco and also sells water wholesale to 26 agencies in Alameda, Santa Clara, and San Mateo counties (Cooley et al. 2016).

If water utilities are located within the local city or county, the respective divisions may operate quite separately from each other and from planning functions. In addition, planning terminologies, time horizons (planners use 20-year horizons, while water infrastructure engineers look at 50 years and more), and regulations differ. All of these factors result in "siloing" of water functions and interfere with an integrated approach to water and land-use planning.

Institutional divisions make it difficult to address problems that cross jurisdictional boundaries, such as watershed pollution and water supply from distant watershed sources and groundwater aquifers. Separation of water utilities' missions and operations from planning functions also makes it difficult to integrate green on-site and distributed infrastructure (i.e., "district") solutions.

ADDITIONAL IMPACTS OF THE CHANGING CONTEXT FOR WATER

The combination of climate change and urban population growth, coupled with legacy water system problems and long-term water management challenges, has wide-ranging impacts on environmental, economic, and social issues. Decisions about where to direct diminishing water resources can raise ecological and environmental issues, and the impacts of water on economic growth and environmental justice are becoming increasingly clear.

Water for Ecological Needs

Human overuse of scarce water supplies and water pollution threaten regional biodiversity and the ecosystem services provided by plants and wildlife. New regional patterns of changing surface water levels also caused by climate change can result in lower water levels in major inland lakes and streams. This can influence the migration and dispersal of both aquatic and terrestrial wildlife, and the dispersal and germination success of plants. Drying landscapes alter the capacity of animals and plants to disperse to new locations where conditions are more suitable for them. Coastal areas that flood incrementally or temporarily may erode protective caps on toxic disposal sites and landfills, resulting in the release of toxins into the aquatic environment that will affect plants and wildlife unless they are prevented by careful planning and redesign (Cesanek and Wordlaw 2015).

Legacy systems have tried to control stormwater runoff by confining flows to channels, basins, and stormwater drains under streets. Changes in land cover caused by development result in hydromodification: changes in a site's natural runoff and transport characteristics. Impervious surfaces, compacted soils, deforestation, and topographic modifications alter the distribution, volume, and flow of water across a site and the speed at which it drains to water bodies. These changes impact the water balance on-site. Less water infiltrates, meaning less is available for groundwater recharge and subsurface flows that contribute to the base flows of receiving streams.

In addition, increased volumes of overland flow cause erosion and sedimentation in receiving streams and transports pollutants that have collected on impervious surfaces in urban areas into waterways (LIDC 2007). As described elsewhere in this report, agriculture uses water and returns it to streams and lakes with the potential addition of nutrients that cause eutrophication. Hydroelectricity plants are a major user of water for cooling, and roughly 75 percent of all industrial water withdrawals are used for energy production and result in cooling water discharges. Many plants recycle the water but return it to streams at higher temperatures, which can negatively impact fish, ecological systems, and other wildlife (Mekonnen and Hoekstra 2012). The battles over how much water can be taken out of the system for consumptive use and how much water needs to remain for aquatic health have raged for several decades, and many states are establishing minimum ecological flow requirements (USGS 2013).

Negative Impacts on Economic Growth

Inefficiencies and failures in the functioning of U.S. water systems—in terms of the quality and quantity of our water supply, water and wastewater treatment processes, and management of drought and flooding—can diminish the attractiveness of American cities, suburbs, and rural areas for investment by the private sector. When cities lose up to 50 percent of treated drinking water to leaks, are under frequent "boil orders" because of pipe breaks, or experience overflow of wastewater into water supply bodies or service interruptions, they do not inspire the confidence of investors choosing where to locate jobs and housing (Cesanek and Wordlaw 2015).

In addition, flooding can have extremely costly impacts on local economies. Urban flooding is often a repetitive occurrence, and costs to individual property owners can be in the hundreds of thousands of dollars from damages to structures, lost valuables, lost wages and other income, and other expenses. Such flood damage can also cause stress and ill health in impacted populations (Festing 2015). Catastrophic flood events have caused excessive economic losses in the U.S. The 1993 Mississippi River flood, the costliest of the 20th century, caused $20 billion in economic losses. The 2011 Mississippi River flood cost an estimated $2 billion across six states from such wide-ranging effects as damage and destruction of homes and businesses; farmland, crop, and fisheries damage; delays of river barge traffic and closure of riverboat casinos; and spikes in gas and food prices (Amadeo 2016). Such economic losses affect the nation's economy and redirect scarce federal financial and staff resources.

Affordability and Equity of Water Services

Water is a universal need, but its cost can create equity challenges, especially for vulnerable low-income populations. The question of affordability can be considered from three different perspectives: the utility's cost of providing water services, the community's ability to pay for increases in water service, and the affordability of water services for individual households, especially economically challenged households.

Investments in water and wastewater systems mandated by federal requirements can result in significant investments by communities in water treatment and distribution. These system improvements and investments can result in higher water and sewerage fees for consumers. In response, the EPA established affordability criteria to give communities flexibility in meeting regulations. These criteria indicate a financial burden may occur if costs are in excess of 2 percent of the median income per household for sewer services and in excess of 2.5 percent for water supply. However, several reputable organizations have criticized these definitions, saying that regulatory relief is not provided in many communities where it is needed (Stratus Consulting 2013b). In 2016, congressional legislation (Senate Bill 2848) was introduced to require a National Academy study on the issue of water affordability benchmarks to be followed by EPA action (U.S. Congress 2016).

Legacy cities—older cities with declining populations and diminished economic conditions—have challenges related to both the affordability and reliability of their water utility systems. Many cities are experiencing net population declines (although this 50-year trend seems to be reversing in many locations) and declining tax bases, threatening their abilities to cover the cost of water services. Contamination of drinking water supplies by lead pipes, which affects 7 percent of the U.S. population, and efforts to reduce combined system overflows are expensive to address. These challenges particularly affect cities in the Midwest and Northeast (Cornwell, Brown, and Via 2016).

As noted in Chapter 3, 97 percent of public water systems are considered "small systems" that serve 10,000 or fewer people (U.S. EPA 2016e). Small systems are faced with the difficulties of small customer bases and lack of sufficient revenues needed to hire experienced managers and maintain and upgrade facilities (NRC 1997). In 2006 EPA officials indicated that these problems had not changed substantially in the previous 20 years (U.S. EPA OIG 2006). In 2016, 2,252 of these small systems were found to be in serious violation of the federal drinking water standards (Meador 2016). EPA officials have promoted consolidation to both improve water quality and lower costs to make water more affordable for small-system users (U.S. EPA OW 2007).

Though average water and sewer costs together account for less than 0.8 percent of total household expenditures—by comparison, electricity accounts for 2.4 percent and telecommunications for 2.1 percent—these costs are rising rapidly (Beecher 2016). From 2006 to 2014 the average annual water bill increased by 5.5 percent and the average sewer bill by 6.1 percent, compared to the average annual increase in the Consumer Price Index (CPI) of 2.4 percent (AWWA and RFC 2017). Figure 4.11 (p. 62) illustrates the rapid increase in water utility service costs (including water supply and sanitary sewer services) as compared to other household costs in the U.S.

Another study found that average monthly water rates in 30 major cities from 2014 to 2015 rose 6 percent for a family of four using 100 gallons per person per day (including supply, wastewater/sanitary sewage, and where available, stormwater) compared to a 1.8 percent CPI increase over the same time period. In these same cities, combined water prices had risen 41 percent since 2010; see Figure 4.12 (p. 63) (Walton 2015). Atlanta and Seattle have the largest combined charges, at more than $300 per month, primarily because of the need to comply with federal court orders (consent decrees) to pay for infrastructure that prevents sewage from going into receiving water bodies used for water supply.

The rate of increase for sewer services has been higher than for water supply services in these cities, and likely in many other cities, due to the state of disrepair of the water infrastructure and the impact of EPA enforcement of sewer overflows. In addition, stormwater services are increasingly paid for by their own category of fees rather than property tax funding, thereby transferring costs from the tax bill to the water bill through an additional charge.

Further increases in water and sewer bills that are anticipated over the coming years raise concerns about the ability of low- and moderate-income households to pay for water. Using the EPA affordability benchmark of 4.5 percent of household income for a combined bill for water and sewers, a recent study found that 11 percent—or approximately 14 million households in the U.S.—were being charged more than that amount. If rates increase by 6 percent, the number would rise to about 15 percent of U.S. households, or 17 million people. With a 41 percent increase, which many analysts think is probable by 2020, almost 36 percent of U.S. households, or 41 million people, would be spending more than they can afford for essential water services (Mack and Wrase 2017).

The costs of water services are clearly rising—due to rising costs of labor and energy, investments in more advanced treatment and monitoring systems, and deferred maintenance costs—but the water industry generally believes that water services are currently undervalued when the importance of water is fully considered in terms of maintaining human health, the economy, agriculture, and other factors. While the cost of water is expected to increase, as a percentage of household income the cost is relatively small and will continue to be so. However, families and individuals on fixed incomes and low- and moderate-income populations can have significant difficulty meeting even small increases in cost-of-water services. For this reason, the water services industry appears to be moving in the direction of creating protective or limiting mechanisms for increases in water cost, subsidies for individuals with financial hardship, and blocks on "water shutoff" for such individuals when accounts are in arrears.

Water Injustice

Water challenges have a disproportionate effect upon many communities, particularly those where minorities and low-income households predominate. These impacts can include threats to safe quality of water supplies, high costs of water services, and negative impacts on water-related cultural and economic activities. The examples below are instructive.

The city of Flint, Michigan, received widespread attention in 2015 when lead contamination was discovered in the local water delivery system. The Flint community is predominantly African American (57 percent) and more than 40 percent of residents live and work at or below the poverty line (Flint Water Advisory Task Force 2016, 2). To save money, in 2013 state-appointed officials decided to stop using water from the Detroit drinking water system, which contained

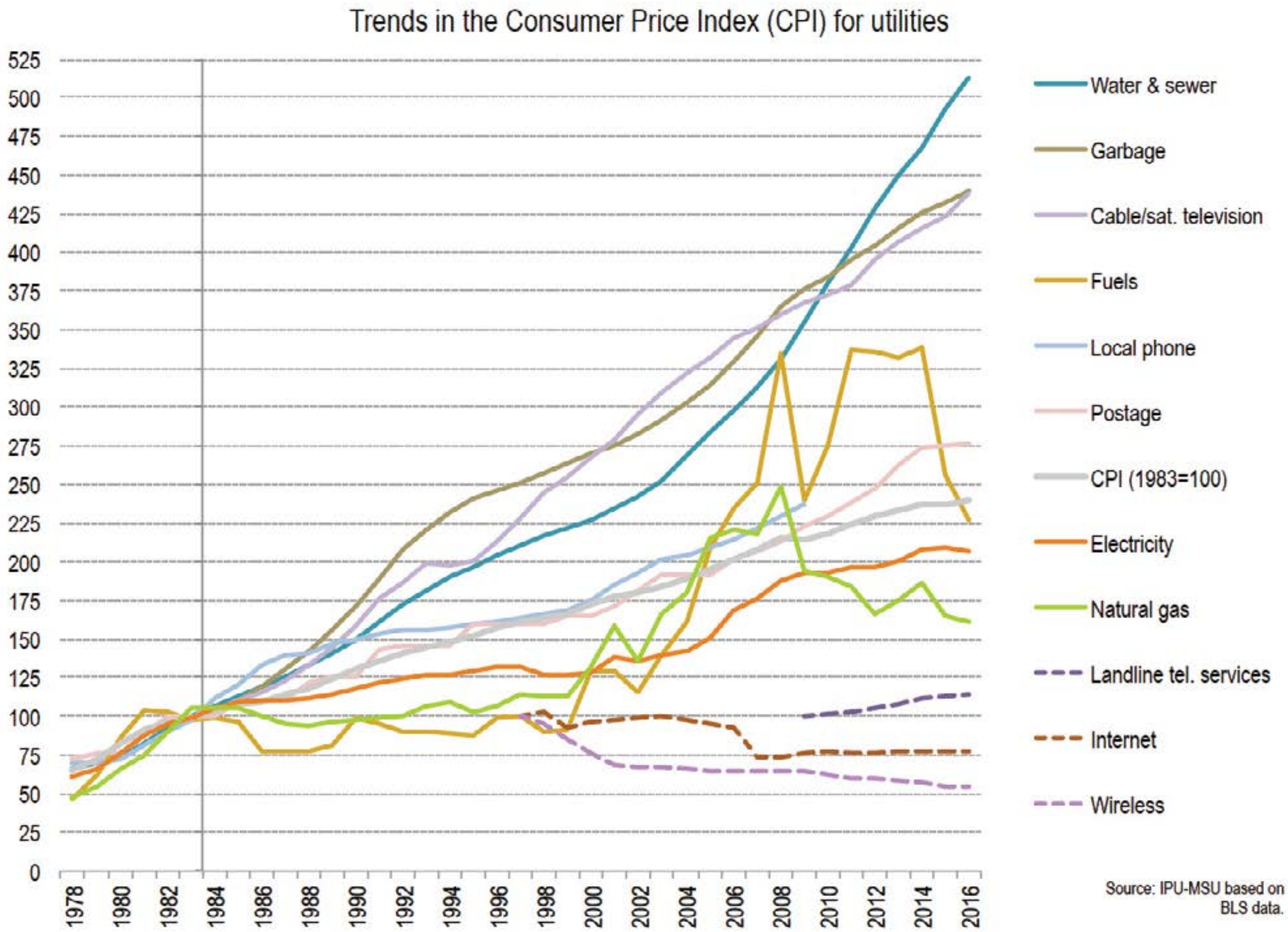


Figure 4.11. Water utility rates are outpacing costs of other household staples and the CPI (Beecher 2016)

corrosion inhibitors to reduce the amount of lead released into the water from pipes. As an alternative water source they used the Flint River. They did not employ these corrosion inhibitors, so lead began to leach into Flint's drinking water as it travelled from the pipe in the street to the house. Some of the water in the Flint River was also contaminated by E. coli bacteria, triggering a violation of the EPA's drinking water standard for coliform bacteria and a local boil-water advisory (Flint Water Advisory Task Force 2016).

To address this problem, Flint officials overcompensated with chlorine disinfection, triggering a violation of the health standard for a class of cancer-causing chemicals (trihalomethanes) that are created when chlorine reacts with organic matter in water (AWWA 2016). As a last straw, in August 2014, the Genesee County Health Department, where Flint is located, told Flint Public Works officials that instances of legionellosis (also known as Legionnaires' disease) had been increasing since April 2014 (Olson 2016).

In California's San Joaquin Valley, studies have documented that unsafe drinking water, polluted with nitrates and other contaminants such as arsenic, is disproportionately associated with lower-income communities of color. This problem was also found in the *colonias* on the U.S.–Mexico border, minority communities in certain Southern rural areas, and on some Native American lands (Balazs and Ray 2014). Toxic waste disposal sites are disproportionately located near minority neighborhoods, with the potential to leach into water supplies (Bullard et al. 2007).

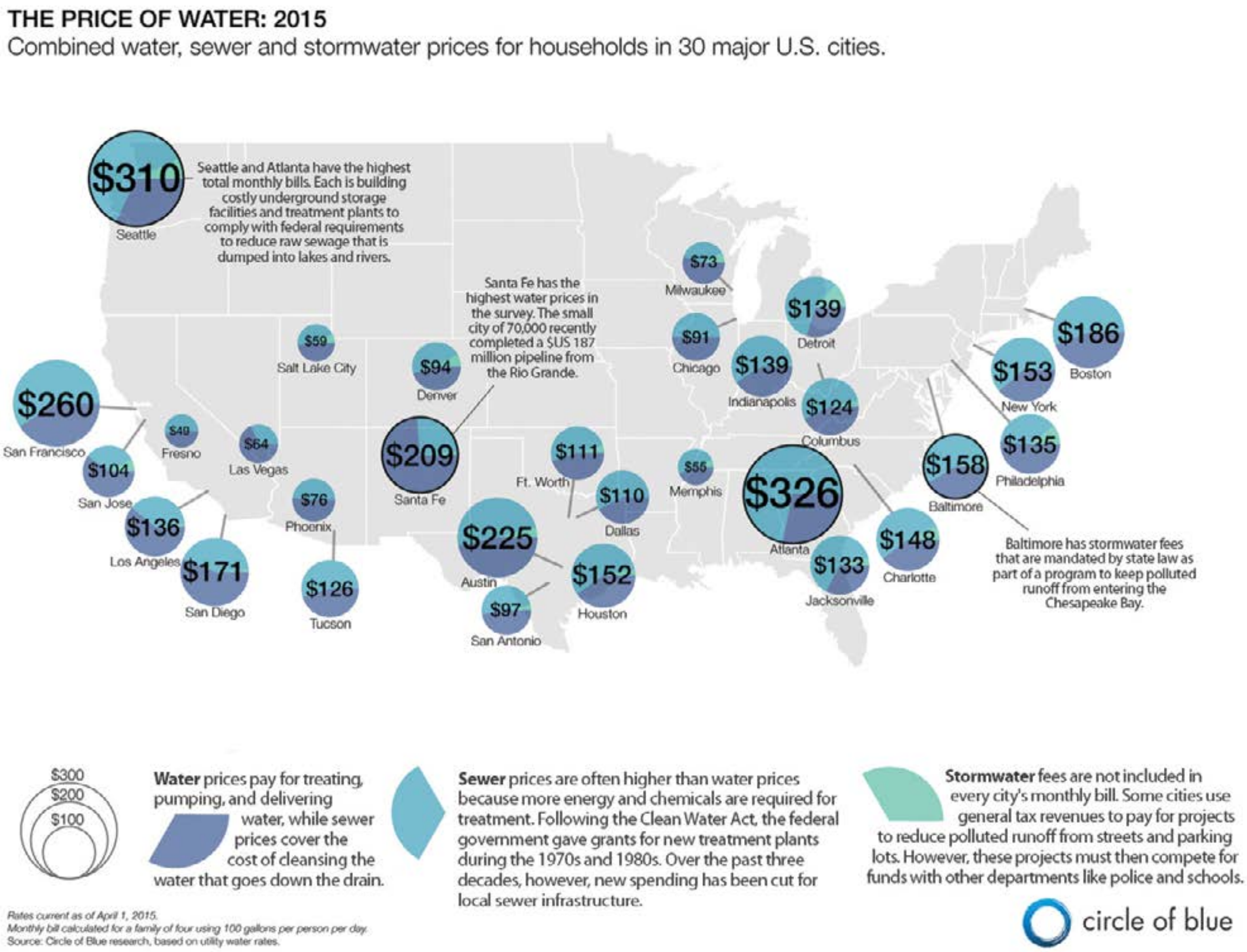


Figure 4.12. Monthly water costs per household for all three water service systems in major U.S. cities (Kaye LaFond/Circle of Blue)

In California, the water supply for low-income farm workers has also been negatively impacted by the drought of 2011–2015. In the rural agricultural Central Valley, 900,000 persons are served by groundwater wells, and in some areas these wells have run dry. In East Portersville, a community of 7,500 residents in Tulare County, private wells have been running dry since the summer of 2014 (Cooley et al. 2014). Five hundred families had to rely upon bottled water or emergency water tanks installed outside their homes. In 2016, a state-funded project connected all 1,800 homes in East Portersville to the water system of a nearby town (Klein 2016).

Flooding also presents special risks to lower-income communities and communities in more vulnerable locations, who may be less likely to receive news and heed warnings from mainstream weather services. Some residents may not have fully understood the implications of a flood designation when selecting their housing location. Historically, lower-cost land for housing was available in floodplains in cities, as well as in rural areas. Today's flood zones typically contain more low-income residents with less education and less access to news than the surrounding upland areas. Floodplains may also house more recent immigrants with limited English language skills. These are the residents and neighborhoods that may decide to shelter in place against the advice of municipal authorities, either because they do not receive or understand the instructions to evacuate, or because they simply do not have the financial resources to temporarily relocate. Risks are weighed differently in these communities, where taking the precaution of evacuating from flood events carries a significant practical price (Cesanek and Wordlaw 2015).

Access to clean, safe, and affordable water is a fundamental human right, and is essential for a healthy population, environment, and economy. Under the AICP Code of Ethics, planners have the responsibility to:

> . . . seek social justice by working to expand choice and opportunity for all persons, recognizing a special responsibility to plan for the needs of the disadvantaged. (APA 2016a)

Justice also requires that the risks to health and public safety from water, or lack thereof, be equal across income levels and other measures of human diversity, so that all citizens share equally in the benefits, as well as the risks and efforts, of maintaining sustainable water systems.

CONCLUSION

This chapter highlights the need for planners to be aware of the impacts of climate change, population growth, and urbanization on water management. Along with challenges posed by legacy water systems, especially those affected by deferred maintenance, these factors are worsening the existing challenges of water scarcity and pollution in certain regions and causing adverse effects upon ecosystems. They have also led to negative water equity impacts on vulnerable communities and populations.

Planners should be aware of these larger impacts to inform their local planning work that relates to water management, and to better plan for future growth and population trends. Leaders in the water-utility sector predict that the significant investments required to protect water systems against the effects of climate change, meet the demands of population growth, and address pollution will necessitate a new, more sustainable, water service delivery paradigm (Sedlak 2014). The next chapter provides two frameworks for planners to better integrate water into planning and sustainability efforts and offers examples of projects and programs that represent recommended practices for water planning and management.

CHAPTER 5

PLANNING FOR SUSTAINABLE WATER: RECOMMENDED PRACTICES

Our built environment is in the midst of a transformation toward more sustainable land use. Industrial-era and postwar cities and suburbs are evolving to a future where better understanding of the natural environment, infrastructure systems, and smart city technologies result in built environments that are more sustainable, resilient, and healthful. Water is a critical resource in a more sustainable future. Planners have increasingly important roles in transforming water systems and resources to advance sustainability and resiliency goals.

Impacts to water resources from existing development and future growth can be reduced and managed in many innovative ways, such as allowing multiple uses and reuse of water and better protecting and restoring water environments. Planning initiatives and practices are beginning to reflect the need to address increasingly severe and unpredictable water management issues, and they are taking on increasingly complex challenges. Progress is being made both at the local level, where individual initiatives are emerging in forward-thinking communities working in coordination with water utilities, as well as at the regional and national scales, where new information systems, alternatives analysis tools, and regulatory approaches are being created.

This chapter seeks to compile an array of recommended practices that are being implemented throughout the country to improve water management and to better achieve One Water objectives. It presents examples of improved (or "best") practices and case study examples for each of the three water service sectors—water supply, wastewater, and stormwater—as well as for integrated One Water management.

First, however, this chapter discusses two strategic planning frameworks that can improve water planning and management by helping planners integrate water issues into planning work: APA's "five strategic points of intervention" and APA's Sustaining Places initiative. These strategic frameworks represent the "how": the roles and functions that planners play in their professional discipline. The recommended practices are the "what": the actions that planners might pursue.

Both of these strategic planning frameworks represent important opportunities for engagement on water issues. The five strategic points of intervention describe the traditional roles of planners, and it is useful to understand how these functions can support better water planning. The Sustaining Places initiative, on the other hand, represents a new paradigm for integrated sustainability that enlarges the traditionally understood roles of planners. Through this initiative, APA has created the Comprehensive Plan Standards for Sustaining Places—a set of principles, processes, and attributes to guide the preparation of comprehensive plans—that can help planners better manage water resources.

WATER AND THE FIVE STRATEGIC POINTS OF INTERVENTION

Planners engage in a great many activities, but those that are central to their professional functions and positions and that hold the most promise for making a difference in most planners' basic work tasks can be boiled down to five key areas: visioning; plan making; standards, policies, and incentives; development work; and public investments (Klein 2011). This characterization represents a traditional understanding of planners' roles and the activities that comprise planning practice. When considering how planners can improve water resource planning and management by applying improved planning practices, it is useful to consider these "strategic points of intervention."

This section describes each of the five areas and provides a brief overview of how planners can integrate water issues into each area. While the five strategic points of intervention represent planners' primary realm, to fully integrate water considerations into each area planners often need to work with other water professionals. Thus, this section concludes with a discussion of points of intersection (i.e., points of coordinated activity on water issues) between planning and other water professions and entities.

Long-Range Community Visioning and Goal Setting

Visioning is often the first step in the community planning process. It allows communities to come to agreement on a desired future. When planners engage residents, business people, and interest groups in long-range visioning exercises, they help the community determine the values that should undergird the plans, implementation tools, and public investments it undertakes.

For water, it is essential to understand basic concepts such as watershed hydrology, condition of the water resource, and building mechanisms so as to integrate water resource issues (too little, too much, or poor quality) into long-range community plans. This can be advanced by planners encouraging community residents to consider how water fits into their vision of an ideal community (e.g., resource protection and stormwater and flood management), and helping residents to understand the importance of avoiding artificial reconfiguration of water environments in creating new livable places. Planners need to create visions that protect and integrate water into urban space, rather than the traditional approach of piping and hiding this natural resource.

Plan Making

Planners help towns, cities, counties, and regions prepare all types of plans: jurisdiction-wide comprehensive plans (sometimes known as general or master plans); subarea plans (such as neighborhood, downtown, and corridor plans); and functional plans (such as transit, highway, sewer, water, housing, public health, economic development, and open space plans).

For water, specific goals and processes can be incorporated into comprehensive plans and functional plans that lead to sustainable capital investments for more sustainable resource management. Such concepts might include protection of source water watersheds, identification of sewered and septic service locations where growth is encouraged or discouraged, and stream buffers and green infrastructure to improve water quality.

The community's general or comprehensive plan should address sustainable water management. This could be a standalone element in the plan where all aspects of the hydrologic cycle are assessed for that location and policies are adopted for water supply, conservation, groundwater and source watershed protection, wastewater, drainage and runoff controls, and water quality. Water can also be addressed as part of the environmental or natural resources elements of the plan. It is important to note that while many comprehensive plans do include some consideration of flooding and water resource protection, processes and practices that achieve One Water objectives are relatively new, and many approaches are either being developed or tested.

Planners should also be aware that many local, county, and state governments, as well as private utilities, create water supply and wastewater master plans to guide capital budgeting and anticipate future facility requirements. In creating or updating the community's comprehensive plan, planners should identify how to improve the synergy of a utility master plan with the comprehensive plan, and work to resolve resource conflicts or varying perspectives regarding future growth and water resource availability. In addition, there may be other resource management plans that should be considered for synthesis with the comprehensive plan, such as local flood management plans and climate change adaptation plans.

Standards, Policies, and Incentives

Planners draft standards, policies, and incentives that have an enormous influence on what, where, and how things get built and how land and buildings get preserved. Zoning, subdivision regulations, design guidelines, landscaping and street tree standards, signage regulations, street and sidewalk standards, and tax policies are but a few examples of the "carrots and sticks" that can be used effectively to build places of lasting resource value.

Zoning ordinances and subdivision regulations can be used to implement comprehensive plan policies and goals that relate to water resource management. Land-use regulations and design guidelines can be used to advance many water-related goals, from protecting water sources to requiring subdivision and site design that minimizes stormwater runoff and water pollution. In addition, the density and layout of subdivisions and new development can significantly affect the sustainable performance of new growth; ordinances can lower development density in aquifer recharge areas and reduce water leakage and pressure loss by reducing the separation of residential units. A detailed discussion is beyond the scope of this report, but see, for example, Daniels 2014.

Performance standards for water use and wastewater disposal are increasingly more common, especially in response to drought conditions in the western states. In addition, new innovative water management approaches include mechanisms and incentives to promote green stormwater infrastructure implementation and wastewater and stormwater reuse, as well as natural stormwater management that improves the quality of receiving rivers and streams. Planners should be aware of such innovations and assess whether and how they might apply to their jurisdictions.

Development Work

Planners often have opportunities to influence the outcomes of development or redevelopment projects. They can serve as leading team members on public-private partnerships that result in new development or redevelopment, and they take a leading role in reviewing and making recommendations on a wide variety of private development plans.

Providing input on more sustainable designs for new development, especially where there are water resource constraints, and creating more holistic water designs, rather than assuming the water and sewer utility will take care of whatever is needed, is essential early in the planning process. The plan review process has many opportunities to share information about more sustainable water management with project developers and ensure that performance standards and resource limits are respected. Approaches include non-impervious cover requirements, on-site stormwater management, stream buffers, wetland protection and enhancement, and on-site or district wastewater reuse.

Public Investments

Towns, cities, and counties undertake major investments in infrastructure and community facilities that support private development and quality of life in their communities. In many ways, the capital improvements program is the most important tool for planners but one that is often overlooked.

Planners' influence over the location and design of sewer and water facilities and other publicly funded investments can be substantial. Water/wastewater utility extension has widely been regarded as one of the major contributors to sprawl, but equally important issues, such as allowing development with low sustainability design to locate within aquifer recharge areas and to discharge stormwater to impaired streams, also worsens water resource management issues. With sufficient training in and understanding of One Water strategies, planners can better engage with developers, utilities, and resource agencies on critical water management issues.

Points of Intersection

It is important to note that the five traditionally understood points of planner intervention described above have not, in the past, typically included a very significant role in water resource planning and management, nor engagement with other water professionals. While there may be additional opportunities for strategic *intervention* as planners, opportunities for strategic *intersection* with other water professionals is emerging as an equally important planning function. For points of intervention, planners are typically the lead party. For points of intersection, planners need to collaborate on water management with a range of water professionals, because each of the many disciplines involved has much to contribute to sustainable water management.

This report calls for a new and more intensive level of engagement by planners in the water resource management process. The land development process tends to drive the need for water, wastewater, and stormwater management services. And the impacts of expanded demand for such utility services can have extensive impacts on the natural environment and the ability of water systems to retain their self-renewing and sustainable conditions.

When engaged in any of the five strategic points of intervention described above, planners should reach out to and collaborate with other professionals from water-related disciplines when opportunities arise. See Chapter 2 for additional discussion of opportunities for cross-sector collaborations to help planners better engage in water management issues within an integrated One Water paradigm. It was suggested, humorously but insightfully, at the APA National Planning Conference in 2015, that planners seeking to become more engaged in water management or who are increasing their involvement should schedule a "take a water utility manager to coffee" activity to open conversations about how land use, the water environment, and utility services connect. There are numerous avenues of cooperative action on water issues, many specific to local geographic settings, that have not yet been identified for formal interaction. Explore!

WATER IN THE CONTEXT OF SUSTAINING PLACES

While the traditionally understood role of planning and planners is well represented by the five strategic points of intervention, planning is shifting toward a new paradigm with a goal of overarching, integrated sustainability. This can be characterized by APA's Sustaining Places initiative, which provides a fresh lens to help planners better integrate water issues into their work.

APA launched its Sustaining Places initiative (www.planning.org/sustainingplaces) in 2010 to define the role of comprehensive plans in advancing the sustainability of human settlements. Over a four-year period, this initiative has created guidance for local governments and planning practitioners seeking to integrate sustainability into comprehensive plans, such that a comprehensive plan becomes a sustainability plan for the community. The Sustaining Places initiative refocuses planners on reducing the impact footprint of land development to help assure a sustainable environment for the long-term future. Resource exploitation, especially water resource exploitation, is not regarded as equitable, economically viable, or environmentally sound.

The APA Comprehensive Plan Standards for Sustaining Places presents six principles, two processes, and two attributes for plan-making standards. Each principle, process, and attribute is accompanied by multiple best practices, which are planning actions that support the implementation of the vision and goals of the plan. The standards provide a framework for planning for sustaining places. For more information, see *Sustaining Places: Best Practices for Comprehensive Plans*, PAS Report 578 (Godschalk and Rouse 2015).

This section explores how the standards can help advance more sustainable water management, and how planners might create additional opportunities for water management best practices. It defines each principle, process, and attribute; distills out those Sustaining Places best practices that are most relevant to water issues; and explains how these general best practices are applicable to water resource management. The Comprehensive Plan Standards for Sustaining Places do not include a specific section, element, or supplement that compiles all sustainable water actions in one document, but APA's Water Working Group has proposed a comprehensive planning framework for water resources to achieve that goal (see Appendix). Further work awaits funding support.

Sustaining Places Principles

1. ***Livable Built Environment***. *Ensure that all elements of the built environment, including land use, transportation, housing, energy, and infrastructure, work together to provide sustainable, green places for living, working, and recreation, with a high quality of life.*

Selected Best Practices:
1.4 Provide complete streets serving multiple functions, including water reuse and stormwater management.
1.10 Implement green building design and energy conservation.
1.11 Discourage development in hazard zones.

Complete streets policies should include provisions for green infrastructure, best stormwater practices, and efficient renewal of water and sewer pipes as they age, in addition to supporting "smart" city monitoring of water use characteristics, wastewater generation, and infrastructure performance. Land-use patterns, consideration of hazard zones, design standards, and energy conservation all relate to how patterns of density require varying amounts of energy to distribute water, collect wastewater, irrigate lawns and landscaping, and protect natural storm mitigation landscapes, such as wetlands.

2. ***Harmony with Nature***. *Ensure that the contributions of natural resources to human well-being are explicitly recognized and valued and that maintaining their health is a primary objective.*

Selected Best Practices:
2.1 Restore, connect, and protect natural habitats and sensitive lands.
2.2 Plan for the provision and protection of green infrastructure.
2.3 Encourage development that respects natural topography.
2.4 Enact policies to reduce carbon footprints.
2.6 Encourage climate change adaptation.
2.9 Encourage water conservation and plan for a lasting water supply.
2.10 Protect and manage streams, watersheds, and floodplains.

Perhaps more than any other Sustaining Places goal, practices that advance harmony with nature are usually consistent with water management best practices. Protecting watersheds and source waters, especially groundwater recharge, and maintaining natural surface water runoff quantity and quality helps advance sustainable water management. Planning interventions and actions can occur both from a conservation strategy (protecting natural resilience systems and aquatic resources) and from a development management and design innovation perspective (more sustainable urban design, mixed land use, and sprawl management) to reduce water demand and increase potential for wastewater reuse.

Treating and piping water in all three sectors—water supply, wastewater, and to a lesser degree stormwater—comprises a significant amount of the energy used for municipal operations, and therefore is responsible for a significant part of a city's carbon footprint. Improved water management can reduce the energy required for water and wastewater pumping and treatment. Where this energy was generated using carbon-based fuels (oil, gas, and coal), the carbon footprint of water utility actions is therefore reduced, improving sustainable performance.

3. ***Resilient Economy***. *Ensure that the community is prepared to deal with both positive and negative changes in its economic health and to initiate sustainable urban development and redevelopment strategies that foster green business growth and build reliance on local assets.*

Selected Best Practices:
3.1 Provide the physical capacity for economic growth.
3.2 Plan for a balanced land-use mix for fiscal sustainability.
3.4 Promote green businesses and jobs.
3.6 Provide and maintain infrastructure capacity in line with growth or decline demands.

Economic growth requires clean, adequate, and affordable water supplies; efficient and sustainable wastewater management systems; and healthy environments and ecosystems. Reliability is key to economic growth, and well-planned, well-managed water assets provide that reliability.

The direct relationship between water and growth affirms and expands the role of planners in ensuring that clean and reliable water is available to adequately support growth. While there are only a few water planning actions that directly stimulate economic growth, nearly every action that advances sustainable water management indirectly supports economic growth. Infrastructure reliability is achieved by planning for long-term resource availability, effective asset management, and protection of the value of natural environmental capital. A wide range of indirect economic benefits often accrue from application of resiliency strategies, including reduced flood impacts, improved recreational facilities, improved health, and increased property valuation.

4. ***Interwoven Equity***. *Ensure fairness and equity in providing for the housing, services, health, safety, and livelihood needs of all citizens and groups.*

Selected Best Practices:
4.3 Plan for the physical, environmental, and economic improvement of at-risk, distressed, and disadvantaged neighborhoods.
4.4 Plan for improved health and safety for at-risk populations.
4.6 Upgrade infrastructure and facilities in older and substandard areas.
4.8 Protect vulnerable populations from natural hazards.

The issue of equity arises in water resource management in at least two ways. First, safe and clean water must be available to all residents, as a basic principle of access to a life-sustaining resource; and second, the cost of water must be affordable to all users, with ability to pay considered in water resource services (water, wastewater, and stormwater utility services). The equitable distribution of cost, especially with respect to economically disadvantaged communities, needs to be carefully considered when assessing investments in new capital water infrastructure facilities.

5. ***Healthy Community***. *Ensure that public health needs are recognized and addressed through provisions for healthy foods, physical activity, access to recreation, health care, environmental justice, and safe neighborhoods.*

Selected Best Practices:
5.1 Reduce exposure to toxins and pollutants in the natural and built environments.
5.5 Provide accessible parks, recreation facilities, greenways, and open space near all neighborhoods.

Conserving and protecting natural environmental capital (e.g., wetlands, source watersheds, ecosystems, stream buffers) integral to a healthy water environment also creates opportunities for healthy communities. Not only does natural environmental capital help keep water clean for drinking supplies and agriculture, it also provides opportunities for recreation, and several studies have shown that green infrastructure contributes to safe neighborhoods. Further, the plants and trees that comprise green stormwater infrastructure can reduce heat island impacts on cities and sequester carbon emissions.

6. ***Responsible Regionalism***. *Ensure that all local proposals account for, connect with, and support the plans of adjacent jurisdictions and the surrounding region.*

Selected Best Practices:
6.3 Coordinate local open space plans with regional green infrastructure plans.
6.8 Include regional development visions and plans in local planning scenarios.
6.9 Encourage consistency between local capital improvement programs and regional infrastructure priorities.

Watershed-level water resource planning and management is a basic component of responsible regionalism. Because water supplies from surface waters and groundwater systems are distributed topographically and not based on political boundaries, water resources need to be equitably shared and managed across local jurisdictional boundaries.

The historic legal rights for water practices in the western U.S. have been based on prior appropriation, which means that the first one to use the water owns most of the rights to the water. This is frequently regarded as antagonistic to responsible regionalism and inconsistent with allowing equitable access to a fundamental resource. Similarly, water rights on the East Coast are based on riparian law, and watersheds may cross the boundaries of many local governments, transcending local land-use authority. (See Chapter 6 for further discussion of water rights and water markets.) Local water and wastewater utility service areas are often misaligned with the source or receiving waters relied upon by the utility; regionalism can help to ameliorate the conflicts that occur in such situations.

Densifying land use typically facilitates more sustainable energy use, but can concentrate water demand to a level greater than can be supported by local sources. Increased residential density also concentrates the amounts of wastewater discharged by treatment facilities into rivers, bays, and oceans, magnifying the environmental impacts of the discharge. Increased density also increases the flow of stormwater runoff generated from greater expanses of impervious surfaces, causing erosion and water quality impacts. For these reasons, it is critically important that water management for cities be coupled to regional management and sharing of water resources.

Sustaining Places Practices

7. ***Authentic Participation***. *Ensure that the planning process actively involves all segments of the community in analyzing issues, generating visions, developing plans, and monitoring outcomes.*

Selected Best Practices:
7.1 Engage stakeholders at all stages of the planning process.
7.2 Seek diverse participation in the planning process.
7.4 Develop alternative scenarios of the future.

Authentic social participation and engagement in planning processes that affect water resources, including the capital water infrastructure planning process (which often occurs outside of or is only loosely coupled to the comprehensive planning process), is vital when evaluating alternative future investments, thereby increasing the potential for more sustainable designs and investments.

Alternative local and regional visions of the future, including land-use plans and the different degrees to which growth is facilitated in plan alternatives, need to consider the implications of each alternative on a region's water resources. Creating and evaluating alternative future growth scenarios allow stakeholders to better explore and understand the impact of land use and zoning on water demand, wastewater generation, and the effects of growth on the water resources needed to support such growth. Greater participation by the community is also valuable to help facilitate a more equitable cost distribution for water investments needed to support sustainable growth, and to allow a wider array of values and perspectives to be balanced.

8. ***Accountable Implementation***. *Ensure that responsibilities for carrying out the plan are clearly stated, along with metrics for evaluating progress in achieving desired outcomes.*

Selected Best Practices:
8.4 Establish interagency and organizational cooperation.
8.5 Identify funding sources for plan implementation.
8.6 Establish implementation indicators, benchmarks, and targets.

Accountable implementation of sustainable water resource investments and management strategies requires a strongly interdisciplinary and coordinated approach, involving participants from many disciplines and levels of government, as well as key stakeholders.

Water resource planning and management functions are often the responsibility of the local utility or the state or regional supply or resource management entity. Utilities and state agencies often work in crisis-response mode, and typically need to act with speed to be responsive to public pressure (for actions such as establishing drought restrictions or addressing supply contamination). Further, new water demands and wastewater and stormwater generation needs arise because of the land development process, and land development occurs much more quickly than new supply development or construction of treatment facilities. This crisis-response pattern of action reduces the potential for accountable implementation, and often does not allow for meaningful stakeholder engagement.

The lack of measured decision making often means that natural environmental capital and equity and resource constraint issues are not adequately examined, nor is the public exposed to the full range of investment trade-offs. Because public and stakeholder engagement can slow the implementation of operational changes or capital investment, the best approach to addressing potential crises effectively is for planners to anticipate the crises, work through scenario planning exercises to identify the most effective response actions, and identify (and implement) risk reduction strategies in advance, which allows for the full range of interdisciplinary participants and stakeholders to provide measured input. This helps to assure that balanced and sustainable decisions are reached, rather than turning to the most expedient crisis-response solutions.

Sustaining Places Attributes

9. ***Consistent Content***. *Ensure that the plan contains a consistent set of visions, goals, policies, objectives, and actions that are based on evidence about community conditions, major issues, and impacts.*

Selected Best Practices:
9.3 Develop a vision of the future.
9.7 Define actions to carry out the plan.

Accountable implementation and public engagement, discussed above, can help assure that water resource planning, investment, and management is consistent with the visions, goals, and policies set by the full range of stakeholders during the sustainable plan development process.

The overall vision statement should establish a clear vision for water investment and management in the urban environment. In addition, facilitating cross-institutional interaction during the water planning process, informed by all stakeholders, helps to avoid the myopia that can result from single-agency implementation and leads to more widely supported water management strategies.

10. ***Coordinated Characteristics***. *Ensure that the plan includes creative and innovative strategies and recommendations and coordinates them internally with each other, vertically with federal and state requirements, and horizontally with plans of adjacent jurisdictions.*

Selected Best Practices:
10.1 Be comprehensive in the plan's coverage.
10.2 Integrate the plan with other local plans and programs.
10.6 Coordinate with the plans of other jurisdictions and levels of government.

One of the goals of this PAS report is to help ensure that water resource planning, investment, and management actions are sufficiently coordinated and developed in concert with the community planning process. It is useful to identify water investment and management strategies and sustainable water practices that can be included within or referenced by the comprehensive plan and other local land management instruments (e.g., zoning, performance standards, etc.). And following the principles of accountable implementation will help to ensure coordination with the many jurisdictions and levels of government that touch on water planning and management.

The above summaries of both traditionally understood strategic planning functions and innovative paradigms for sustaining places outline many of the central roles of professional planners and relate those roles to key water management and investment issues. The purpose of this review of traditional and evolving planning roles is to help the reader understand how planning frameworks can serve to advance and support the sustainable water recommended practices that are considered in the following section.

RECOMMENDED PRACTICES

The remaining sections of this chapter compile an array of recommended ("best") water planning practices in each of the three water service sectors—water supply, wastewater, and stormwater—that are being implemented throughout the country to improve water management and better achieve One Water objectives. Brief project examples are provided for each sector that illustrate more integrated approaches to water management. The chapter concludes with several examples that illustrate One Water management practices.

The representative recommended water planning practices, organized by the water utility function they relate to (water supply, wastewater management, and stormwater management), can be implemented by planners (often in concert with other water professionals), and have been recognized as successfully helping to achieve more sustainable water management.

While many practices are summarized in the sections below, the examples included are illustrative and should not be considered a comprehensive inventory of planning approaches and practices. New approaches, alliances, interdisciplinary strategies, and roles are constantly evolving and being tested. Readers are encouraged to be creative in applying the experiences of others to their challenges. Creative adaptation, modification, and interdisciplinary approaches can make a world of difference in improving the potential usefulness of existing practices or in creating innovative new practices.

Water Supply Practices

There are four main roles for planners that relate to water supply. One is to coordinate with the local water supply provider to assure that the water utility water management plan and its capital improvement program reflect the vision of the local government, and that the utility's water facilities and investments are consistent with the local land-use plan. Planners should review the utility's water management plan and its capital budget to ensure that assumptions about future water demand, alternative water sources, and conservation measures are included, regardless of whether the utility is a public or private entity (Johnson and Loux 2004).

Another role is to be sure that the community's own long-range or comprehensive land-use plan is linked to adequate water quantity and quality and supports One Water management (see Chapter 2). A third role is to help ensure that local development regulations protect traditional water resources and appropriately allow for new water sources. A fourth is to ensure that when specific development proposals are made, there will be adequate water supply and site-specific infrastructure for the project, and that the project does not compromise the water environment (Johnson and Loux 2004). The following are some specific suggestions for planners.

Water and Land-Use Planning

Some states, including California and Arizona, have created strong incentives and programs to better link land development and water supply. Colorado, in particular, has been active in this area. The state has developed the Colorado Water Plan, which sets goals of integrating water-saving actions into land-use planning, and it offers trainings for local governments and water providers on incorporating land-use practices into water conservation plans (Colorado 2017).

City or county land-use planners can improve planning and water management by sharing data, plans, and information about their comprehensive plans and development proposals with water utilities, and the reverse is also true. The local general purpose government also has the responsibility for reviewing the applications of the water department or special district as it builds new water supply projects.

Projecting Water Demand. Industrial-era water supply systems were planned for maximum water use, using population projections and based on inexpensive water and energy (for pumping and treatment). Climate change, sustainability goals, and population growth are changing this approach. The planner, if working with the water utility, should encourage the use of an end-user-analysis approach, including exploring the relationship of land use to water demand.

Population projections have been most commonly used because the data is relatively easy to acquire and because of historical precedent. Total population estimates are multiplied by per capita water demands to arrive at projections. This method does not adequately provide for conservation and water reuse, however. Disaggregated and socioeconomic models use computer simulations to project population as well as jobs and housing growth and changes in consumption patterns and trends. They are more precise than population-based per capita projections, but are more challenging to create and can be more difficult for the public to understand; however, they are much more accurate. Incorporating land-use elements in demand projections shows planners and the public exactly what the impact of different land-use proposals or projects will be on the water supply (Loux, Leigland, and Elmer 2014).

Demand Management and Conservation. Demand management and conservation strategies (often called water use efficiency programs) should be related to, and referenced in, the comprehensive plan. California's population has more than doubled since 1960, but substantial efforts to reduce water use through pricing incentives and water-saving technology requirements, as well as recent drought-related conservation requirements, have dropped the state's estimated 2015 water use back near 1960 levels; see Figure 5.1 (Mount and Hanak 2016). San Francisco's population grew by 10 percent between 2005 and 2015 while at the same time per capita urban water use fell by 17 percent, thanks to the city's water conservation education programs and water-use efficiency ordinances (Nagappan 2016).

Planners can play influential roles in implementing conservation strategies by working with local utilities to develop and adopt development regulations or other incentives to promote conservation. These can include landscaping requirements, incentives for repair of leaking fixtures, and requirements for indoor and outdoor residential water conservation.

Development Regulations

Planners can use zoning and subdivision regulations to protect water supplies. Land-use regulations should implement the goals and objectives spelled out in a comprehensive plan, area plan, or a specific water plan. For example, a common goal is to protect public water supplies that rely on groundwater. One action to help achieve this goal would be to draft a wellhead area protection ordinance to safeguard aquifer recharge areas and groundwater supplies where relevant. A wellhead protection ordinance lists permitted land uses in a radius of up to several hundred feet around public ground-

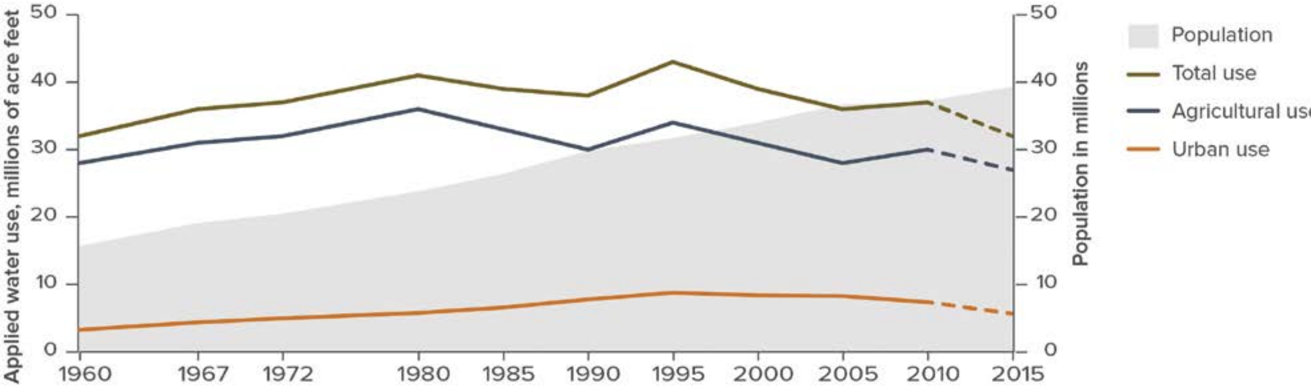


Figure 5.1. California's agricultural and urban water use rates compared to population growth (PPIC Water Policy Center)

water wells. No hazardous materials are allowed within the wellhead protection area and impervious surface lot coverage is tightly restricted to minimize polluted runoff that could seep into the groundwater (Daniels 2017).

A wellhead protection ordinance can also take the form of an overlay zone. An overlay zone sits on top of a base zone (usually residential or commercial) and adds additional restrictions that a developer or landowner must follow. Other types of overlay zones to protect water supplies include floodplain overlays to limit development that would contribute to flooding, as well as steep slope overlays to restrict development on steep slopes where runoff could cause severe soil erosion and increase the volume and speed of flood waters (Daniels 2017).

Communities can address water shortages by enacting "water offset" policies and regulations. These policies require new development to offset its water use by reducing water use elsewhere locally in order to be "water-neutral." Research on such water-neutral or "Net Blue" strategies are under way in several locations, including work by the Alliance for Water Efficiency (www.allianceforwaterefficiency.org/net-blue.aspx). Communities can change their building permit regulations to require offset of new water use through on-site water efficiency measures and the replacement of inefficient fixtures in preexisting facilities (Christiansen 2015).

Review of Development Projects

Planners have the responsibility to ensure that adequate water is available for developments such as a new subdivision or a large-scale change of use in a built-up jurisdiction. A helpful tool during the review process is a current list of planning applications and development proposals showing the status of each major project, its size and proposed land-use mix, location, required permits, and specific water needs. This can serve as a tracking system for land-use planners, water planners, other infrastructure providers, and the public (Johnson and Loux 2004).

Questions to ask during the review process include (NC DENR 1998):

- Are all sources fully on line and producing water? Are there dry year limitations with any sources, water rights or environmental limitations, or anticipated dry year cutbacks or delivery issues?
- What is the water balance for the area and have all potential water sources been investigated and accounted for?
- Are there potential water quality risks (especially for groundwater) that might affect the use or availability of a source?
- When planned water sources are included in a water supply assessment, are they fully funded and permitted?
- If agricultural water transfers are part of the water supply reliability estimate, have all legal and permit hurdles been cleared? What is the nature of the transfer and for how long is it available?
- Has the water supplier conducted a risk assessment of the water supply portfolio, and what "margin of safety" has the water supplier considered in each type of hydrologic year?
- Does the water supplier have a plan for a prolonged drought, and what type of cutbacks or auxiliary sources (such as agreements with neighboring districts) are planned for?
- Are all of the local facilities in place, or at least financed, to treat, store, distribute, and deliver water? What share is being financed by the development community and what share is being financed by existing and future rate payers?

Collecting information about water resource availability, competition for use of water, and planning for water demand management to discern where demand might exceed supply is essential when considering approving new development. Continuing past patterns of sprawl development, without reference to the carrying capacity and the resource variability in the geographic setting, increases the likelihood of new conflicts over water use.

Land Conservation for Water Quality Protection

State and local governments are increasingly taking a regional approach to protecting water supplies and managing stormwater runoff through the preservation of key resource lands. Several large U.S. cities rely on distant water sources to meet their water demands. The development of rural lands close to public reservoirs not only increases competition for water supplies with these far-off cities, but also introduces serious potential pollution threats. Pollution may come from several sources, such as malfunctioning on-site septic systems, farm and lawn fertilizers, pesticides, manure from farming operations, and oil- and salt-laden runoff from roads. Land conservation can be an important tool to help protect the quality of drinking water sources. Protection of natural landscapes also ensures the preservation of green infrastructure and its benefits in stormwater management and other ecological services. See the sidebar for a discussion of how land preservation has been used to protect drinking water supplies.

Examples of Interdisciplinary Water Supply Innovation

Major drought conditions emerged in California and the West Coast region from 2012 to 2017, and water resource conflicts reemerged in the Colorado River Basin during that same period. For many years, but especially during recent droughts in 2007, 2014, and 2016, Georgia, Alabama, and Florida have been battling over the future allocation of water in two major river basins—the Alabama-Coosa-Tallapoosa and the Apalachicola-Chattahoochee-Flint basins—that cross their borders (Southern Environmental Law Center 2015). These are but three of many examples of inadequate water supply in the U.S. affecting regions, states, and local governments.

The lack of sufficient and dependable supply, exacerbated during drought conditions, has increased awareness of the value and need for more integrated and interdisciplinary water supply management. Such interdisciplinary interactions can bring together planners with hydrogeologists, civil and environmental engineers, landscape architects, ecosystem experts, hydraulic modelers, lawyers and regulatory experts, elected officials, economists, and professionals from many water-related professions seeking to bring expertise in support of more sustainable water management. Some examples follow.

California Water Action Plan, California Department of Water Resources. The Regional Water Management Planning Act (SB 1672) was passed by the state legislature in 2002. Bond acts approved by California voters have provided $1.5 billion to support and advance a more integrated approach to water management. Cities, counties, water districts, community groups, and others across the state have worked together to organize and establish regional water management groups. The fundamental principle is that regional water managers are best suited and best positioned to manage water resources to meet regional needs.

These self-identified regions integrate and implement water management solutions, which is a foundation of Action 2 in the California Water Action Plan, developed by the California Natural Resources Agency, the California Department of Food and Agriculture, and the California Environmental Protection Agency (California Natural Resources Agency et al. 2016). The majority of California's water resource management investments are made at the local and regional levels. The California Water Action Plan seeks to complement and leverage local water management efforts. Successful implementation of the plan involves increased collaboration between state, federal, and local governments; regional agencies; tribal governments; and the public and the private sectors.

The improved water management actions proposed in the plan are as follows: (1) Make conservation a California way of life; (2) Increase regional self-reliance and integrated water management across all levels of government; (3) Achieve the coequal goals for the Delta; (4) Protect and restore important ecosystems; (5) Manage and prepare for dry periods; (6) Expand water storage capacity and improve groundwater management; (7) Provide safe water for all communities; (8) Increase flood protection; (9) Increase operational and regulatory efficiency; and (10) Identify sustainable and integrated financing opportunities. Implementation of the plan is under way.

Environmental Justice Network in Action, Seattle. Seattle Public Utilities (SPU) initiated a program it called an Environmental Justice Needs Assessment in 2002. By 2009, it had been renamed the Environmental Justice Network in Action (ENJA), and involved 20 different organizations that were engaged in outreach and communication both to and from SPU. Outreach events have led to insights about the best methods with which to reach communities that are not normally in direct communication with a public utility,

LAND PRESERVATION TO IMPLEMENT WATER SUPPLY PROTECTION AND MANAGE STORMWATER RUNOFF

By Tom Daniels, professor of city and regional planning, University of Pennsylvania

Land preservation takes two general forms: (1) the fee-simple purchase of land by a government agency or private, nonprofit land trust, or (2) the acquisition of conservation easements through which the land remains in private ownership but the uses are typically limited in perpetuity to agriculture, forestry, and open space. If the land trust or government agency wants to manage the land, then fee-simple purchase is recommended. But if the goal is to protect working farm or forest landscapes, then conservation easements are preferred. Conservation easements are less expensive than fee-simple purchase and can include a management agreement for soil and water conservation practices.

A variation on the conservation easement is a riparian easement, which only restricts development along a stream corridor rather than the entire property. A riparian easement is likely to cost much less than a conservation easement. The riparian easement can include vegetation requirements for the riparian buffer to help intercept runoff and keep it from entering the waterway. Riparian easements have become popular in agricultural areas as ways to protect waterways and yet enable farmers to continue farming the large majority of their land.

Agriculture is a leading source of water pollution, as runoff from farm fields can carry pesticides, herbicides, fertilizers, and manure into waterways. Addressing agricultural runoff through land preservation offers the opportunity to compensate farmers for improving their conservation practices and for keeping their land open.

New York City's drinking water comes mainly from reservoirs west of the Hudson River in the Catskill Mountains and Delaware Valley. The watershed that feeds these reservoirs covers some 1,600 square miles and is still quite rural. Because of increased development in the early 1990s, the U.S. Environmental Protection Agency (EPA) gave New York City a choice: either build a $6 billion plant to filter its drinking water or draft and implement a watershed protection plan to safeguard the water quality.

In 1997, New York City decided to work with the counties and towns in the watershed in the Catskill/Delaware region. The city was willing to pay landowners to protect land near reservoirs through purchases of land and conservation easements to keep the land largely undeveloped, and make improvements in farming practices through whole-farm plans.

In 1997, the city owned about 50,000 acres, or less than four percent of the land in the Catskill/Delaware watershed. As of 2012, more than 128,000 acres had been preserved at a cost of more than $350 million (Daniels 2014). The city also spent about $35 million in working with dairy farmers to create whole-farm plans to improve farmers' soil conservation, stormwater runoff, and manure management practices, so that bacteria such as giardia, cryptosporidium, and E. coli would not enter the streams and contaminate the reservoirs (New York 2012).

The 1996 amendments to the Safe Drinking Water Act require each state to create a Source Water Assessment Program to evaluate its water systems. The amendments also established the Drinking Water State Revolving Fund of state and federal money that states can use to loan money to water systems for construction and upgrades to water systems. Up to 10 percent of the State Revolving Loan Fund may be used to make loans for the purchase of land or conservation easements to protect water supplies. For example, water systems in Maine used more than $190 million in Drinking Water Revolving Loan Funds between 1997 and 2012 (Maine Center for Disease Control and Prevention 2012). Some of the funds have been used to acquire land next to public drinking water supplies (U.S. EPA OW 2000).

including an emphasis on visual and experiential communication—including tours of SPU facilities, videos, and community meetings with hands-on activities.

SPU has used this partnership to identify the concerns of communities, including concerns about water services and rates. It has also built capacity for organizing and for more effective communication within the water utility and among the community groups. SPU is making racial equity an integral part of its promise to customers, making sure all communities in Seattle can access and benefit from the utilities' projects and services (SPU 2016).

Through ENJA, SPU is using GIS to help determine if certain neighborhoods have a higher proportion of drinking water shutoffs. Even without "hard" demographic data, this can lead to the development of a fairer policy. SPU is embedding race and social justice and service equity policies and practices across the utilities, and modeling and advocating for inclusive community engagement within the utility in partnership with communities.

Environmental Justice Coalition for Water, California Public Utilities Commission. In California, the Environmental Justice Coalition for Water (EJCW; https://ejcw.org) was formed by a statewide coalition of nine grassroots organizations and advocacy groups to train local community officials and activists how to advocate successfully for justice in water planning. The organization advocates for inclusive, community-based decision making about water systems with the goal of making water clean, safe, and affordable in low-income communities and communities of color. It asserts that access to clean, safe water is a basic human right. It releases publications about injustices in the California water system and conducts training and advocacy sessions. In 2008, authorities dedicated 10 percent of integrated regional water planning funds in each region to disadvantaged communities (California Department of Water Resources 2016). EJCW helps to make sure those funds reach communities that need them the most, and coordinates a statewide strategy for making the best use of the money.

Wastewater Practices

At the city, county, and regional levels, planners should be part of conversations regarding the implementation of innovative wastewater infrastructure. Sewers are powerful determinants of where growth in an area will go—in shaping development, a city's choice of sewer investment can be more important than the city's land-use plan (Scott et al. 2005).

In addition, the field of wastewater management is seeing exciting new developments involving on-site and district-based nonpotable reuse of wastewater. Following the discussion of wastewater and land-use planning, below are some recommended practices planners should be aware of to consider if and how they can be integrated into local projects and practices.

Wastewater and Land-Use Planning

The history of sprawl in the U.S. includes many examples of how the availability of water supply and sewers from the extension of infrastructure into less-developed land, usually at the periphery of cities and suburbs, strongly stimulates leapfrog development and development of environmentally sensitive locations. Studies have shown that sewered vacant land with access to an interceptor or trunk pipeline in suburban communities is worth from two to four times as much as equivalent unsewered land in the same communities (CEQ 1976). A large interceptor that is run out to the new office park south of town will suddenly make all the land it traverses attractive to development, even if that land is identified elsewhere as open space or agricultural.

The local general-purpose government has a variety of mechanisms to ensure that installation of sewer infrastructure is guided by the land-use vision of the community rather than vice versa. Local policy makers can decide where and, just as importantly, when to expand municipal wastewater service (Tabors 1979). Examples of this power to control the extension of water and sewer service in accordance with growth management objectives can be seen around the country.

Planners can also work with wastewater utilities to integrate their sustainability goals into the general plan and development regulations. Spokane County, Washington, developed a plan in 2002 that called for wastewater services only within its urban growth boundary to protect the Spokane-Rathdrum Aquifer. To prepare the plan, some of the existing sewer service areas designated by the various wastewater utilities had to be changed to comply with the land-use plan (Spokane County 2002). In Lancaster County, Pennsylvania, the county's growth management plan establishes urban growth areas and calls for municipalities and utility authorities to align zoning and water and sewer service districts with the growth areas (Lancaster County 2006). In New Jersey, state regulations require the preparation of wastewater management plans (WMPs) for each planning area in the state (NJ DEP 2016). The WMP must assess the cumulative water resource impact of future development and become a land-regulating component of the areawide water quality management plan. Areas eligible to receive public sewer service must be consistent with local growth goals, and public sewers cannot be extended to conservation or low-growth areas.

Water Reuse, Recycling, and Reclamation

There is an emerging consensus among wastewater utilities, architects, and planners that we need to rethink our definition of wastewater, because it contains valuable resources including water, carbon, nutrients, and trace metals. In addition, wastewater has embedded energy that can be captured. The current trend among wastewater engineers is to name all the liquid treatment aspects of wastewater treatment "water reclamation" or "water resource recovery." The change in nomenclature is already under way.

Water is typically treated to become potable water supply and pumped—using significant energy—to a location where it will be used for cleaning, sanitary use, and washing. Then it becomes "wastewater." Opportunities for on-site cleansing, filtering, and reuse of wastewater (e.g., irrigation, use for nonpotable purposes such as toilet flushing, or groundwater recharge on site) can reap significant sustainability benefits by avoiding the costs of long-distance piping to a regional treatment plant and wastewater treatment at that plant. Most importantly, this reduces demand for on-site potable water use, especially for outdoor irrigation and environmental uses (lawns, gardens) that experience losses due to evapotranspiration.

The interest in making more efficient use of wastewater has resulted in a significant number of pilot projects that are exploring its reuse. The California State Water Resources Board (2011) estimates that treated municipal wastewater recycling grew by about 10 percent per year between 1970 and 2009. The recycled wastewater can be reused to offset many potable and nonpotable uses, reducing the flow of pollutants into surface and groundwater sources (Asano et al. 2007). The offsetting use depends upon the degree of treatment—often called "fit for purpose" water:

- Wastewater that has undergone primary treatment can be used for surface irrigation or orchards and some crops.
- Secondarily treated wastewater can be used for groundwater recharge of nonpotable aquifers, industrial cooling processes, wetland habitat, and a wider variety of crop and on-contact irrigation such as median strips.
- Tertiary treated water can be used for applications that involve bodily contact such as golf course and park irrigation, or fountains and decorative lakes.
- Wastewater that has undergone advanced treatment can be reused for industrial needs and even potable water supplies.

Most water reuse in the U.S. in urban areas comes from a centralized wastewater treatment plant that delivers reclaimed supply using a second set of pipes for separate distribution. The city of Irvine, California, has been delivering recycled water to commercial buildings for over a decade with "purple pipes." The water can be used for toilet flushing and other nonpotable uses (Richter 2008). Sonoma County, California, uses purple pipes to deliver recycled water for uses including crop irrigation, large landscaped areas such as golf courses and cemeteries, industrial processes, and fountains (Figure 5.2, p. 80) (Sonoma County 2017). The state of New York has been promoting water reuse for several decades. Policies supporting these efforts can be included in the comprehensive plan, and funds to implement them included in the utility's capital improvement plan.

One of the most exciting efforts in the wastewater field today is the use of the energy contained in sanitary wastewater for heating and cooling. At the False Creek Energy Center in Vancouver, British Columbia, heat pumps transfer the energy from the wastewater pumping station to a loop distribution system. Sewage from 300 apartments provides 90 percent of the heating and cooling for 100 apartments (Baber 2010). In Colorado, the Denver Museum of Nature and Science has employed this system to reduce energy consumption by up to 60 percent (Denver Museum of Nature and Science n.d.). The East Bay Municipal Utility District in Oakland, California, powers its recycled water treatment plant by incinerating sludge and food scraps from the local solid waste program (EBMUD n.d.). See Chapter 3 for more information about such innovative practices. Planners can put policies in place to support such efforts in the comprehensive plan.

Perhaps the ultimate expression of water reuse is zero emission efforts, which seek to mimic the closed-loop natural water and wastewater cycle (Otterpohl 2005). These efforts use source separation of the wastewater into "black," "gray," and "yellow" wastewater to recapture and reuse all the water and its nutrients. Zero-emissions or "net zero" approaches usually have higher costs than conventional systems, but research is under way to explore alternative technologies and approaches, such as work conducted for the Environmental Control and Life Support System project at NASA's Marshall Space Flight Center (Joshi 2012).

Decentralized and Distributed Wastewater Management Systems

Today, smaller on-site or decentralized and satellite systems are possible with new technologies such as advanced filters and intelligent monitoring systems. They are used for servicing dispersed small wastewater flows and small community-scale and district-scale systems, independent of a centralized wastewater system. They also can be part of a larger centralized system of

Figure 5.2. "Purple pipes" in Sonoma County, California, deliver recycled water for irrigation uses (Sonoma County Water Agency)

collection and treatment, to reduce the costs of transporting wastewater over long distances. The wastewater is collected, treated, and reused at or near the point of generation. Recently the idea has come into vogue in the environmental and the engineering communities because decentralized systems can be more cost effective and environmentally friendly, and they keep water within local watersheds (Daigger 2009).

Implementing decentralized systems where there are currently centralized collection and treatment systems can be challenging, due to existing investments in the central systems. But where centralized facilities are reaching capacity or are constrained by discharge limitations, decentralized systems can serve as effective alternatives.

Natural Treatment Systems

Natural treatment systems are both an old and a new approach to wastewater treatment. This is an area of considerable interest today both in the U.S. and abroad because of the importance of wetlands in carbon sequestration and their ability to naturally treat wastewater.

Constructed wetlands can be designed for stormwater treatment or for final-stage tertiary treatment in sanitary wastewater treatment, and for surface or subsurface flows (Figure 5.3). They are attractive in rural areas where land costs are low because they can provide advanced wastewater treatment with low energy costs. In urban areas of the U.S., where land costs are higher, they are more useful for tertiary treatment and to act as buffers for wet weather effluent flows from storm sewers or from combined sanitary and storm water sewers (Smith 2008). Planners should be aware of the potential for natural treatment when they are involved in siting wastewater treatment facilities; they should make sure land is available and that there are suitable conditions for natural treatment facilities. These facilities offer the most potential in warmer climates where natural treatment is available year-round.

Examples of Interdisciplinary Wastewater Innovation

The water sector that is experiencing the greatest innovation and expansion in new technology is wastewater reclamation and recovery. The following examples show how communities are pursuing innovation in wastewater management.

Nonpotable Water System Permitting, San Francisco Public Utilities Commission. To prepare for projected climatic changes and population increases, and to reduce system vulnerability to seismic activity, the San Francisco Public Utilities Commission (SFPUC) evaluated its water supply system to identify options for increased water efficiency and reuse. SFPUC noted a host of potential sources for recycled water including "living machines" (systems of constructed wetlands that collect and treat sewage), rainwater harvesting technologies, and graywater reuse systems. However, California plumbing codes lacked explicit instruction on how to maintain these systems and protect public health when using recycled sources of water. In 2012, SFPUC developed a program to streamline the permitting process for

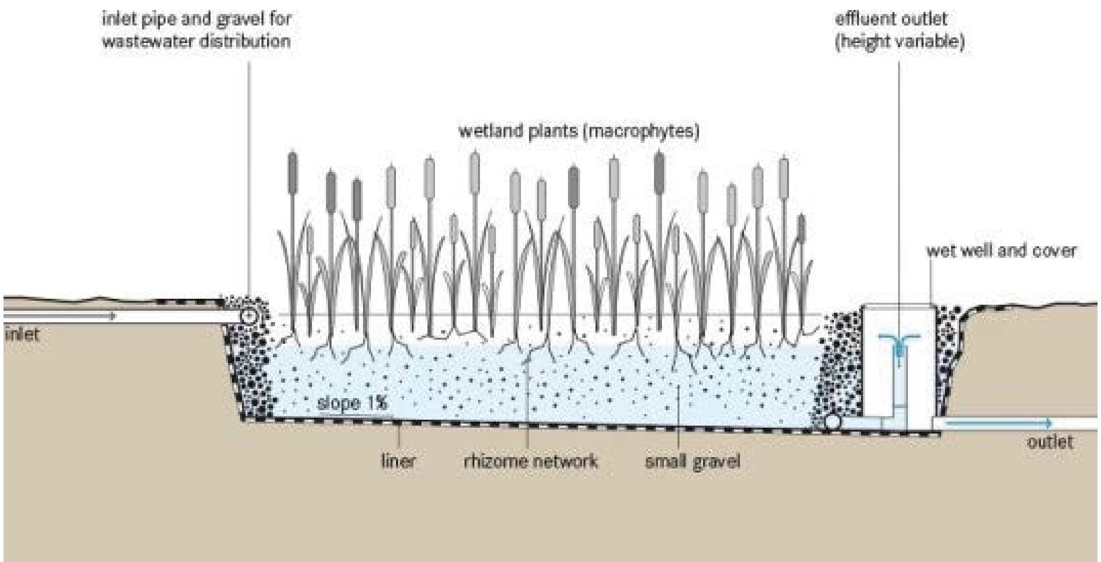


Figure 5.3. Constructed wetlands are a natural way to treat wastewater (Tilley 2014, in Conradin et al. 2010)

the installation of nonpotable water systems (SFPUC n.d.). By collaborating closely with different city departments, specifically the Department of Public Health and the Department of Building Inspection, the program established regulatory guidelines and specific city department responsibilities, and provided technical assistance for developers interested in installing nonpotable water systems in a number of new commercial, multifamily, and mixed use developments (SFPUC 2014).

Bullitt Building, Seattle. The goal of Seattle's Bullitt Center is to show the capabilities of today's technologies and prove that buildings can be completely self-sufficient for energy and water. One of its most ambitious objectives was to meet the standards of the Living Building Challenge (https://living-future.org/lbc), the world's most rigorous proven performance standard for buildings (Bullitt Foundation 2013). The challenge facing the project was to navigate existing policies and look for opportunities to change them when they presented an obstacle to high-performance green design.

Required elements for the Living Building Challenge related to water included collecting rainwater on the roof, storing it in an underground cistern, and using the rainwater throughout the building for nonpotable purposes (Bullitt Foundation 2013). In support of such efforts, Seattle has created the Living Building Pilot, a program allowing variations from code requirements and offering incentives to encourage new construction to meet the Living Building Challenge's standards (Seattle DCI 2016).

Urban Fabrick Collaborative, San Francisco. The sustainability nonprofit Urban Fabrick Collaborative is developing a water reuse practice guide intended to help teach architects and engineers about water reuse at the building and district scale (Worthen 2016). The guide will help planners understand how wastewater reuse can be implemented at the building scale.

Solaire Building, New York. The Solaire Building, built in 2001, is a 293-unit residential building in the Battery Park City redevelopment area with an internal wastewater recycling system that collects black and gray wastewater, treats it in the basement, and uses the recycled water for toilet flushing, air conditioning water, and irrigation of a nearby park.

The original redevelopment plan contained policies that promoted water reuse due to concerns about future water shortages—identified as a need by planners. When the proposal was selected, on-site water recycling guidelines were not in existence for the state. Recycled water will now be able to be used for laundry supply and sidewalk washing; the New York City Building Department has approved these uses and codified them (Elmer 2015).

Stormwater Practices

Planners can advance policies to integrate stormwater best practices into the design of the city through the comprehensive plan, the capital improvement plan, and development regulations (Novotny, Ahern, and Brown 2010). Best practices include replacing gray infrastructure conveyance systems for stormwater that remove runoff from a site as quickly as possible with more decentralized green systems that seek to infiltrate and store stormwater near to where the rain lands.

In the past three decades, planning for urban stormwater has evolved from a primary concern with adequate drainage and flood control to a more integrated approach that adds concerns about mitigating stormwater flows on-site, treating stormwater pollutants, and protecting and restoring natural drainage channels. As the change in paradigm occurred and strategies expanded to include natural and biological methods, so did the actors involved. This planning was originally done by engineers, but today land-use planners and others work together not only on traditional public works projects but on processes that result in behavioral changes of institutions, land owners, and individuals (Randolph 2004; BASMAA 1999).

Planners need to work with other water professionals to incorporate appropriate planning, regulation, and design elements to address water quality impairment concerns that arise from stormwater runoff. Below are recommended practices for this sector of water resource management.

Development Regulations

Planners are using subdivision and land development regulations to capture, infiltrate, and slowly release stormwater. For example, in Philadelphia all new development is required to retain the first inch of rainfall on-site in a 24-hour rain event. To achieve this standard, developers are required to install green infrastructure in the form of green roofs, rain gardens, trees, porous pavement, and cisterns. The goal is to mimic the predevelopment hydrology as much as possible. As older properties are redeveloped, the amount of stormwater runoff will decline, resulting in fewer combined sewer overflow events. The use of green infrastructure is expected to save Philadelphia billions of dollars compared to the construction of huge tunnels to capture stormwater (Daniels 2017).

Planners can also create a separate stormwater management ordinance, such as those required for all Maryland counties. The ordinance can include setbacks from waterways for new development, and buffer strips, vegetation, and the retention of trees above a certain pole size to absorb stormwater runoff (Daniels 2017).

The common theme with zoning and subdivision and land development regulations is to design with nature at the site level where the precipitation falls. The result is development that helps to protect water supplies and causes less runoff. The greener development also contributes to a more attractive and resilient urban environment.

Low-Impact Development and Green Infrastructure

As suggested in the previous section, many stormwater management programs and practices now seek to reestablish or functionally duplicate predevelopment stormwater patterns by capturing rain where it falls, slowing down the speed of the stormwater runoff, and increasing the ability to infiltrate rainfall on-site. Many of these practices are concerned with reducing the extent of the urbanized impervious area and improving the infiltration potential of runoff from the impervious area, and use methods and designs that slow the speed of urban runoff through temporary storage of runoff. These methods are known as low-impact development (LID) designs and green stormwater infrastructure.

LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source, instead of relying solely on large-scale end-of-the-pipe facilities at the bottom of the drainage area. LID addresses stormwater through small-scale landscape practices and design approaches that preserve natural drainage features and patterns (U.S. EPA 2017f). Green stormwater infrastructure uses vegetation, soils, and other elements and practices to restore the natural processes required to manage and infiltrate water into the ground and create healthier urban environments (U.S. EPA 2016c). It includes a range of designs, from green roofs, green walls, rain gardens, and pervious pavers at the site and building level, to systems of parks and open spaces at the neighborhood, city, or regional levels (Figure 5.4).

Source Control for Pollutants

Besides slowing down the flow of stormwater, federal Clean Water Act regulations seek to reduce pollutants in urban runoff that enter streams and rivers and waters of the U.S. The ideal strategy for reducing pollutants in stormwater runoff is to prevent them from getting into the pipe collection system—an approach called source control.

There are many approaches for local planners to draw on to create and implement source control policies and provisions both in the comprehensive plan and development regulations, as well as in the capital improvements plan. One major approach to consider at the planning level is to use green infrastructure to filter and settle pollutants in runoff before infiltrating or slowly releasing the water to a waterway. Another planning-level approach is to designate green buffers along streams and riparian areas that will naturally filter pollution in runoff.

Actions at the site level involve installing pollution-reduction designs and technologies, such as using oil and water

Figure 5.4. Green stormwater infrastructure can take many forms, including this bioswale in Greendale, Wisconsin (Aaron Volkening, Flickr CC BY 2.0)

separators for parking lot runoff. Oil, grease, antifreeze, brake dust, and tire particles all find their way into stormwater.

For municipal operations, regular street sweeping can remove many stormwater pollutants before they enter the water. Such programs may be implemented in coordination with a parking ban on certain days of the month to ensure that street sweepers can access gutters on a regular basis to remove trash. Ordinances or clauses in covenants can address either the amount of lawn or the maintenance of lawns to reduce excess application of pesticides and herbicides. This also applies to the maintenance of public spaces such as parks and cemeteries.

Stream and Creek Restoration

Stream and creek restoration can also reduce the speed of stormwater flows, promote infiltration, repair channel erosion from high rate runoff, increase wildlife diversity, and improve the recreational amenity value of the natural waterway. In many locations, such restoration forms the basis of economic revitalization and development efforts along key rivers and streams. Such restoration efforts, important to a natural systems approach, must be considered and designed at a district or citywide level to assure the long-term stability of the restoration action.

One such example is Lower Phalen Creek, in Saint Paul, Minnesota. The creek flows from a series of lakes outside of Saint Paul to connect to the Mississippi River. As the area developed, flooding caused the city to bury the creek underground in a large storm sewer system completed in the 1930s. In the past two decades, the creek has been a target for restoration initiatives in the local neighborhoods.

Part of the flow of Phalen Creek (Swede Hollow Park) was restored aboveground in the 1990s, largely due to the efforts of neighborhood councils working together with city officials and state and federal agencies (Pinkham 2000). This process is being repeated on another stretch of the creek—Lower Phalen Creek—with a local stakeholder group (Lower Phalen Creek Project n.d.). The current plan includes removing the underground sewers and creating a new stream channel—allowing daylight to once again reach the waterway—while expanding the riverfront park along the Mississippi to provide more riparian habitat for migrating waterfowl and create a series of bicycle trails for residents (Saint Paul 2001).

Another daylighting example comes from Dubuque, Iowa. More than half of the city's residents either live or work within the watershed for Bee Branch Creek, which is located entirely within the city limits. Like many other cities, the city had routed the creek through an underground storm sewer in the downtown area. However, the storm sewer did not have sufficient capacity to contain water from flash floods. Since 1999, six federal disaster declarations have been issued for flooding in Dubuque (Tome 2014). The flood of 1999 coincided with a tornado warning, but basement shelter areas were flooded and citizens had to choose between water or wind (Dubuque n.d.b.).

Subsequently, the city established a stakeholders' committee, which considered enlarging the underground storm sewer or daylighting the creek. The city opted for the daylighting. The city partnered with private and nonprofit organizations to secure $47 million for restoration work from local, state, and federal grants. The Bee Branch Creek Restoration project involved replacing almost one mile of storm sewer with the daylighted creek and building a greenway that is designed to take on stormwater during rain events and move it through the area without flooding adjacent properties (Figure 5.5). The greenway also contains a trail system, an amphitheater, a play area, and an urban garden. The Lower Bee Branch Creek project was completed in 2017 (Dubuque n.d.a.).

Integration of CSO/SSO Remediation Projects with Street Projects

In the U.S., several cities have built sustainable combined street and sewer projects during the past seven years that serve many purposes (Portland Cement Association n.d.). Most faced substantial obstacles in integrating multiple funding sources, regulations, timetables, and interagency goals. Progress has been complicated by restrictive rules about what work can be designed and built from each funding source (transportation, water/sewer, private). Current best practices continue to emphasize interdisciplinary solutions to street, sewer, and right-of-way design and construction (Mustafa and Birdsall 2014). Many older cities with combined sanitary and stormwater systems and histories of repeated overflows (CSOs) during storm events (due to lack of capacity at the treatment plant for huge volumes of stormwater runoff), as well as sanitary system overflows (SSOs) from sewers and septic tanks, are under court orders to halt CSOs and SSOs under penalty of large fines and imposition of consent orders (Carr, Esposito, and Walesh 2001).

The conventional response was to require the cities to build billion-dollar CSO storage tunnels to retain the polluted stormwater until it can be safely and slowly treated by the wastewater treatment plant. In the last few years the EPA has permitted cities to build green infrastructure and use natural systems while replacing the combined storm sewers. Local engineers in cities are also beginning to realize that integrated street and sewer projects are efficient and welcomed by the public (ASCE 2013). One such example is Philadelphia, where the city has committed to meeting CSO regulatory goals using green stormwater infrastructure through its Green City Clean Waters program (PWD 2016).

Several states and cities have begun exploring integrated transportation/sewer projects. One example is the city of Boston's Smart Utilities project, a collaborative effort underway between city government and local utility companies to improve coordination and integrated planning

Figure 5.5. Before-and-after pictures of the restoration of Lower Bee Branch Creek, Dubuque, Iowa (City of Dubuque)

among utilities for more affordable and sustainable neighborhood urban services (Boston PDA 2017).

Examples of Interdisciplinary Stormwater Management Innovations

Stormwater management has been identified through the APA Survey of Planners on Water as the water sector that has the greatest involvement by planners. This is because stormwater and runoff are closely tied to land use, impervious surfaces, and the water environment.

Interdisciplinary approaches to stormwater management seek to leverage the work of civil engineers in designing drainage systems, landscape architects, and architects in creating building exterior spaces, and planners in applying zoning, comprehensive plan, and code guidance to design more sustainable drainage systems. Site stormwater management and drainage designs are best created by a team that can marry the many goals of managing runoff, from human safety issues related to flooding, environmental concerns in filtering and improving the quality of runoff, and planning goals of increasing site sustainability and resiliency. These reflect the principles of One Water management, as described in Chapter 2.

Industrial Park Green Infrastructure, Milwaukee, Wisconsin. Milwaukee relies on a combined sewer system, and during heavy rains the system overflows into neighboring rivers and Lake Michigan, polluting them. This combined sewer system along with many industrial areas, development, brownfields, and lack of natural filtration led to compromised ecosystems.

Milwaukee turned to green infrastructure to address this problem. Its most well-known project is the Menomonee Valley industrial site because of its scale and effectiveness in reducing stormwater runoff into Lake Michigan. This is a key example of the sustainable redevelopment of an underutilized, contaminated industrial site. Green features include a 70-acre stormwater park with recreational trails that is expected to treat 100 percent of runoff from adjacent industrial and commercial areas (WERF 2009b).

Merging Stormwater Features with Parks and Recreation, Bellevue, Washington. Flooding concerns and an increasing population caused Bellevue to take action to better manage stormwater. Instead of using underground pipes, natural drainage systems and preserved open spaces were used to reduce the amount of time and money spent on fixing leaking underground stormwater pipes. The city's Utilities and Parks and Community Services departments formed a partnership in which the former built stormwater management features, and the latter created recreational facilities at or near the stormwater management features (WERF 2009a).

Thornton Creek Water Quality Channel, Seattle. The Thornton Creek watershed is Seattle's largest watershed and drains into Lake Washington. The creek was buried in a 60-inch underground pipe to allow development. However, because of cracks and deterioration in the pipe, urban runoff began to leak into and cause water quality issues in nearby Lake Washington.

The city convened a group of stakeholders from business, community, and environmental interest groups to assess how to better manage runoff and improve water quality in Thornton Creek and Lake Washington while promoting open space, livability, and economic development. A group of 22 stakeholders recommended that a biofiltration swale be built to slow stormwater runoff and retain pollution-laden sediment (Figure 5.6, p. 86). The facility has fulfilled its stormwater and water quality function and further serves as an anchor to private development for residential and retail developments, which are estimated to bring an additional $200 million to the Northgate neighborhood (SvR Design Company 2009).

Greater New Orleans Urban Water Plan. The devastation of Hurricane Katrina exposed to the world several of the planning challenges facing the city of New Orleans, with water management and water infrastructure being most critical. In response, the first "Dutch Dialogues" workshops were held in New Orleans in 2008. Cosponsored by the American Planning Association, these intensive workshops brought together Dutch urban designers, engineers, landscape architects, planners, academics, and government officials to engage with American counterparts to explore creative solutions and holistic concepts for flood risk reduction, green and gray infrastructure with multiple benefits, resiliency, and smart redevelopment. Similar workshops have since been held in New York; Bridgeport, Connecticut; St. Louis; Tampa Bay, Florida; Los Angeles, and various locations in Virginia.

Building on the Dutch Dialogues workshops, New Orleans convened a team of local and international water management and climate adaptation experts to create the Greater New Orleans Urban Water Plan in 2013 (Waggoner and Ball 2013). This was the first regional water plan of its kind in the U.S. It integrates infrastructure planning, land-use planning, and urban design at a regional scale, and provides a framework with which to guide public and private investments for the next 50 years. The plan signals a paradigm shift in water management, from a complete reliance on pumping stormwater and groundwater—fighting water—to finding ways

Figure 5.6. The Thornton Creek Water Quality Channel removes pollutants from urban stormwater runoff while helping to revitalize the Northgate Urban Center (MIG|SvR)

to slow and store stormwater—living with water—while addressing soil stability and groundwater issues.

"Game of Floods," Marin County, California. In 2014, a Marin County supervisor initiated a planning group in the district of southern Marin to identify community assets that are vulnerable to sea-level rise. The senior county civil engineer, Roger Leventhal, worked with a local landscape architect in San Francisco to develop a game to be played in community workshops that he called the "Game of Floods." Approximately 90 community members played the game at the first public event in November 2014, and used it to learn more about adaptation options as well as communicate their priorities and intentions to county staff and elected officials. The county offers the complete set of game materials as downloads on its website (Marin County 2017). The game has won several awards, including the 2017 APA National Planning Achievement Award for Public Outreach.

Retrofitting Rain Gardens, Burnsville, Minnesota. Urban runoff in Burnsville was causing eutrophication to occur in Crystal Lake. This lake had historically been clean and clear. Excessive amounts of nutrients from sewage, fertilizers, and other nitrates and phosphates led to increased algal growth in the lake and very low levels of dissolved oxygen, threatening the health of the biological community. Public support and stakeholder involvement resulted in the city constructing rain gardens in the neighborhood. Monitoring data showed that the rain gardens achieved greater than 80 percent reduction in runoff volume during representative rain events (Barr Engineering n.d.).

Tujunga Wash Greenway and Stream Restoration Project, Los Angeles. Alterations to the Los Angeles River and its tributaries have left the once complex, biodiverse Los Angeles River system with water quality issues and habitat loss, while public access to open space along the river is restricted.

In attempt to resolve these issues, multiple stakeholders worked together to support the creation of the Tujunga Wash Greenway and Stream Restoration Project. This state- and county-funded project provides benefits to the community and natural environment of the river ecosystem (Robinson et al. 2013). A pipe routes urban runoff from a flood control channel and delivers the water to a newly created stream with some of the natural characteristics of the once free-flowing

Tujunga Wash. Native plants in the streambed help clean the water and provide wildlife habitat.

ONE WATER EXAMPLES

As suggested by the examples provided in the last section, expanding the set of best practices that advance One Water approaches and mechanisms is essential to move toward more integrated water resource management.

The collaboration among planners and other water resource professionals encouraged by One Water approaches will also be key in addressing the new water management challenges created by climate change and other emerging factors. The sidebar on p. 88 describes important considerations, actions, and roles for planners as they pursue more integrated approaches to help better manage water in the 21st century.

As described in Chapter 2, One Water strategies seek to manage all the many dimensions and forms of water use as one system of resource management, bringing together water supply, wastewater reclamation, and stormwater management into one integrated management approach. Below are three additional examples of One Water best practices in the U.S.

Green City Clean Waters, Philadelphia. As of 2016, the Philadelphia Water Department (PWD) was in its fifth year of implementing Green City Clean Waters, a program to reduce combined sewer overflows and improve water quality (PWD 2016). To achieve this goal, PWD is completely reinventing its water resource and green infrastructure management programs to improve the water quality of Philadelphia's creeks and rivers, improve the biological and ecological conditions in the streams, reduce flooding through better management of stormwater, and recreate a green cityscape in Philadelphia (Figure 5.7).

The overall program consists of multiple interrelated programs. PWD is forging new alliances with other city departments to identify program elements in each department that would be strengthened and enlarged by joint action; for example, PWD is working with the parks and streets departments to implement green stormwater infrastructure, assuring that green stormwater infrastructure is compatible with park uses.

Creating an integrated approach to water resources and urban design has put PWD in the forefront of water resource management among major U.S. cities. PWD's integrated approach is being studied by other cities, as well as the state and federal regulatory agencies, as a model for reforming urban water resource management.

San Francisco Eco-District Plan. Approved by the city's board of supervisors in 2013, San Francisco's Eco-District approach calls for integrated infrastructure planning at the site and district level. According to project consultant Bry Sarte, "SFPUC's district water program is one of the best innovations in the country in terms of laying the critical groundwork to support district infrastructure as a backbone for an eco-district" (Elmer and Kehoe 2014).

The Central Corridor Eco-District, located around the new central subway line that will serve Moscone Center, San Francisco's downtown conference and event space, is currently under design. Along with green and walkable streets

The Investment in Sustainability: Triple Bottom Line

ECONOMIC BENEFITS

About 250 people employed in Green Jobs per year

SOCIAL BENEFITS

Increase of over 1 million recreational user-days per year

Reduction of approximately 140 fatalities caused by excessive heat over the next 40 years

Increase in property values of 2-5% in greened neighborhoods

ENVIRONMENTAL BENEFITS

1.5 billion pounds of carbon dioxide emissions avoided or absorbed

Air quality benefits on average leading to 1-2 avoided premature deaths, 20 avoided asthma attachs, and 250 fewer missed days of work or school per year

Water quality and habitat improvements including 5-8 billion gallons of CSO avoided per year, 190 acres of wetland restored or created, and 11 miles of stream restored

Reduction of approximately 6 million kW-hr of electricity and 8 million of kBTU of fuel used per year

Figure 5.7. Philadelphia's Green City Clean Waters program is resulting in significant economic, social, and environmental benefits (PWD 2009)

INCREASING RESILIENCE IN THE FACE OF CLIMATE CHANGE THROUGH GREATER COLLABORATION AMONG COMMUNITY SERVICES

By Katy Lackey, research manager, and Lauren Fillmore, senior program director, Water Environment and Reuse Foundation

The shift to One Water marks growing collaboration both within the water sector and among the water sector and other community services and stakeholders. This is increasingly important as communities face more frequent and intense extreme climate and weather events, the aftermath of which can be disruptive and costly. A recent study found a statistically significant increase in billion-dollar climate and weather disasters of about 5 percent per year since 1980 (Smith and Katz 2013). This increase parallels worldwide documentation of increasing intensity and frequency of heat waves, heavy precipitation, and coastal storm events (IPCC 2014). Most climate scientists expect this trend to continue.

Water services are part of the nation's most critical infrastructure and valuable investments. Adequate and reliable water resources are necessary for a robust community. How can planners work with water managers to build community resiliency and address water issues related to climate change? What factors are important and how do these translate into specific planning actions? A 2014 collaborative study of research and water organizations lends some perspective.

The study's report, *Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future* (Beller-Simms et al. 2014), examined how drinking water utilities, water resource recovery facilities, stormwater utilities, and other local water resource managers in six river basins responded to recent extreme events: what happened, how information was used to inform decisions, what institutional dynamics helped or hindered, and how communities plan and build resilience for extreme events in the future.

Despite the unique attributes of each region, several common themes emerged:

Managing the Risks of Extreme Events

- ***Cascading Nature of Extreme Events.*** Localities are dealing with multiple types and occurrences of extreme events, many of which have become more severe and more frequent in recent decades.
- ***Integrated Planning for Multiple Risks.*** The variety of extremes experienced in communities necessitates managing multiple risks of different types.

Building Resilient Communities

- ***Response and Preparedness.*** Emergency response is an essential component of preparedness. Ensuring the ability to recover following extreme events is among communities' top priorities. To enhance long-term preparedness, communities are beginning to plan infrastructure to withstand vulnerabilities and increase the flexibility of existing systems.
- ***Public Awareness.*** The community must understand the risks to water resources and define their risk tolerance. This awareness must extend to other community services and include planning professionals so they may integrate water resource resiliency considerations into comprehensive and action plans and future projects.
- ***Community Decision Making Within a Basin.*** The complex array of decisions needed to support resilience within a water basin requires coordination across water service areas, professional disciplines, and jurisdictional boundaries. Focused leadership helps communities navigate new paths to resilience.
- ***Multidisciplinary Collaboration.*** Multidisciplinary collaboration and communication increases access to actionable information for science-based decision making.

The report found, however, that the impacts of climate change and extreme weather events, along with community responses, are local. Understanding of hydrologic and meteorological phenomena at the local scale is key, and requires local involvement. Planners and water managers can help communities understand climate data and local conditions, and use it to support decision-making and future planning.

Taking local initiative—whether done with or without the involvement of the federal government or national organizations—and collaborating with locally based institutions is the leading trend as communities work to build water resilience. As communities experience multiple weather or climate-changing events, these efforts help navigate through the information, resources, and strategies needed to move forward, raise public awareness, and, where necessary, rebuild differently in the aftermath.

Keeping these common themes in mind, important roles for planners emerge. Collaborations between water

TABLE 5.1. STRATEGIES AND PLANNING ACTIONS THAT SUPPORT RESILIENT COMMUNITIES AND SOUND WATER MANAGEMENT

Resilience Strategy	Water Sector Action(s)	Role(s) for Planners	(Most) Applicable Region
Improve drainage	• Green infrastructure • Low-impact development • Street tree programs • Storage retention	Work with water utilities to prioritize areas for green installations and plantings that can meet both water drainage and other community needs (e.g., parks and recreation, community revitalization and equity). Encourage pervious pavers in new development projects.	Northeast, South
Preserve watershed function	• Expand riparian buffers and wetlands • Enhance groundwater recharge • Avoid fast pipe runoff conveyance	Discourage urban expansion in key floodplains and along rivers and streams important for storm barriers, drainage, or water supplies. Support polices for joint funding and programs on groundwater banking during high precipitation periods. Maintain natural watershed runoff characteristics.	All—especially coastal and near-coastal areas.
Improve water quality	• Advance and invest in water/wastewater treatment • Natural and gray protection barriers for waterways • Public education and outreach efforts	Include protections along waterways in city-design. Encourage awareness of the impact increased impervious surface and building density has on water quality. Increase the visibility of recycling/trash stations, street-cleaning programs, and public education about water quality. Promote policies to reduce waste or increase pollution trading credits.	Midwest, East
Promote adequate water supply	• Reuse of "fit for purpose" treated wastewater • Promote wise use of water (conservation) • Plan to retain, detain, and infiltrate stormwater runoff • Reduce nonrevenue water loss	Consider wastewater reuse in planning golf courses and green spaces. Work with the building sector to develop LEED credits for water reuse and incorporate where appropriate. Include eco-districts in city plans that can capture and reuse water on-site.	West, South
Reduce GHGs and heat island effects	• Energy and water conservation programs • Waste-to-energy recovery projects • Expand tree canopy and cover	Work with utilities to create consistent messaging about water use and conservation among constituents. Encourage new and redevelopment building projects to incorporate submeters and real-time water use alerts. Promote use of renewable natural gas, especially for local government vehicle fleets and uses. Use sewer systems for thermal—both heat recovery and cooling.	West, South, and dense urban areas
Invest in and protect infrastructure	• Elevate critical infrastructure to protect from flooding (e.g., pumps, motors, control rooms) • Scenario-based planning and regional collaboration to reduce risk to new infrastructure	Include water infrastructure upgrades and replacements (for both aging and high-risk assets) in capital improvement plans (CIPs) and climate change/sustainability plans. Collaborate with water utilities and community agencies for better understanding of water rate increases and to lessen the impacts on low-income communities. Work with local and regional agencies to redirect pedestrian and car traffic around priority infrastructure projects (so communities can better support upgrades in the water sector, rather than being temporarily and negatively affected by them).	All

Source: Adapted from Beller-Simms et al. 2014

Note: Many water-related actions and subsequent roles for planners will support coordinated implementation of multiple resiliency strategies. For instance, green infrastructure and street tree programs can improve drainage and mitigate heat island effects. Joint water and planning actions may be applicable in all climate regions.

managers and planners and innovations in the water sector build resilience by improving drainage systems, preserving watershed functions, improving water quality, assuring adequate water supplies, and reducing greenhouse gas emissions and heat island effects, while protecting the community's investments.

Planners can support and collaborate on water-sector actions, but is it enough? What else might a community do to reduce vulnerability and manage risk when the exact nature and extent of the threat is unclear?

While specific strategies can help build resiliency, planners and water managers must work together consistently to meet the dual challenge of population growth and changing climates. Rather than a "one-and-done" adaptation plan, the use of "flexible adaptation pathways" provides a continuous, dynamic management approach to risk by allowing for the modification of future actions. Acceptable risk is defined and set as the target threshold. Steps are taken to minimize risk, based on best available information (NASA 2013). Rather than locking into a long-term strategy based on imperfect understanding, communities can adjust their approach while keeping the level of risk within an acceptable boundary and buying time to develop more actionable information as new data is collected and efficacy of initial steps is assessed.

This requires a great deal of attention on climate data and an understanding of climate information that is fed directly into land-use and development decisions, water policies, and community action plans. Water managers and planners can utilize this flexible approach by including one another in strategic planning processes, as well as engaging in regular scenario-planning exercises based on refined climate information at a given time.

and watershed and flood management elements, the plan envisions district-scale nonpotable reuse; on-site water recycling, water capture, and reuse; and two thermal energy plants where energy and wastewater systems are integrated (San Francisco Planning Department 2012).

The San Francisco Planning Department has made available a series of eco-district presentations that address topics including integrated water resource management, transformative water and energy infrastructure, and water reuse opportunities in the city (http://sf-planning.org/eco-district-presentation-series).

Calumet Stormwater Collaborative, Chicago Region. The Chicago region experiences significant flooding from both small and large storm events that cause considerable damage to property and infrastructure and impact quality of life. These storms, which are becoming more frequent and intense, are predicted to only increase due to the latest climate projections.

In response, the Metropolitan Planning Council (MPC) formed the Calumet Stormwater Collaborative (CSC) in 2014. This initiative was launched to bring together diverse stakeholders in the Calumet region of south Chicago and its suburbs to facilitate a new level of coordination across government agencies, utilities, researchers, nonprofit organizations, and communities (MPC 2017). The Calumet region was specifically chosen in order to provide additional resources and capacity to serve moderate- and low-income communities on tight budgets.

This collaborative effort was established to address three central problems:

- Stormwater overwhelms current infrastructure.
- Green infrastructure's role in stormwater management is still evolving.
- Coordinated action between government units and other stakeholders controlling land, infrastructure, financing tools, and regulatory powers is necessary to solve systemic problems in systemic ways (i.e., a One Water strategy).

The CSC provides a forum to align efforts, identify synergies, partner on initiatives, and share best practices in stormwater management (Figure 5.8). CSC members meet monthly and partner together to bring planning assistance to municipalities and build intergovernmental and cross-sector partnerships through knowledge sharing, coordination, and deployment of the latest practices in stormwater management at a range of scales (Figure 5.9). This One Water integrated, regional approach produces improved decision

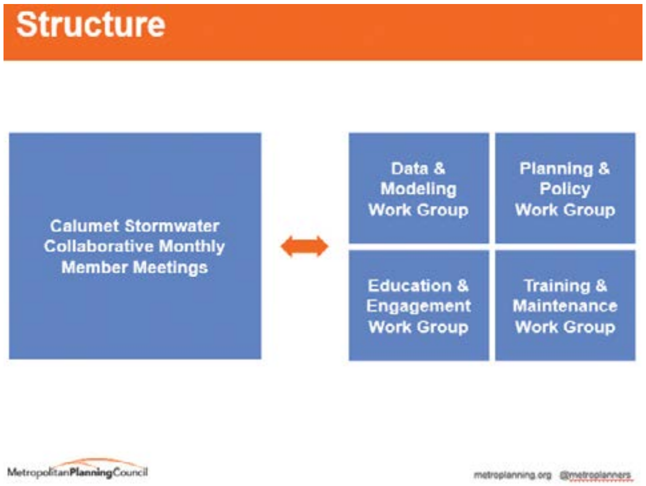


Figure 5.8. Organizational and functional structure of the Calumet Stormwater Collaborative (Danielle Gallet, Metropolitan Planning Council)

Figure 5.9. Calumet Stormwater Collaborative meeting in action (Danielle Gallet, Metropolitan Planning Council)

making and better investment outcomes that assist communities in reducing urban flooding.

To date, achievements of the CSC include creating new, free decision-making tools and data-sharing portals such as a regional mapping viewer and green infrastructure design templates; bringing planning assistance to municipalities; expanding and establishing local expertise through community education and engagement; leveraging and creating new funding sources and dedicated revenue streams for local communities; and conducting market analysis on workforce development opportunities in green infrastructure installation and maintenance.

The CSC program's success is being measured in many ways. Key metrics include fundamental elements of a One Water strategy, including increases in the number of local government with green/gray infrastructure projects; increases in public recognition of progress toward improved stormwater management; and increases in connectivity and interjurisdictional partnerships between CSC members (i.e., evidence that synergies and partnerships between members is providing value and having positive impacts in the region).

Finally, the CSC itself is a model for how to establish, engage, and retain intergovernmental and cross-sector partnerships to address complex urban problems. It has been going strong since 2014, with more than 35 member organizations actively involved, and is still growing. The lessons learned in how to bring multiple agencies, communities, and stakeholders together to work collaboratively within the One Water paradigm make this a useful case study for other regions.

CONCLUSION

Water has received much attention in recent years. This chapter has described a wide range of recommended practices and technical approaches for use by planners and their interdisciplinary colleagues to help advance the goals of more sustainable water supply, wastewater reclamation, and stormwater and natural system management. The practices described here should be creatively adapted as local situations may require.

The principles of One Water management and other natural systems management described in this chapter are readily adaptable to similar geographies and water resource settings. In many cases, implementation of these best practices will benefit from collaboration and interaction between planners and other water professionals, such as hydrologists and hydrogeologists, civil and environmental engineers, landscape architects, environmental scientists, economists, lawyers and regulatory experts, local government officials, and others.

Research and development regarding new best practices is advancing rapidly, with new approaches, regulatory and legal mechanisms, interdisciplinary collaboration, published guidance, and technologies emerging monthly. The study of water resource management is clearly one field that does not suffer from lack of analysis and published information. However, strategies, practices, and technical approaches that marry the work in the domain of the professional planner to water system legal approaches, engineering approaches, and natural system capacity models have recently benefited from increased attention and interest.

While both planning frameworks discussed in this chapter—the five strategic points of intervention and the Sustaining Places initiative—are functionally dependent on comprehensive planning, it is important to note that best water management practices for comprehensive planning are still being defined and tested for inclusion in comprehensive plans. As noted earlier in this chapter, APA's Water Working Group has proposed a comprehensive planning framework for water resources to achieve exactly that goal (see Appendix).

Though much work in this area has yet to be done, the water resource challenges that are being addressed provide a rich inventory of effective approaches that have already been successfully deployed. This chapter was designed to inspire innovation and collaboration—and to inspire planners to use these examples to inform their own research and practice.

CHAPTER 6

THE FINANCIAL ASPECTS OF WATER

As previous chapters have noted, U.S. water infrastructure systems face the challenges of aging facilities additionally stressed by population increases and climate change. To adapt, replace, and reinvent our water system is not only a technical and organizational challenge, but a financial one as well.

The current water system was built and financed based on a series of fee structures and capital mechanisms adapted to each of the water service sectors. Historically, water infrastructure budgets have not been integrated between the different water service sectors, nor with city or county capital improvement programs. The One Water paradigm and recommended practices described earlier in this report call not only for integrated water-sector planning but also for breaking down the barriers between "silo" financing and fee structures of the separate water utility sectors. This paradigm also calls for new and creative ways of financing investment for the new vision of water.

This chapter addresses that need. It begins by describing how the true costs of water are not fully reflected in current pricing schemes and the challenge this presents to sustainable water resource management. The chapter next presents basics on pricing, fees, and rate structures for the three major water systems: supply, wastewater, and stormwater. It then turns to capital financing, before addressing financing approaches for innovative water best practices. An overview of water markets and water law rounds out the chapter before it concludes with discussions of how to promote affordability for low- and moderate-income households, and how planners can contribute to more sustainable water financing.

THE PRICE AND COST OF WATER

Historically, water has been treated as a common good, available to all at a price based only on the cost of treating and delivering the water. However, in the water sector there are significant costs to society and the environment that are not incorporated into water prices or fees to the consumer. The field of economics teaches us that any item of value that is not assigned an appropriate price reflecting that value will be overconsumed or inefficiently managed. This means that the well-being of our society can be negatively affected by current consumption and production patterns of our water services (Ostrom 1990).

In the case of water supply, water withdrawals by municipalities or agricultural uses can negatively affect ecosystems dependent upon those same sources, and can result in less water available to present and future users in the watershed or aquifer. These kinds of costs to the environment and the larger society are called negative externalities. If these costs were incorporated into the price of water services, economists argue that our use of water resources would be more efficient (Gaffney 2016). Water markets have also been found to more efficiently allocate water than the current system of water rights (Goemans and Pritchett 2014). Additionally, water reuse, another breakthrough for a more sustainable water system, is not competitive with traditional water sources in most areas because water is not priced to reflect its true cost (NRC 2012).

Urban water supply infrastructure reflects the inefficiencies of the current pricing system. The price of water varies substantially among utilities, even when the water is drawn from a shared source and is supplied by systems of similar age and capacity. Some municipalities and utility commissions, in attempts to discourage overconsumption, put price premiums on consumption above certain amounts. Other cities charge the same price for the first gallon and the millionth gallon. There may be efficiencies of scale—marginal cost of production, distribution, and amortization of capital costs—being passed on to the consumer, but this pricing does not capture other economic uses of water well, especially in times of scarcity.

In addition, the agriculture sector has traditionally paid less than the residential and commercial sectors for the water it consumes. Thus, the use of water across regional and local landscapes, and across the many types of crops, livestock, and agricultural product processing, is inefficient (Cooley et al. 2014; Wichelns 2010). High-value, water-dependent crops are presently grown in arid areas, sometimes supported by federal subsidies (Hanak et al. 2011). The droughts of 2011 to 2017 in the U.S., particularly in California, have demonstrated that current practices for crop selection, planting, and harvesting schedules are not optimal when water is scarce.

The divergence in the price of water and the practices governing the distribution of water often encourage overconsumption as well as overinvestment in the infrastructure needed to supply the water (Baumann et al. 1998; U.S.EPA OW 2016). If water is underpriced, conservation will be difficult, because reduced water use reduces short-term revenues of water supply agencies. However, conservation has been shown to reduce water fees in the long term, particularly where communities can avoid new infrastructure costs by lowering water demand (Bishop and Weber 1996; Blanco et al. 2012).

Pricing inefficiencies also plague efforts to keep pollution out of urban water sources. In recent decades, substantial investments have been made to protect the quality of water for humans and ecosystems. Chief among these are wastewater collection systems and treatment plants. However, the cost of wastewater service does not include the full costs to remediate pollution caused by nitrogen, phosphorus, and other contaminants not removed by treatment and discharged into the receiving water body. As a practical matter, it is also difficult to calculate in financial terms the long-term and downstream impacts on human health, ecosystems, and local economies caused by polluted water supplies, whether costs are charged back to the potable water treatment process or to the wastewater treatment plant.

In the case of stormwater runoff, urban development charges for streets and storm drains also do not fully recover the costs of pollution discharged during storm events into receiving water bodies, or the erosion of streams and riverbanks and ecosystem losses.

Finally, the price of water may be efficient, but not equitable. Rural areas may have prices for residential water use higher than some households can afford. Urban areas may build new facilities to meet the demand for suburban irrigation, thus forcing up overall prices for inner-city residents who do not irrigate or who cannot afford the services (Cooley et al. 2016).

The price of water services is therefore a key factor in being able to influence more efficient use of water, reduce pollution, and contribute to the use of more sustainable and equitable water technologies and systems. Today, the U.S. Environmental Protection Agency (EPA), as well as the European Union's Environmental Agency, advocate full-cost pricing, where all costs, including operations, maintenance, and capital costs, are recovered. Full-cost recovery is one of the four "pillars" of EPA water management (U.S. EPA OW 2016; Dige et al. 2013). Still others, while acknowledging the role of full-cost pricing, also advocate innovative financing mechanisms and subsidies to pay for pilot projects for innovative water technologies. This can help transform our current system to one suited for the equity challenges of the 21st century (Quesnel et al. 2016; American Rivers et al. 2012).

PRICING AND RATE STRUCTURES FOR WATER SYSTEMS

The major actors in rate setting and spending on water are state and local governments, with local governments, including water utilities, predominating. About one-third of infrastructure spending (including capital and operations and maintenance) is for water service infrastructure; this share has risen slightly since 1956 (CBO 2015). Nationally, public water spending by local governments increased 78 percent from 2000 to 2012 in nominal dollars. Long-term debt (for capital expenditures) grew 101 percent during that period. As a percentage of local expenditures, water service fees grew from 6.3 percent in 2000 to 6.7 percent in 2012 (Anderson 2015).

A water utility can be a freestanding special-purpose district or agency with its own elected board or a department within the local general-purpose government. In the latter case, the department is usually legally structured as an enterprise fund—that is, revenues generated by that particular water service cannot be used for other purposes. Their customers, called ratepayers, are also taxpayers and community members—and so financing water services should be a concern of planners in drafting land-use plans, crafting regulations, and reviewing development projects.

The price of water services is passed on to consumers through fee or rate structures, or user fees. Rate structures, as the utilities call their fee schedules, are designed to retire (pay back) the debt service incurred with bond issuance, to pay for the costs of operations and maintenance, and to generate capital reserves. The following sections describe fee structures for water supply, wastewater, and stormwater services.

Fee Structures for Water and Wastewater Services

Water and wastewater utilities use a combination of a fixed (base) fee and a variable fee for their water rate structures.

Fixed charges generally include the price the customer pays as a base charge to help cover costs for maintaining existing infrastructure and repaying loans and bonds used to build that infrastructure. Variable charges, in the case of water supply, are the price the customer pays for the volume of water used and reflect the costs of providing water, such as costs for chemical treatment to provide safe water and energy to move and deliver water.

Today, most local water agencies meter use and charge by volume (Raftelis 2015). Most sanitary sewage is not metered, so residential sewer fees are typically based on a percent of water use, and are included in the water bill (Stratus Consulting 2013b).

Reclaimed water rates pose a special issue because reclaimed water usually costs more to produce than water from conventional sources and can be of lower quality. However, use of reclaimed water reduces the demand for potable water and may even help lower costs when it is used to recharge groundwater supplies. Reclaimed water rates set by water utilities are generally based on some percentage of the potable water rate. Some agencies price reclaimed water below the potable water rate to encourage its use (AWWA 2015).

There are several different types of rate structures that can be used by water utilities and, by extension, the wastewater utility, as these bills are often based on the water supply bill. The fee type can also vary among residential, commercial, and industrial users. See the sidebar on pp. 98–99 for descriptions of the various fee structures currently in use by water utilities.

The type of fee structure used can influence water use. Using conservation rate structures can reduce water demand by 7 to 20 percent. However, it may be difficult for a utility not facing an imminent crisis to switch from a uniform rate structure to an increasing block rate structure, which is the most common conservation rate structure. This is because water agencies have elected boards (in contrast to other utilities such as electricity and media) and although water fees are the lowest of all the utilities for a typical family's monthly budget, a change in the way fees are assessed often results in consumer complaints to the elected board (Donnelly and Christian-Smith 2013).

Utilities are generally moving away from flat and uniform rates (historically the earliest type of fees) toward increasing block rates, despite the political implications. In 1996, 39 percent of water agencies used uniform rates, 33 percent had declining block rates, and 4 percent were still using flat rates, while 22 percent used increasing block rates and another 2 percent employed seasonal price structures (U.S. EPA OW 2002a). More recently, a 2015 report found that flat rate use had dropped to 1 percent and uniform rate use to 29 percent, while the use of increasing block rates had risen to 50 percent (Figure 6.1) (AWWA 2015).

Water and sewer system fees have land-use and equity effects. Research has shown that the costs of providing sewer (and water) service are higher in areas that are farther away from existing centers and that have larger lot sizes. If water and sewer costs are charged to the development, there is an incentive for the developer to minimize these costs, which may have adverse effects on infrastructure quality. In addition, where average cost pricing is used for both new development and replacement of existing infrastructure, those in more compact areas—often minority or low-income residents—subsidize the costs of those in less-dense areas (Speir and Stephenson 2002).

Planners can support the utility's conservation efforts. They can also work with the utility to encourage it to meter

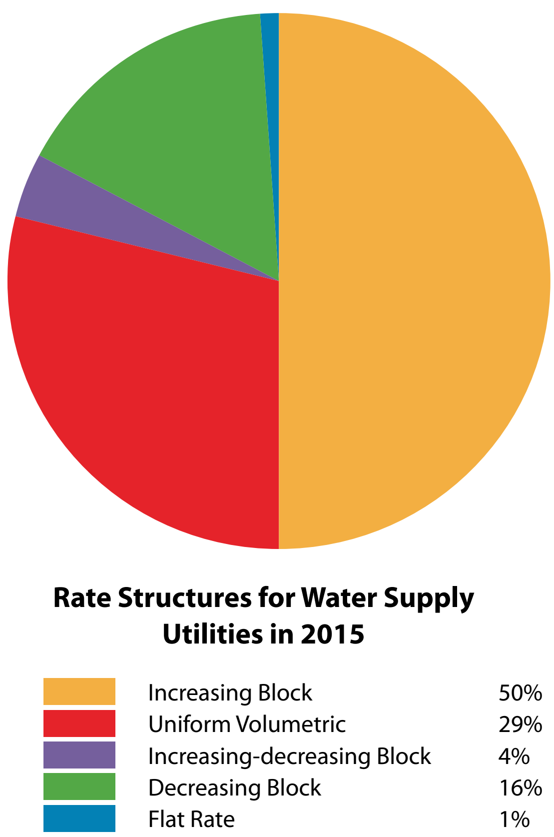


Figure 6.1. Types of water rate structures used by U.S. water agencies, 2015 (Authors, data from AWWA 2015)

RATE TYPES

According to the EPA, water rates should be set "such that they reflect the full long-range costs of operation and maintaining a water utility, as well as the scarcity and value of the resource, while also encouraging and rewarding conservation and efficient use" (U.S. EPA OW 2016, 32). Fee or rate structures usually consist of two parts: a fixed charge to cover costs that must be covered regardless of the amount of water used, and a volumetric charge that varies with the amount of water consumed.

Conservation fee structures, which apply to the volumetric portion of the fee, can send price signals to consumers to use less water in the summer or during peak-use periods, thus avoiding the need for new capital facilities. This sidebar describes both the traditional types of fee structures—which do not encourage conservation—as well as the various types of conservation fee structures.

Nonconservation Rate Structures

Flat Fee is a rate structure where all customers are charged the same fee per unit of water use, regardless of the amount of water used. Flat fees are the simplest type of rate structure and are rarely used today. They generally don't provide revenue sufficient to operate the utility and are not good at promoting water efficiency.

Uniform Rate is a constant per-unit price for all metered units of water consumed on a year-round basis. It differs from a flat fee in that it requires metered service. Some utilities charge varying user groups different rates, such as charging residential households one rate and industrial users a different rate. Uniform rates provide some stability for utilities and encourage conservation if the charge is set high enough, because the consumer bill varies with water usage.

Declining Block Rate is a structure where water usage amounts are divided into "blocks" and the unit price of each succeeding block of water use is charged at a lower unit rate than the previous block(s). This rate structure is popular in rural areas where there are large farming populations or areas with large users such as heavy industry and where water is plentiful.

Conservation Fee Structures

Increasing Block Rate, or ***Tiered Schedule,*** is a rate structure where the unit price of each succeeding block of usage is charged at a higher unit rate than the previous block or tier. Increasing block rates are designed to promote conservation and are most often found in urban areas and areas with limited water supplies. Half of today's water utilities use this type of schedule. In North Carolina, for example, municipalities that use increasing block rates for residential use include Aberdeen (with six blocks), Durham (with five blocks), and Charlotte (with four blocks) (NC League of Municipalities and UNC Environmental Finance Center 2017). Table 6.1 provides Durham's tiered monthly water rate schedule.

Seasonal Rates cover a specific time period. These kinds of rates are established to encourage conservation during periods where water demand peaks but water supply may decline. This

TABLE 6.1. 2017 TIERED MONTHLY WATER RATES, DURHAM, NORTH CAROLINA

Tier	FY 15 Rates	FY 16 Rates	FY 17 Rates	FY 18 Rates
Tier 1 (0–2 CCF*)	$1.77	$1.82	$1.88	$1.93
Tier 2 (>2–5 CCF)	$2.67	$2.74	$2.83	$2.91
Tier 3 (>5–8 CCF)	$2.92	$3.00	$3.10	$3.19
Tier 4 (>8–15 CCF)	$6.36	$3.91	$4.06	$4.16
Tier 5 (>15 CCF)	$5.72	$5.86	$6.07	$6.23

Source: Durham Water Management Department 2017

**CCF=100 cubic feet*

TABLE 6.2. 2017 SEASONAL RESIDENTIAL COMMODITY CHARGE FOR WATER USAGE, SEATTLE

Seasonal Water Usage	Inside Seattle	Outside Seattle	Shoreline & Lake Forest Park
Off-peak usage (Sept. 16–May 15)	$5.15	$5.87	$6.25
Up to 5 CCF* per month during peak usage (May 16–Sept. 15)	$5.29	$6.03	$6.42
Next 13 CCF per month during peak usage (May 16–Sept. 15)	$6.54	$7.46	$7.93
Over 18 CCF per month during peak usage (May 16–Sept. 15)	$11.80	$13.45	$14.31

Source: Seattle Public Utilities 2017

**CCF=100 cubic feet*

also helps reduce the need for new capital facilities. Examples of seasonal rates may be increases for the summer season due to increased demand associated with lawn watering. Los Alamos County in New Mexico has tiered or increasing block rates during the summer months. Seattle has a similar fee structure: a base service charge based on water pipe diameter, plus a tiered commodity charge with higher rates during the months of May 16 through September 15 that increases sharply with the amount of water used. Table 6.2 provides Seattle's seasonal rate schedule, which is also location-based.

Time-of-Day Pricing also covers a specific time period and requires a water meter that records use 24 hours a day. This concept is widely used for electricity. This type of fee structure could be used to reduce demand during daily peak-use periods and avoid the construction of a "peaker plant," which is usually more expensive than a large-scale plant. A 2009 pilot study of this fee structure in Palm Desert, California, resulted in residential use reductions of 50 percent during peak times (12–6 p.m. weekdays June 1–October 2) and a 17 percent reduction overall. No such effect was seen for industrial and commercial users (House 2010).

Drought Rates are similar to seasonal rates, but instead of applying higher rates during a specific time period, rates are authorized by the fee structure based on the local area's drought level. Higher levels of drought result in higher prices for water to meet the level of water restrictions necessary. California's Cucamonga Valley Water District established such a fee schedule in 2015. Its fee ordinance sets fees necessary to balance the books for water restrictions of 10, 15, 20, 25, 35, and 50 percent (CVWD 2015). The East Bay Municipal Utility District (EBMUD, which covers the communities of Oakland, Berkeley, and others in the East Bay of San Francisco) established a drought surcharge fee based on water use by tiers (EBMUD 2016). Table 6.3 provides EBMUD's drought surcharge fee schedule for 2016.

Water Budget-Based Rate is a rate structure where households are given a "water budget" based on the number of people living in the house or property size. If use exceeds that amount, they are charged at a higher rate. This strategy has worked to decrease irrigation water use in many instances. A number of California utilities have established this fee structure, including the Rancho California Water District, the Eastern Municipal Water District in Los Angeles, the Monte Vista Water District, and the Irvine Ranch Water District. The latter established the model for this type of fee structure in 1991 (IRWD n.d.). Not all economists, however, are enamored of the use of this technique because it interferes with market efficiencies (Beecher 2012). Table 6.4 provides the Irvine Ranch Water District's commodity charge for residential detached dwelling units, which increases rates based on the percent of "allocated" water used.

TABLE 6.3. 2016 DROUGHT SURCHARGE FEE SCHEDULE, EAST BAY MUNICIPAL UTILITY DISTRICT, CALIFORNIA

	Maximum Applicable Drought Surcharge in 4 Stages			
	1	2	3	4
Single-Family Residential Accounts				
<172 gpd*	$0.00	$0.25	$0.63	$0.79
172–393 gpd	$0.00	$0.33	$0.85	$1.07
>393 gpd	$0.00	$0.43	$1.12	$1.40
Multifamily Residential	$0.00	$0.34	$0.88	$1.10
All Other Accounts	$0.00	$0.34	$0.87	$1.09

Source: East Bay Municipal Utility District 2016

**gpd=gallons per day*

TABLE 6.4. 2017 WATER BUDGET-BASED COMMODITY CHARGES FOR RESIDENTIAL DETACHED DWELLING UNITS, IRVINE RANCH WATER DISTRICT, CALIFORNIA

Tier	Percent of Allocation	Rate per CCF*
Low Volume	0–40	$1.36
Base Rate	41–100	$1.70
Inefficient	101–140	$4.09
Wasteful	140+	$12.06

Source: Irvine Ranch Water District 2017

**CCF=100 cubic feet*

water use, if it does not do so—a good first step toward conserving water and reducing demand (AWWA 2015). Policies supporting water conservation can be adopted as part of the comprehensive plan, which sets the policies for local development.

Fee Structures for Stormwater Infrastructure and Programs

Stormwater runoff has traditionally been the responsibility of city or county public works departments, along with maintenance of streets, curbs, and storm drains. Special flood control districts existed in some areas, and the U.S. Army Corps of Engineers was responsible for large systems. The local systems were funded by municipalities' general funds as part of street and sewer improvements and maintenance.

However, with the passage of the 1987 amendments to the Clean Water Act, cities and counties were required to address pollution from urban runoff. Most local governments did not have special utilities for this function, so the responsibility was often assigned to the public works department. Large cities and counties were asked to come into compliance first (Phase I), and then a decade later the smaller ones followed (Phase II).

Early financing for off-site municipal infrastructure investments relied upon general funds from property taxes. On-site improvements were the responsibility of the owner of the parcel. Many major stormwater control systems, such as detention or retention ponds built in association with large parking lots, were included in the cost of development, either as a direct cost of construction or through development impact fees called system development charges (SDCs). Some localities began to charge fees for stormwater or to raise their sanitary sewer fees. The Phase I communities began with low rates, but the smaller Phase II communities were quite aggressive with rate structures since many did not have large general fund budgets (Veal and Mullins 2003).

The best practice today is for a locality to establish a stormwater utility (SWU) empowered to set fees. It can be housed in the public works department supported by an enterprise fund, or it can be a freestanding agency or special district (Matichich and van der Tak 2013). There are an estimated 2,000 to 2,500 SWUs in the U.S.; see Figure 6.2 (Campbell, Dymond, and Dritschel 2016). Many local governments still fund stormwater programs with the general fund through property taxes, but user fees are replacing general funds and today most SWUs rely upon some type of user fee. Over time, the emphasis in the stormwater management field has also shifted from flood control to a variety of programs operated by SWUs, including green infrastructure solutions.

Most SWUs today tie their fees to the amount of impervious surface of a parcel and hence to the volume of storm runoff generated by the user. This is now possible because of striking advances in parcel-based data systems. Satellite imagery from sources such as Landsat 5 or IKONOS-2 is a cost-effective way of estimating the presence and degree of imperviousness for large areas such as an entire metropolitan area or a watershed. Utilities can purchase digitized data from aerial photography that includes building footprints, driveways, sidewalks, and streets that have been adjusted for topographic relief (Berthiaume, Quiroz, and Ivey 2015). This data can be used to identify the impervious surface on an individual property or parcel. The National Oceanic and Atmospheric Administration also has a downloadable tool for ArcGIS that can calculate the percent of impervious surface for watersheds, municipalities, or subdivisions (NOAA OCM 2016).

There are several methods of fee calculation and rates used by SWUs. These include flat fees per water meter or parcel. Some methodologies use equivalent resident units (ERU) as an indication of impervious cover. An ERU is typically based on the average impervious area on a single-family residential parcel, although some communities define it as the average of all residential parcels. For nonresidential properties, residential equivalent factors (REF) may be used. This method calculates a fee based on the amount of runoff from a parcel compared to the runoff from a typical single-family residential property for a typical storm. It can account for differences in the permeability of the pervious surface. Tiers are also used, and a few methodologies use number of parking spaces, gross size of parcels, or numbers and sizes of water meters.

A survey by the University of Western Kentucky found that in 2015, the ERU was used by 47 percent of 1,538 SWUs. The flat fee was used by 15 percent, and a tier system which charges a single fee for a certain range of impervious area in the parcel was used by 14 percent. The REF is used by 9 percent. A dual system using one fee for residential and another for nonresidential was used by 6 percent. Other variations accounted for the rest (Campbell, Dymond, and Dritschel 2016).

Nationwide, the average monthly single-family residential stormwater fee in 2015 was $5.14. Fees ranged from zero up to $69.25 per month, although other studies that take into account fees for combined sewer overflows show higher maximums, such as $237 for Portland, Oregon, in 2013 (Campbell, Dymond, and Dritschel 2016; WEF 2013). The statutes in many communities link their fee levels to the Consumer Price Index so that additional legislation is not needed to raise fees as the cost to provide service increases over time (a problem for earlier stormwater fees).

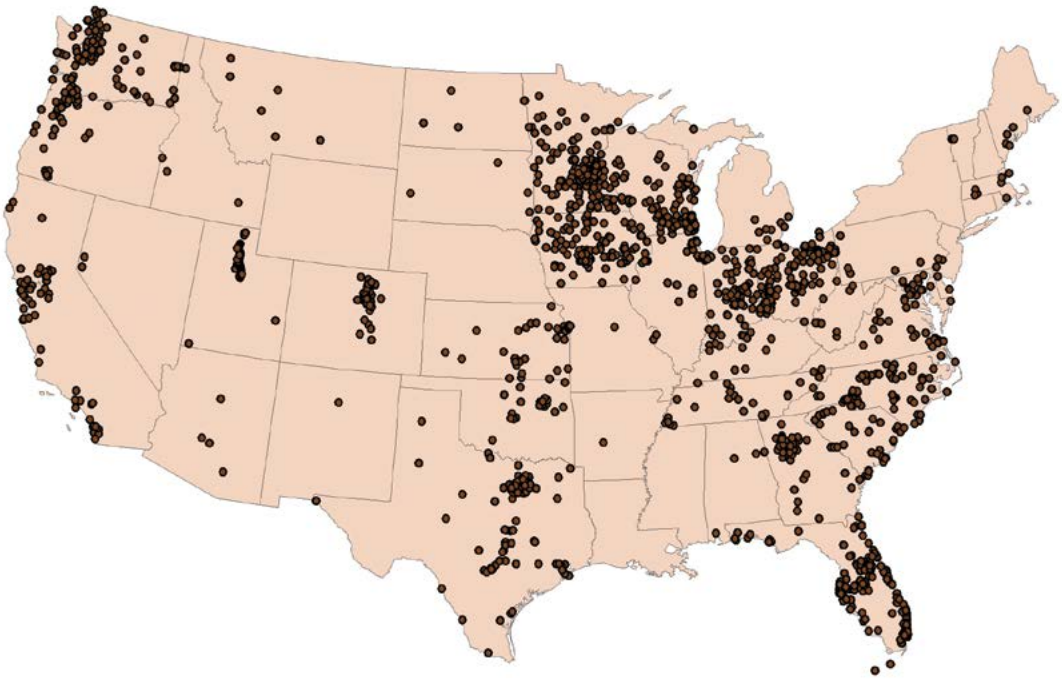


Figure 6.2. Location of stormwater utility fee programs by state as of 2016 (Western Kentucky University SWU Survey)

CAPITAL IMPROVEMENT STRATEGIES

Prior to the 1950s, the federal government played a major role in building dams, levees, reservoirs, and other water containment systems. Since the late 1950s these expenditures have declined substantially, but some are still made by the federal government, especially in the western U.S. by the Bureau of Reclamation (CBO 2015). In the 1970s and 1980s the federal government made significant investments in wastewater treatment plants due to Clean Water Act requirements, but today federal capital expenditures for local water services are much reduced.

Historically, water and wastewater utilities have relied on bonds for capital investment and user fees for operations and maintenance, as noted above. This section focuses on capital financing aspects and the sources of investment funds: bonds, state and federal revolving funds, and development impact fees.

Bonds

Most large-scale capital facilities for all three water sectors are paid for by funds from bonds issued by the local water utility or the local government. A municipal bond is an interest-bearing certificate that is exempt from federal income tax and, in many jurisdictions, state taxes as well. Bonds are similar to promissory notes—a promise by the issuer (the water agency or local government) to repay the investor the principal of the loan plus interest at the end of a fixed period of time, which can be anywhere from one to 40 years.

There are more than 55,000 issuers of municipal bonds in the U.S., and they range from the very large, such as the states of California, New York, and Illinois, to small rural school districts (Agriss 2008). State authorities have been the largest borrowers (for bridges and major waterworks), followed by special districts (e.g., water agencies), cities, and colleges and universities (U.S. Census Bureau 2003). In 2014, around 70 percent of local water and wastewater utilities issued bonds or other debt to borrow $34 billion to pay for water infrastructure (Copeland et al. 2016). Despite recent droughts, water bonds are still considered excellent investments (Cleaver 2015).

Tax-Exempt General Obligation Bonds. General obligation (GO) bonds are backed by the full faith and credit of the issuing government. Forty-two states require voter approval of GO bond issues. Although GO bonds were the original mechanism local and state agencies used to finance large-scale capital improvements, in 2015 these bonds were only 38 percent of all new issues, having been overtaken by revenue bonds (SIFMA 2016).

GO bonds generally have a lower interest rate than revenue bonds because they are backed by the taxing power of the government. In 2014, California issued a GO bond for $7.5

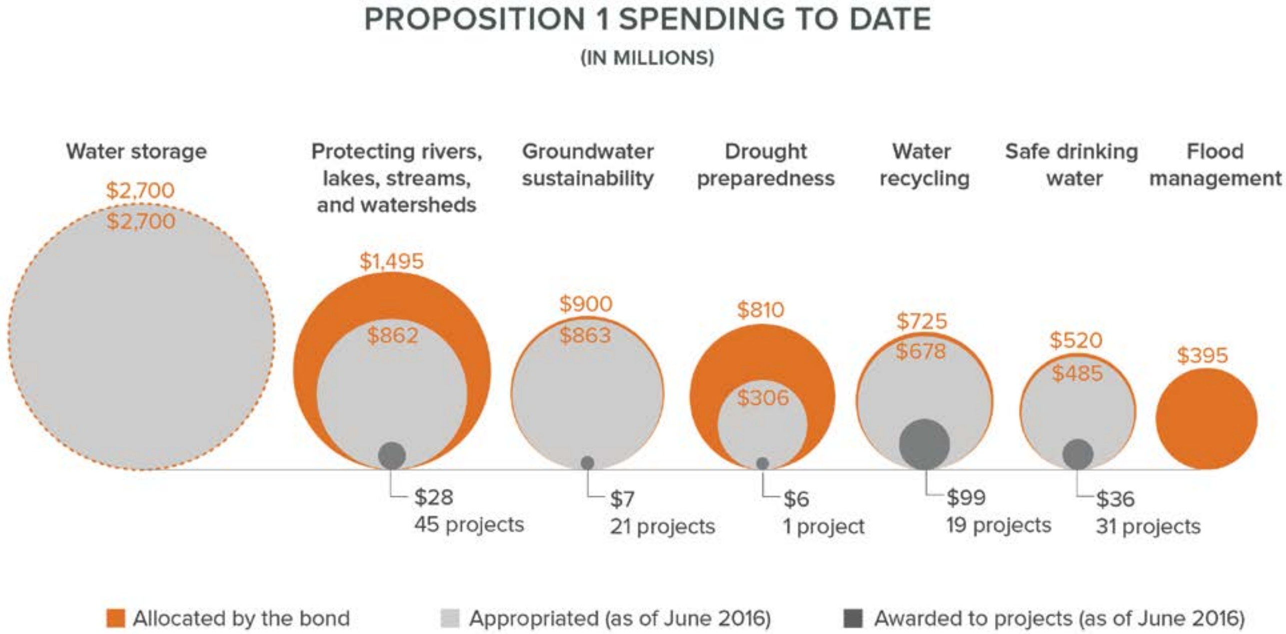


Figure 6.3. Allocation of California's Proposition 1 spending on water improvements (PPIC Water Policy Center)

billion for water improvements for regional and local water agencies and departments (Jezdimirovic and Hanak 2016). Figure 6.3 shows how the funds were allocated and how much has been drawn down as of 2016. The debt is paid for by funds from California's annual budget (taxes).

Revenue Bonds. In 2015, 56 percent of all new municipal bond issues were revenue bonds (SIFMA 2016). These are the workhorse of single-purpose special districts formed to build and operate water and sewer infrastructure. Revenue bonds rely upon user fees or dedicated revenue sources from the proposed capital facility to repay investors. In most states, revenue bonds are not legally part of a government's debt ceiling and do not require voter approval. They carry a higher interest rate because they are less secure than GO bonds, but they are still tax-exempt (Provus 2006).

Bond Ratings. Rating agencies establish letter grade ratings (e.g., AAA, AA, A, B, C) for a particular bond issue, which sets the interest rate that the utility will have to pay. The rating agency is primarily concerned about whether the project will produce the revenue to repay the loan. The rating agency will also want to know that the agency is well managed and that it will have funds to repay the loan after considering needs for operating and maintenance (Provus 2006). This is called "coverage ratio." In the past, rating agencies required ratios of 1.5 to 2.0 of net available funds to the debt service of the bond. More recently, they have required a ratio of about 1.3 to 1.4, lower if the project is strong and higher if it is a weaker project (Thau 2011).

Another concern of the rating agency is the local debt supported by the same tax base of the jurisdictions served by the utility. Although water utilities for supply and wastewater treatment are typically either separate from or discrete legal entities within local governments, the bond market makes its determination about interest rates for water infrastructure based on the debt that all the agencies in the jurisdiction have—the school district, the water agencies, and the local government. The level of debt as a percentage of the local government's budget is scrutinized, with 10 percent or more raising questions. Rating agencies also use debt per capita (including debt from overlapping jurisdictions) to assess the ability of residents to support debt. Additionally, rating agencies look at local debt as a percentage of real estate market value in the jurisdiction, with 2–5 percent considered normal, above 6 percent high, and above 10 percent a credit problem (Marlowe et al. 2009).

Federal and State Revolving Low-Interest Loan Funds

During the 1970s and 1980s, the federal government funded a grant program that provided more than $60 billion to construct publicly owned and operated wastewater treatment projects. The grant program ended in 1987 and was replaced with the Clean Water State Revolving Loan Fund (CWSRF), which consists of seed money for states to capitalize state loan funds. Beginning with a federal investment of $39 billion, state revolving loan funds had issued 36,000 low-interest loans amounting to more than $111 billion to communities through 2015. This has funded water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed and estuary management (U.S. EPA 2017b).

Nationally, interest rates for CWSRF loans average 2.2 percent, compared to market rates that average 4.5 percent. Therefore, a CWSRF-funded project costs 19 percent less than projects funded at the market rate. CWSRFs can fund 100 percent of the project cost and provide flexible repayment terms up to 20 years (U.S. EPA 2017b).

In 1996 the Safe Drinking Water Act was amended to provide funds to states to operate the Drinking Water State Revolving Fund (DWSRF). The objective of this program is to help ensure safe drinking water. It functions in a similar fashion to the CWSRF above. The initial federal investment was about $19 billion. By 2016 the revolving loan funds had provided more than $32.5 billion to water systems through 12,800 assistance agreements (U.S. EPA 2016d).

In 2014, the Water Infrastructure Finance and Innovation Act (WIFIA) created a new federal loan program for water infrastructure to work with state revolving fund programs. WIFIA authorizes the EPA to provide long-term, low-cost rate loans for up to 49 percent of eligible project costs for projects $20 million and above for large communities and $5 million for small communities (population of 25,000 or less). The $30 million appropriated for WIFIA in its inaugural year of 2017 will provide approximately $1.5 billion in credit assistance and finance over $3 billion in water projects (U.S. EPA 2017a). The EPA will give funding priority to projects for adapting to climate change and extreme weather, energy efficiency of treatment plants and water systems, green infrastructure, and repair or replacement of deteriorated water infrastructure systems. By May 2017, the EPA had already received 43 letters of interest from communities (AWWA 2017). Concerns have been expressed, however, that this program might divert funding away from the state revolving funds in the long run (Ramseur and Tiemann 2017).

Development Impact Fees for Water Facilities

In the 1980s, many local governments struggled to finance water and sewer infrastructure to accommodate rapid development. Existing facilities were no longer able to keep up with growing populations. City and county regulations required on-site water, sewer, and storm infrastructure but most did not address needs for off-site, large-scale facilities, such as water supply or sewage treatment plants. Accordingly, some cities and counties began to charge a one-time fee during the development review process that allowed the locality to fund the cost of the new infrastructure needed to support that project. The practice was subsequently codified through litigation by developers and ultimately by state enabling legislation (Galardi et al. 2004). These fees can be called development fees, impact fees, connection fees, SDCs, or capital contributions charges.

There are three approaches to establishing development impact fees. The first is a system buy-in or reimbursement approach for new development based on existing facilities and costs. Under the second approach, new development pays for the cost of new facilities. The third is a combination of these two. All three approaches are used for water supply, wastewater, and stormwater today, and are regulated by enabling state legislation and case law. However, discussions about impact fees for capital improvements have only recently been incorporated into fee-setting guidance from water, wastewater, and stormwater professional organizations. The planner and the utility can typically coordinate on this during the project plan review process.

Legal justification of the development impact fee is based on documentation of the methodology. Ideally, this is based on a detailed capital improvement plan so that the costs of the infrastructure can be allocated to the development. To do this, an indicator is selected (often called a scaling measure) to distinguish between different classes of users so that customers who are larger or use the infrastructure more intensively pay the costs of the capacity required to serve them. For water and wastewater, this indicator can be the water meter size, the number of plumbing fixtures, or any other measure readily available that is a reasonable surrogate for the development's share of the capital costs (Nelson 1995). For stormwater, the indicator typically used is the percentage of impervious surface of the development.

FUNDING FOR WATER SYSTEM INNOVATION

As experts note, the future will require new types of water system infrastructure:

> Utilities will need to invest in improvements that some people today might not even consider infrastructure

> but that by the 22nd century will seem as natural and essential to utility systems as dams, aqueducts and deep tunnel pipes do today. This new infrastructure will include drought-resistant landscaping, low-impact development, water-efficient appliances, building and manufacturing systems and even point-of-use catchment and treatment systems. Frequently, it will be installed not on utility property but on the property of utility customers. (Leurig and Brown 2014)

Distributed and multipurpose systems—including satellite treatment plants, on-site water and nutrient reuse (including stormwater harvesting), and green infrastructure—have been noted by many as ways of addressing some of the problems with the industrial era system (Novotny, Ahern, and Brown 2010; Nelson 2012; Brown 2014).

It is often less costly—and can be profitable for private investment—to implement distributed water services by capturing and managing water where it falls and using treated wastewater on-site (Broaddus 2012). Distributed and multipurpose systems reduce the transportation costs of water and wastewater. When water and nutrient reuse is involved, they also reduce pollution from wastewater treatment plants into receiving water bodies and reduce demand for potable water from large-scale treatment facilities. They also reduce energy use and carbon emissions.

However, traditional governance systems and financing mechanisms are difficult to use for these innovative systems and ideas. There are many regulatory barriers at the state and local levels and a lack of organizational commitment and capacity by the water utilities. A blue-ribbon commission was launched in 2016 to develop model state and federal guidelines for on-site nonpotable water systems (WE&RF 2016), but public agencies are reluctant to try new technologies when public health can be at risk. In addition, the municipal bond market has been geared to large-scale water projects. Financing for distributed systems and small-scale water projects will be a new challenge for the bond market.

Leading-edge cities and states have already been using bonds for conservation and green infrastructure on private properties. For example, New York City sold bonds to finance water conservation programs, such as buying back older toilets that use more water than newer ones and installing or replacing water meters. Seattle has used bonds for distributed infrastructure systems since the late 1990s. The Southern Nevada Water Authority in Las Vegas funded a landscape conservation program for private properties with the proceeds from bonds, with over $30 million spent from 2009 to 2013 (Leurig and Brown 2014). In some cases the utilities have not used revenue bonds, but instead encumbered their private credit or attributed specific water savings or stormwater retention to individual green infrastructure subprojects (Leurig and Brown 2014).

A shift toward distributed and small-scale systems will require changes in the financial markets as well as local and state regulations to permit more sustainable water systems. One key issue is improvements such as distributed infrastructure on private properties. Revenue bonds, where the debt is repaid from dedicated enterprise funds, may fill this gap. In many localities and states, private property improvements are neither authorized nor precluded from bond proceeds, but leading-edge utilities have been able to obtain legal opinions necessary to issue the bonds. However, for this practice to become widespread, explicit enabling legislation is needed.

Municipal bonds are not the only mechanism that can be used to fund water innovations. Tax increment financing (TIF) by a redevelopment agency specifically enables the local redevelopment authority to use public funds on private properties for a public purpose. TIF funds bonds that are repaid by the increment in taxes from a property's predevelopment tax revenue and postdevelopment revenue. The redevelopment agency must make the argument that the private sector would not otherwise have undertaken the development of the parcel and therefore the public agency must step in. Individual states have different redevelopment laws (White and Kotval 2013).

Redevelopment agency involvement and funding could also be used to develop eco-districts with multipurpose infrastructure and on-site net zero solutions in the U.S. Eco-districts are large-scale developments where water, energy, and solid waste systems (and transportation and telecommunications) are integrated in a holistic way (Elmer and Fraker 2012). Versions of the redevelopment agency concept have been used in Europe for the eco-districts of Hammerby, in Stockholm, Sweden; Kronsberg near Hannover, Germany; Vauban near Freiburg, Germany; and Bo01 near Stockholm. In these cases public agencies took over old industrial sites or sites otherwise available for large-scale urban development, and acted like redevelopment agencies in putting together the framework for the sites. Key decisions were to require the energy, waste, transportation, and stormwater utilities to use decentralized and net-zero approaches. Similarly, building developers were required to install green infrastructure (Fraker 2013). In the U.S., the Battery Park Redevelopment District in New York City had requirements that made green projects competitive in the district (Terrapin Bright Green 2017).

Other financing techniques for distributed and on-site water infrastructure include special assessment districts and BIDs (business improvement districts). If the property owners of a neighborhood wish to finance a local infrastructure program, including services, they can establish an assessment district where the funds go for a specific purpose. This is administered by the city or county, or a water district. The owners must vote to establish the district and the assessments are added to their tax bills (Elmer and Leigland 2014).

Subsidies from water utilities are also possible. The water district of New York City agreed to a lower fee for water services for the Solaire Building because the building implemented an on-site blackwater water reuse system. The San Francisco Public Utilities Commission provides development subsidies for on-site water reuse and recycling (SFPUC 2017).

Public-private partnerships, such as those used in the electricity sector for distributed electrical systems, may also be considered. Although it is not likely that these partnerships will become widespread for the centralized utilities, they could be used for financing on-site multisector improvements. Other innovative financing techniques used in the electricity sector that could be adapted for funding distributed water system infrastructure development include aggregating small projects to facilitate transactions and overcome risk; alternative investment structures such as real estate investment trusts, YieldCos, and master limited partnerships; end-to-end service companies that facilitate resource flows between financing and implementing institutions; net metering programs for water reuse; on-bill financing and repayment systems (e.g., property assessed clean energy, or PACE, programs); "green banks" dedicated to sustainable utility development; and end-user or public benefit fees imposed by utilities on ratepayers (Quesnel et al. 2016).

WATER MARKETS AND WATER RIGHTS

Water marketing can be defined as "the voluntary transfer of the right to use water from one party to another on a temporary, long-term, or permanent basis, in exchange for compensation" (Hanak and Stryjewski 2012, 7). Water markets are created by the interactions of buyers and sellers regarding quantities and quality of water. They can reallocate water rights from lower- to higher-valued uses, thereby, according to economists, making water use more efficient. They can also be used to incentivize conservation in low-cost water sectors such as agriculture to make more water available for higher-valued residential markets.

Most recently, water markets are being used as a way of addressing the undersupply of environmental "goods." Water markets can quantify the benefits that people receive from healthy ecosystems to translate them into credits that can be bought, often by environmental groups (IWW & IWR 2012). Water markets are governed by water rights.

Water Rights

Water rights for surface water can be divided into two categories: riparian rights/reasonable use doctrine and prior appropriation. Water rights for groundwater was dominated by the rule of capture but this is now changing. All three are discussed below.

The riparian rights concept arrived as part of the expectations of early settlers from England to the water-rich eastern region of the country. According to this doctrine, the property owner adjacent to a river can withdraw as much as needed for use on the property as long as there is no harm to the downstream user. This worked when water needs were low. The doctrine of "reasonable use" to refine the unlimited use of a riparian right emerged in the later part of the 19th century as mills and other industrial uses with large water needs began to threaten the water supply for downstream users. Eventually the courts allowed eastern cities to import water from other watersheds—as New York City does now from upstate New York (Adler 2009).

Prior appropriation doctrine arose in the semi-arid west where water needed to be moved from rivers to users. This doctrine holds that the first entity to take water from a surface water source for a "beneficial use" has the right to continue to use the same amount of water for that given use ("first in time, first in right of use"). Beneficial uses include agricultural, residential, and commercial uses. Only recently has ecological use been accepted as a beneficial use and only in a few locations.

Today, in western states, users apply for a permit from the state that specifies the quantity of water that can be diverted from a surface water source within a given time period. Priority for water use accrues to those by the date of water diversion. If the water is not used in that time period, the user loses the right to the water (Adler 2009). Thus, in these water-scarce states, owners of water rights have an incentive to use water rather than conserve it.

Groundwater rules in many states follow the rule of capture or absolute ownership doctrine. This allows the landowner the right to "capture" as much groundwater beneath his or her property as can be put to a beneficial use. No set amount is guaranteed and water can be withdrawn at any rate, even if other property owners nearby are harmed. This approach is still in practiced in some eastern states, but generally state courts have ruled that owners must use only a fair share (Joshi 2005).

Adverse effects of overdrafting (removing too much groundwater) include land subsidence (sinking) and saltwater intrusion into freshwater aquifers in coastal areas. California's Central Valley has been experiencing subsidence since 1922; this is the largest area of subsidence in the U.S. and the resulting groundwater shortages have affected low-income households (see Chapter 4). Some other states with subsidence issues are Arizona, Florida (Barlow 2003), and Wisconsin (Luczaj and Masarik 2015). Saltwater intrusion into freshwater aquifers as they are depleted is found on both the east and west coasts (York 2016; Barlow 2003).

Water Trading, Water Banking, and Water Markets

In the western U.S., water markets operate within river basins or sub-basins as most of these states prohibit water transfers out of the basins. Most short-term trades are made within a sector, especially in the case of agriculture. Agriculture-to-urban transactions often involve long-term leases or sale of the water rights. The growth of water markets is impeded by the lack of regulatory authority and the high capital costs of conveyance infrastructure in many areas (Howe 2011).

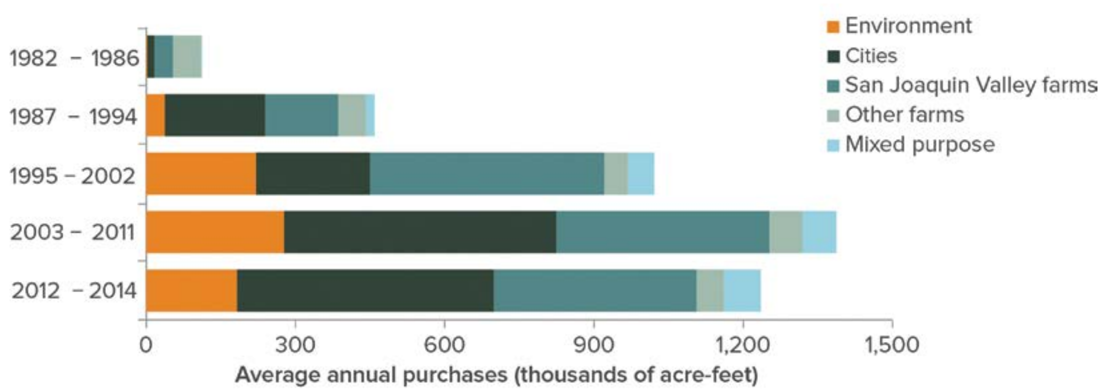
Water markets have been used to address scarcity issues. Many "senior" water rights, which are more valuable than "junior" rights because of their ability to prevail over the junior rights in time of scarcity, are owned by agricultural uses. Hence, in California, there are many trades between low- and high-value agricultural uses, as well as between agriculture and residential uses (Hanak and Stryjewski 2012). Figure 6.4 shows water transfers from 1982 through 2014 by different users within California. For example, in San Diego, the urban water agency purchased agricultural water rights, which have a low cost, at residential water rates to permit more development in that area. The agriculture owners employed conservation measures to free up their water for the urban area (Loux 2005).

A related practice is groundwater banking in depleted underground aquifers. Arizona has been practicing groundwater banking for some time (Gies 2015). In 2017, when historically high amounts of precipitation fell in California, many water districts pumped water into recharge basins or empty underground aquifers (Griswold 2017). See Hanak and Stryjewski 2012 for a useful overview of groundwater banking in California.

Environmental Water Markets

From 2003 to 2012, nationally about $56 million in water rights—620,000 acre-feet of water—were traded for environmental purposes. These trades were prompted by endangered species regulations and require collaborative efforts by public and private entities (Garrick et al. 2009). Most buyers in this market are federal and state agencies and nonprofit organizations. Sellers have been irrigation districts and agricultural owners. Recently tribes and operators of hydroelectric facilities have shown interest in participating in environmental water markets (WestWater Research 2014). Table 6.5 summarizes environmental water market transactions in 12 western states.

Figure 6.4. Water transfers in California from 1982 through 2014 (PPIC Water Policy Center)



SOURCE: Updated from E. Hanak and E. Stryjewski. California's Water Market, By the Numbers: Update 2012 (PPIC, 2012).
NOTES: The figure shows actual volumes purchased by different sectors. "Mixed purpose" denotes purchases by agencies with significant urban and agricultural uses, such as the Coachella Valley Water District and the San Luis Delta Mendota Water Authority.

Oregon and Washington have been the most active states to embrace water markets for instream uses to preserve fish and wildlife (Szeptycki et al. 2015). Water law in Oregon is governed by the prior appropriation doctrine; water is owned by the people of Oregon and managed by the state through a permit system that specifies how much water is contained in the water right. Beginning in the early 1990s, Oregon's laws permitted water conserved by a senior owner to be transferred to instream uses and not to be used by other junior water holders (OWRD n.d.). One of the first market transfers occurred in the Deschutes River, where salmon could no longer find a passage as a result of overuse by local irrigation districts. Steelhead and salmon have since returned to the streams (IWW & IWR 2012).

Despite such successes, water markets face a number of challenges. Conservation groups may be blocked by state water codes from buying existing water rights, administrative procedures are time consuming, and water conservation efforts may result in more water going downstream to other lower-priority users that did not have to pay the costs of the effort (Aylward 2009). In addition, it is difficult to accurately value ecosystems, which can provide clean drinking water much more inexpensively than large-scale infrastructure facilities and new supply development. These services are often not reflected on utilities' balance sheets, which could help expand debt capacity for other capital improvements (Broaddus 2012).

TABLE 6.5. TRANSFERS OF WATER RIGHTS TO ENVIRONMENTAL USES IN 12 WESTERN STATES

State	Number of Total Transactions	Average Review Time
Arizona	0	N/A
California	34 (15 long term/permanent; 15 short term; 4 emergency)	1.3 years (long term); 4 months (short term)
Colorado	34 (7 temporary)	6.5 years (long term)
Idaho	30	3.8 months (state water bank)
Montana	50 (1 pending)	1.5–2 years
Nevada	57 (18 temporary)	
New Mexico	1	
Oregon	113 transfers; 1800 leases	2.8 years (transfers); 30–40 days (leases)
Texas	Approximately 20	1 year
Utah	8	1–2 years
Washington	1118 (586 temporary donations)	6 months–6 years
Wyoming	1	1 year

Source: Szeptycki et al. 2015, p. 3

HOW PLANNERS CAN GET MORE INVOLVED

Forward-thinking water utilities understand that development needs to be coordinated with water planning in a way that was not required 50 years ago. Less clear to them might be the aid that planners can provide for financing decisions and strategies. Though comprehensive plans, development regulations, and project reviews are their typical purview, planners can also effectively participate in the financial decisions their communities make through capital improvement plans (CIP) and budgets, fair and equitable fee structures and programs, and cost reduction measures.

Capital Improvement Plans

Water utilities typically have long-term CIPs and yearly budgets that reflect investment and pricing decisions as noted in the previous sections. Budgets are usually separated by function (supply, wastewater, and stormwater), regardless of whether the utilities stand alone or are part of the city or county government.

Planners have not historically been involved in the preparation of water utility CIPs; this has been the purview of the water utility or the water/wastewater department within the public works department of the city or county. These documents, known as facilities plans, are usually prepared by specialized contractors. They provide long-term programs for infrastructure and are then translated into specific budgets for the water utility. The water utilities' capital budgets are usually not incorporated into the city or county's budget and CIP unless the utility is part of the local general-purpose government. This must change to take advantage of the synergies that are possible with integrated water and development planning. The planner must insure that the CIPs for the water sectors are consistent and integrated into the city or county's CIP and comprehensive plan. Regional studies and integrated regional CIPs would also be optimal.

In addition, methods of valuing the benefits of infrastructure investments should fairly estimate their value to future generations, as well as today's citizens, in order to judge the capacity of these systems while the environment changes. Debt periods that are selected to pay for today's infrastructure investments extend far into the future, and must not be allowed to prevent future generations from being able to adapt to new circumstances.

Fair and Equitable Fees

Planners have a responsibility to work with their local utilities to ensure that the procedures for setting fees and collecting revenues are fair and equitable. (See the discussion about affordability in Chapter 4).

Low-income households typically use less water than high-income households (Osann 2016), but higher demands from wealthy users may cause the overall cost of water services to rise as infrastructure projects are built to address the higher overall demand. For example, in Hillsborough, California, where median household income exceeds $250,000, per capita household water use in 2015 was 181 gallons per person per day (pppd), compared to 43 gallons pppd in nearby East Palo Alto, where the median household income is less than $53,000 (Cooley et al. 2016).

Most water utilities have regulations that do not permit them to subsidize water fees for low-income households, but innovative utilities and states have been pioneering a variety of programs. In these cases, planners may be able to assist the utility in finding sources of funds to subsidize water fees for vulnerable populations. For example, the city of San Diego recently approved a program that permits customers to make a tax-deductible donation to fund water bills for low-income households (Bowen 2016). Santa Rosa, California, began a similar program in 2016 for 1,000 households in which 50 percent of the cost of water bills would be paid for by voluntary donations and revenues from leasing public property for cell phone towers (Cooley et al. 2016). The EPA provides additional examples of successful consumer affordability programs on its Water Infrastructure and Resiliency Finance Center website (www.epa.gov/waterfinancecenter), and the Pacific Institute (n.d.) also has similar examples.

In addition to fee rates, administrative processes and procedures for billing may discriminate against low-income households. Some utilities send out bills every two months. This can pose a hardship for some families. Flexible payment plans, level billing throughout the year, changing the billing date to match the customer's paycheck, and due-date extensions are some features employed by utilities in the Bay Area to serve low-income households (Cooley et al. 2016). Full due-process protections before service terminations is something that planners can propose to water service utilities if they don't already provide them. Installment plans to pay off old debt and assistance in reading water bills can also help residents.

Planners should ensure that preparation for the comprehensive plan includes an analysis of low-income households' ability to accommodate future water price increases. Comparisons of existing and projected costs with neighboring or similar jurisdictions might be helpful. The U.S. Conference of Mayors, American Water Works Association, and Water Environment Federation have published an assessment tool for water rate affordability (see Stratus Consulting 2013a). Planners can use this tool within their jurisdictions as part of the initial conditions assessment in a comprehensive plan update.

Cost-Reduction Measures

Many water utilities can reduce the costs of operation, maintenance, and debt payments. Although local land-use planners may not be as influential as their water utility counterparts in some of these decisions, there are opportunities for some planners to play at least a minor role in two areas: conservation and source water protection.

Conservation should be a primary strategy to reduce demand and eliminate the need for expensive new facilities that would cause rates to be raised to cover the cost of the bonds to fund them. Putting funds into leak reduction efforts for the utility's infrastructure, or establishing building regulations jointly with the utility to reduce leaks at the household level, will also reduce the need for new facilities. These programs can be considered as part of the capital planning process or as freestanding efforts. For example, a nonprofit may be willing to work with the local government and the utility on such a program.

Another cost driver is pollution in drinking water sources. If water treatment plants did not have to contract for costly regimes to remove the nitrates, phosphorus, and other pollutants from urban and agricultural runoff and from factory farm pollution, costs for water services would be lower. In January 2016, Des Moines Water Works began planning for an $80 million investment in denitrification technology to remove pollution caused by runoff from agricultural fertilizers and other chemicals (Des Moines Water Works 2016). The high costs for removing the herbicide atrazine from the local water supply caused a group of water agencies to sue the manufacturer. The case was settled for $105 million in 2012 (Berry 2012). Planners are trained to bring together groups in collaborative efforts to solve problems such as these, where the possibility of a win-win exists.

CONCLUSION

The role of the planner in helping to address challenges to more sustainable water systems in the U.S. is a critical one. Comprehensive plans and development regulations that are linked with local water capital improvement plans and budgets (or even better, multijurisdictional or watershed capital plans and budgets) are key to more sustainable, environmentally friendly, efficient, and equitable water provision. Part of creating these linkages involves understanding the financial underpinnings of the water system.

The coming years will see many changes to the water system that has worked so well for so long to protect our health, contribute to a vibrant economy, and make urban living possible. These changes will require investments by local governments and partnerships between local utilities and land-use and environmental planners. The information provided and the tools outlined in this chapter should enable planners to make significant contributions.

CHAPTER 7

PLANNING FOR WATER: THOUGHTS FOR THE FUTURE

This report is part of a larger effort by the American Planning Association to integrate water into land-use planning practice, much as transportation and housing issues are now seen to be inextricably intertwined with land use. This report introduces a very complex subject matter—water—for which planning practices are rapidly evolving in the 21st century as planners seek to implement more integrated water systems. Yet more needs to be done by the planning profession, water professionals, and the engineering and architectural community to address water resource management challenges, protect our cities from climate change impacts, and transition to the next generation of One Water infrastructure.

KEY QUESTIONS FOR THE PLANNING PROFESSION

As our communities grow, improved planning practices will better anticipate changing patterns of growth and resource use and provide more approaches to guiding that growth. Relative water abundance and weak or nonexistent restrictions on many types of development were largely the norm in the past. The planner of the 21st century now faces resource scarcity, increased competition over available resources, climate change variability and risk, infrastructure deficiencies, funding shortages, and local political barriers.

Planners have important roles in addressing the challenges listed above. We have enormous capacity to find technical solutions to individual issues, but we need a stronger comprehensive approach to "connect the dots," especially on issues like scarcity, safety, and quality as they relate to resource management on a regional scale. The following questions and preliminary guidance came out of the APA Water Task Force's work and are designed to help set future directions for planners involved in water issues (Cesanek and Wordlaw 2015).

1. How can planners better address key drivers and causes of water vulnerability?

Planners need to better understand the environmental/hydrologic and economic/political contexts that have contributed to the water issues they face today, thereby better understanding why water management is complex and conflict-ridden and how we reached this point of vulnerability. This report will serve as initial guidance, but as planners gain more experience in water and development, a wide variety of specialized materials and resources will be developed. The more expertise that planners have in water resource issues, the greater will be their abilities to provide more sustainable management opportunities using land-use, infrastructure, environmental, and economic planning tools.

The water supply used daily in homes and business usually originates in another location—in some cases in a different state—and its transport has been engineered so as to increase its convenient availability and use for society's needs. While such convenience can provide social, economic, and agricultural benefits, it also requires energy and resources, and causes sustainability dysfunction and inefficiencies. Such issues, involving triple-bottom-line sustainability, require the involvement of professional planners in land development densities and patterns, utility location, demand forecasting, natural environment conservation, capital financing, and community engagement to help create more sustainable outcomes.

2. How can planners build collaborative strategic partnerships and better operate across professions, communities, and regions?

We often look to federal and state government systems to fund projects of regional scales, especially if they cross jurisdictions. However, we can also achieve success by working at the local level and helping citizens to engage in building stronger economies and healthier ecosystems. We can evaluate our regulations to ensure they encourage innovative ideas in how stormwater management and wastewater reuse are integrated into development. Technology is advancing. Private industry is a leader in this and should be able to play a significant role in better management of water.

Water is ubiquitous in the urban environment. Water services—including drinking water treatment and distribution, wastewater collection and reclamation, and stormwater management services—are provided every moment of every day. The connections between water resource management and land-use planning are extensive and complex. By connecting with professional associations that are dedicated to addressing water issues in the urban environment, planners can leverage expertise, spearhead initiatives for sustainability and resiliency, and identify synergy with stakeholders. APA has a role to play in helping to establish such connections.

Water service sector professionals recognize that the ways in which buildings and neighborhoods are planned and constructed can offer solutions to a community's water challenges regardless of drought, flood, or water quality impairments. Enabling planners to interact early and often with these professionals to integrate water system needs and opportunities with other infrastructure services will help achieve community resiliency and sustainability.

Utilities believe that they have a "duty to serve," which historically has meant a focus on providing the water services their communities demanded rather than involvement in local planning decisions. But long-term, sustainable water resource planning will require water professionals and planners to work together. Due to short-term focus and the absence of resources and authority, utilities lack leadership and power to confront the challenges and to collaborate on the necessary scale. The best scale for addressing water resource challenges—the watershed—is perhaps the weakest political scale for action. However, planners have critical opportunities and roles in connecting the scales of analysis, understanding, and action.

3. What role can planning and design play?

Within the land management and development process, planners can help communities identify visions for improved water management, work with urban designers to create more water-sensitive urban spaces, and work with architects and landscape architects to recommend sustainable utility designs and green spaces. In the past, the focus of the design community (with some stunning exceptions) has been on mostly perfunctory utility extension and inclusion of more water-efficient shower, sink, and toilet appliances. Rather than assuming that new water and wastewater infrastructure service can always be extended to new development affordably, planners should work with utility leaders in the community to plan the most sustainable water resource use and infrastructure designs for new locations of development. As cited earlier, a few communities have already adopted ordinances to require that new development be water-neutral (in terms of requiring new water supply); these kinds of innovative approaches work at the front end of the planning and design process, rather than at the back end of water and wastewater infrastructure expansion and building design.

Urbanism and urban design has shifted toward a collaborative process merging the landscape, regional, and ecological scales with urban infrastructure issues. This creates an opportunity to address issues through both planning and urban design. Urbanism provided an important framework for this type of approach by placing cities into a broader environmental context. While this approach has done much to advance urban theory, it comes with a shortcoming: Regions and watersheds are usually politically and administratively impotent. To effectively implement larger-scale strategies, designers must consider the political and administrative landscape, forging interjurisdictional coalitions in the pursuit of those interests that are shared between distinct political units.

Spatial planning can no longer suffer from the trade-off or competition of interests. Instead, spatial planning must give direction and shape through vision and stories, in laws and regulations, and through programs and projects—helping to forge a wider, more inclusive perspective on the built environment. Such planning calls for design excellence to make explicit and confront differences, rather than relying on traditional or generic solutions. In such cases, design innovation can lead the spatial development process.

4. What knowledge and tools should be applied? What new tools are needed?

Planners need better information about managing water resource issues and expanded toolsets for identifying the water resource needs and impacts of alternative land-use scenarios. Scenario planning is a structured method designed to help communities better evaluate alternative future land-use and infrastructure decisions. Scenario planning models can help assess the effects of different assumptions and plans in meeting future community needs and goals. Scenario planning can also help communities understand their abilities to adapt and respond to new issues and changing circumstances such as climate change and energy security. For more information on scenario planning, see Holway et al. 2012.

Planners also need to help prevent misinformation from being used to promote false vulnerabilities and risks or promote dependence on infrastructure that may increase system vulnerability. An improved analytical framework for planners is needed to help guide the effective use of data for building community-driven resilience and water sustainability.

Geographic information systems (GIS) can provide a common platform for knowledge sharing and planning among the water supply, wastewater, and stormwater sectors. Historically, communities and their water utilities have not shared common platforms and have operated independently once population projections have been made and basic land-use patterns have been established. Common, validated, and objective data can help avoid actions based on insufficient or inaccurate information. Scenario planning that includes water, wastewater, and stormwater decisions will be an effective strategy for planning practitioners.

5. How can planning address uncertainty and risk, and anticipate instability?

Of the top 10 global risks of highest concern identified by the World Economic Forum for 2015, water crisis was listed first in terms of impact and eighth in terms of likelihood. Additional global risks can be explicitly linked to water-related issues: failure of climate change mitigation and adaption, greater incidence of extreme weather events, and food crisis (Cann 2015).

The importance of understanding the risk of alternative courses of action has been raised by prominent water organizations to steer decision making to lower-risk outcomes. Planners can help by connecting scales of analysis, integrating various technical disciplines, and building community and stakeholder consensus toward land-use, development, and infrastructure decisions that allow consideration of a fuller range of options, all toward the goals of reducing risk and impact, increasing the resilience of water systems, and enhancing sustainable and equitable outcomes.

Risk analysis is in its early stages for many communities. Flood- and disaster-preparedness professionals are on the cutting edge of assessing risk, and their tools can be borrowed or adapted for the land-use planning process.

PARTNERSHIPS AND CONVERSATIONS

The challenge of breaking down silos and engaging across disciplines is ever present in the planning profession. And given the interdisciplinary nature, range, and complexity of water management, it is virtually impossible for any single profession to identify all the system interactions and solutions. Planners should embrace this challenge and forge new connections with their counterparts at water-focused agencies, organizations, and departments.

There are increasing opportunities to engage in productive, inclusive conversations with a broad base of practitioners, citizens, and stakeholders who depend on sound water management. Interdisciplinary efforts have proven to be transformative by synthesizing the knowledge of different disciplines to guide decisions for improved outcomes. Planners must better define the dimensions of water resource challenges, work interactively with peer professions such as engineering and landscape architecture, and use decision support and public communications tools to support interactive work environments. Most importantly, planners must work interactively with their water and wastewater peers to promote closer cooperation and sustainable water resource planning across these sectors.

The Water Environment & Reuse Foundation and the Water Research Foundation are engaged in two separate but interrelated studies of mechanisms and approaches to fostering better interaction between planners and planning professionals, to be published in late 2017: *Integrating Land Use and Water Resources: Planning to Support Water Supply Diversification* (Becky Fedak et al., WRF Project No. 4623) and *Joining-Up Urban Water Management with Urban Planning and Design* (Philip Stoker et al., WE&RF Project No. SIWM5R13). APA has supported these research efforts, and the mechanisms proposed for improved interactions, the various processes proposed for problem definition, and the recommendations for various forms of engagement will be very useful for planners seeking to expand their roles in water management.

Only a few water professionals and planners are engaged in active long-term conversations and interactions today. Many are not involved in the others' spheres of influence and day-to-day work, despite the success that occurs when they are. Thus, inefficient and siloed solutions continue to be planned, financed, and constructed by local governments, water utilities, and developers, a situation that must change.

> Increasing evidence demonstrates that unsustainable land use practices result in human-induced drought conditions, and inadequate water supplies constrain land development in growing cities. Nonetheless, organizational barriers impair coordinated land and water management. Land planning is strongly influenced by political realities and interest groups, while water management is focused on the single-minded goal of providing reliable water for future development, often set apart from other priorities.
>
> . . . Water managers and land planners are generally aware of the physical interconnections between land

> and water, but there is little cross-sector involvement. . . . Focusing on shared concerns about outdoor water use, climate variability, and water-sensitive urban design is a fruitful first step in integrating the practices of land planning and water management for climate adaptation and sustainable resource use. (Gober et al. 2013)

As noted in Chapter 2, the interdisciplinary collaboration of the many agencies and professionals engaged in water management is essential to sustainable outcomes and wise water management, because the many perspectives on effective management require careful balancing. Toward this end APA has implemented a robust water planning initiative and in 2017 created the Water and Planning Network (discussed later in this chapter) to provide a new forum for exchanging information, research, and creating new connections between planners and other water professionals.

In the past, the planning community has typically assumed that water supply and wastewater management is a service that will be provided efficiently by utility agencies and others. We have learned that a broader vision and broader engagement helps to create more sustainable water management outcomes. Creating new conversations that lead to exchanges of information and science will help to forge new permanent partnerships that will not be limited by siloed missions.

WATER EDUCATION FOR PLANNERS

Given the interdisciplinary nature of water management challenges, and because solutions to water resource challenges range from economic to social to technical, an expanded education and training process is needed to prepare new planning professionals to meet these challenges.

This evolution of the professional planner is an important and necessary step forward. Understanding how to better address water management issues (including water quality, scarcity, and safety) will help planners create ecologically and economically sound urban systems. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change emphasized the importance of educational efforts and tools to aid in addressing climate change, noting that "adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can help create resilience to uncertain hydrological changes and impacts due to climate change" (IPCC 2014, 14). By creating educational opportunities that reach beyond the classroom to include executive and field-based learning, we will see a new generation of planners capable of creating more sustainable cities designed to protect natural and water resources.

As planners, we have responsibilities not only to practice but to continue educating ourselves, the communities around us, and future planners. We need to improve water education for planning students so they are adequately prepared to address water challenges from the start of their planning careers. At the same time, educational opportunities must be made available for elected and appointed officials and practicing planners who are facing water-related challenges that require action now. APA can offer guidance, support, and perhaps most importantly, essential educational opportunities to prepare planners and decision makers to lead and respond effectively to emerging water challenges.

While planning-school curriculums have adapted in the past to include new technologies such as GIS, new subject matter is still often relegated to specializations and elective courses. The intersection of planning and water, energy, and climate is the new normal and should be integrated into traditional planning education side by side with land use, zoning, and transportation. There is enough literature, technical tools, and real-world applicability that warrant some level of insertion into the basic working knowledge of new planners, while standardizing deeper specialization opportunities as well.

It is important to arm planners, both in the classroom and in continuing education, with more technical skills to address water issues so they have the confidence to participate in water management dialogues. Planners working in water management may be hesitant to step up and direct the conversation. In the roles of facilitators we usually yield to more technically inclined water experts to take control. While their expertise is indeed a necessary part of the discussion, it is the planner who can see the big picture and connect what water experts are saying to other important urban issues. Planners should be encouraged to update skillsets that incorporate more technical knowledge (engineering and hydrology, for example) so that we can not only facilitate the water management dialogue but also drive it.

The profession should work with other disciplines to foster education programs and water-based curricula for primary, middle, and secondary schools as well as university and community colleges. Educating people about water-related principles, issues, and opportunities, as well as providing training for jobs in this emerging sector, are essential.

Beyond the classroom, planners have responsibilities not only to practice but to continue adding to their knowledge of water trends, challenges, and opportunities that impact

ACADEMIC WATER SURVEY

To better understand current planning program content related to water, APA conducted a survey in cooperation with the Association of Collegiate Schools of Planning (ACSP) in 2016. The results of this survey provide a broad framework for the types of collaborations, additions, and interdisciplinary opportunities that should be integrated into the planning curriculum.

Chairs from 44 of the 104 masters planning programs with membership in ACSP responded to the APA-ACSP questionnaire, along with three department heads of undergraduate planning programs that do not have graduate departments.

Academic planning department heads generally viewed water as a top issue (26 percent) or a top-10 issue (48 percent). Adequate water supply was the most cited problem, with pollutants in water supply, stormwater management, and failing infrastructure tying for second place. A clear majority—78 percent—felt the planning profession in their state was not involved enough in water, although the remaining 22 percent felt involvement was just about right.

The department heads responded positively to ideas for enriching water offerings—only eight indicated that nothing more was needed. Almost half (49 percent) thought a textbook on water oriented to planners would be helpful, as would individual modules to include in existing courses, such as a land-use planning course (47 percent). A smaller number thought that online course availability would be a good idea for their program (31 percent).

An important suggestion to improve planning practice was to broaden transportation and infrastructure classes to include water infrastructure. The linkage of water supply planning (and sanitation) to housing was also felt to help in understanding the link between formal and informal infrastructure systems. Joint engineering programs in water and land use, such as some graduate programs now have for transportation and land use, would be an excellent step forward.

planning practice. The general public is often unaware of issues around access to water, water quality, and wastewater or stormwater treatment unless faced with an immediate threat. In the U.S., rapid development occurred during the 20th century with little consideration of environmental impacts. Plentiful and affordable access to water and energy masked the true cost of development. Now communities are trying to deal with the consequences, placing planners and policy makers in critical and central roles. To effectively lead, planners must be able to educate themselves and their communities on water—from immediate local issues to regional and national issues as well.

APA is poised to play a key role in in providing water education for planners. APA has developed new relationships and bolstered existing partnerships with several water-focused organizations that offer resources and collaborative opportunities for planners. This extensive network, comprised of national water service organizations, federal agencies, foundations, and others, offers planners ways to educate themselves and their communities on water issues. Examples of these organizations and agencies include the American Water Works Association, the Water Research Foundation, the Water Environment and Reuse Foundation, the American Water Resources Association, and the National Oceanic and Atmospheric Administration.

The above associations reflect just a fraction of the water resources available to planners. And with more water professionals using the One Water strategy as a framework, interdisciplinary educational opportunities are becoming increasingly available to the planning profession. The profession should focus its efforts on working with other disciplines to foster education programs and water-based curricula for primary, middle, and secondary schools as well as university and community colleges. Broadening the education of the populace about water-related principles, issues, and opportunities, as well as providing training for jobs in this emerging sector, is essential if the planning profession truly wants to integrate water management into traditional planning practice.

APA'S WATER AND PLANNING NETWORK

APA is dedicated to adding value not just to this growing network of water disciplines, but to its own members, ensuring they receive the guidance, support, and access to practical and educational opportunities they need to do their jobs well. Rising to the challenge and understanding its responsibility, in May 2017, APA launched the Water and Planning Network (WPN).

The mission of the WPN is to provide a professional forum for the interdisciplinary exchange of ideas and planning methods. It will operate as a communications and information-sharing network to connect members to the most current water research, science, policy, technology, and best practices.

The WPN will:

- promote a deeper understanding among planners about water science and engineering and the ways in which land use, land development, and urban design significantly affect the health of the water environment
- provide opportunities for planners to improve core skills, toolsets, and methods in order to manage water more sustainably and more equitably
- create better and more frequent connections and engagement between planners, design professionals, and water professionals by establishing new mechanisms for interdisciplinary interaction
- advance One Water planning methods and interactions that support an integrated approach to water management

As land-use, economic, and weather patterns have changed, so have our water needs. What has not changed is the fact that water is essential to the future of every community. Planners should not consider water management to be a specialized issue within the planning field, but part of a planner's basic working knowledge and day-to-day practice. APA members are encouraged to embrace and utilize the WPN, along with APA's robust network of water partners, as a valuable resource and connection to water experts to facilitate that important transition. Critical to the success of the expanded APA engagement on water will be similar engagement by professional planners to expand their skills and knowledge on water management and create the new connections and partnerships that make more sustainable water outcomes possible.

CONCLUSION

In the past decades, planners interested in water issues have focused on water as a natural resource and environmental feature, as well as from the perspective of flood control and hazard mitigation. Water service issues addressing water quantity and quality—typically expressed as water supply, wastewater management, and stormwater infrastructure—were left to the water utility agencies and companies. Today, water planning is undergoing rapid change because of the impacts of population growth, increased dwelling in cities, climate change and climate events, infrastructure deterioration, and the continuing influence of the environmental movement.

In summary, this report focuses on the following key themes for action:

- recognizing increasing competition for water resources (from population and employment growth and attendant food and energy needs) and increasing risk from inadequate and unreliable supplies
- shifting the water management paradigm to One Water management to create more sustainable management systems
- promoting greater interdisciplinary engagement in solving water management issues
- identifying a wide array of recommended practices that can be adapted by the planning community to improve water planning
- recognizing the need for continued expansion of the water planning toolkit to provide better guidance for sustainable comprehensive planning and a stronger central role for planners in water management

Planners play key roles in influencing land-use patterns and helping communities guide how development and redevelopment occur. Planners do this by planning at all scales, creating land-use regulations, and reviewing development projects. This provides planners with opportunities to advance more sustainable water systems. Planners can incorporate dynamic, nature-based, sustainable systems that do not rely solely on pipes, pumps, and treatment plants to solve water problems. Planners can help reconnect society to water's natural setting—and identify the complex interdependencies between water use, wastewater disposal, runoff management, surface and groundwater resources, and the natural environment—to start solving the many challenges of planning for land use and water resources.

APPENDIX A: RECOMMENDATIONS FOR IMPROVED COMPREHENSIVE PLAN GUIDANCE FOR WATER RESOURCES PLANNING

Prepared by Daniel J. Van Abs, PHD, AICP, and the APA Water Working Group

The American Planning Association (APA) Board of Directors created an APA Water Working Group in 2015. As one of its primary objectives, the Water Working Group sought to foster the preparation of improved guidance for planners and planning/zoning board members. Planning professionals and appointed officials understand the critical role that water resources play in sustainable communities, as recognized in Planning Advisory Service (PAS) Report 578, *Sustaining Places: Best Practices for Comprehensive Plans* (Godschalk and Rouse 2015), and the 2015 report of the APA Water Task Force (Cesanek and Wordlaw 2015), and they need better information on how to incorporate these issues into planning.

PAS Report 578 includes water issues in several of the core principles for planning to achieve sustainable places, and the processes and attributes of sustainability planning also require diligent attention to water resources and water utility functions. The 2015 APA Water Task Force Report addresses planning needs directly, under Core Theme 2: "Better incorporate water into the comprehensive planning process, as a component of both Comprehensive/Master Plans and Sustainability Plans."

Water issues are most commonly addressed as specific and separate issues (e.g., water supply, water quality, stormwater management, water utility capacity), and often through capital improvement documents that are separate from comprehensive plans. However, water resource management issues increasingly require a more integrated "One Water" approach, whereby a wide variety of water resource needs, impacts, and management strategies are addressed within all relevant aspects of comprehensive plans, in a way that makes water resources and water utility functions an integral component of community planning, design, form, and function.

An integrated water and land-use planning approach optimizes the value of water as an urban, community, and regional amenity, helping water utilities provide critical services in the most cost-effective and beneficial manner possible. We cannot achieve our objectives for water resources and utilities through efforts that are not sufficiently coordinated with land-use decision making. Planners operating at the community, regional, and watershed levels can provide integration that is not possible for individual regulatory agencies or water utilities.

A new resource is needed that provides a sufficiently detailed, nationally applicable, and highly user-friendly guide that helps planners incorporate water resource management and water utility issues into comprehensive plans, using One Water strategies. An initial framework for this guidance is provided below.

BACKGROUND

Water is life. Insufficient water can result in disruption, decay, or death, not only of biota and people, but of communities and economies. The lack of water need not be total—in the absence of effective planning and action, a major drought can badly damage the economic and social underpinnings of affected areas, even though supplies might not entirely run out. Likewise, a major coastal storm or riverine flood can disrupt water supplies and infrastructure in general for long periods, or result in the discharge of untreated sewage to rivers that serve as water supplies. The recent problem faced by Toledo, Ohio, is instructive; they had an entire Great Lake at their doorstep that they couldn't use for drinking water. What if the toxic algal bloom of 2014 had lasted weeks longer?

The lack of water need not be sudden. The long-term overuse of an aquifer can cause insufficient water supply for very long periods, resulting in a major challenge to communities that have limited cost-effective alternatives. Aquifer depletion has been documented in regions from the east coast to California (Konikow 2013).

The lack of water need not be a problem with natural supply. Communities that let demand exceed their infrastructure capacities can be damaged economically, socially, and politically even if additional supplies are theoretically available. Land-use decisions that allow increases in water demand beyond available water supply create long-term conflict over the limited resource. And significant construction periods are needed to build new water infrastructure.

The lack of management, collection, and treatment capacity for both wastewater and stormwater systems creates its own stresses on communities, ranging from local water pollution and street flooding to major infrastructure costs to meet federal and state regulatory requirements.

Community planners too often have little involvement in planning, developing, or expanding wastewater and water supply infrastructure, which are seen as the province of the utilities and engineers. In turn, utilities often have little to do with land-use planning and community design that forms the basis of water demand and the generation of wastewater and stormwater. The assumption is that the utility will address the water infrastructure needs that result from development and redevelopment, regardless of what they are. In most cases, only when constraints on supply or infrastructure emerge does wider-ranging discussion begin. APA seeks to foster a multidirectional dialogue among planners, planning schools, engineers, utility professions, and other water professionals to improve integrated multi-stakeholder water planning and decision making.

Exacerbating the water problems we face are a set of overarching challenges. In many urban and suburban areas, much of the water infrastructure was developed during the major city-creating period of the late 19th and early 20th centuries as well as the great suburban boom of the post-World War II period. This infrastructure all too often has not been properly maintained; in some cases it is failing, and in other cases declining in quality to the point where failure is imminent. Estimated 20-year costs to address water supply infrastructure needs alone are roughly $2 trillion, split about evenly between the maintenance and replacement of existing infrastructure and the creation of new infrastructure to address growth (AWWA 2012).

In addition, climate change is clearly modifying the pattern of rainfall, with some regions experiencing much more frequent severe rainfall events. Anticipated changes based on global climate models indicate that various portions of the nation will experience even more severe rainfall events, more frequent droughts, declining snowpack, or other major water challenges (Melillo et al. 2014). While climate change mitigation efforts continue both locally and internationally, it is clear that change is already occurring and adaptation will be necessary regardless of the success of mitigation (U.S. EPA 2014).

Other issues include an increasing understanding of the effects of water consumption on aquatic ecosystems, which has resulted in calls to modify how and the extent to which supplies are extracted from ground and surface waters so that ecosystems may be maintained (Poff et al. 2009).

Finally, two related but distinct terms are gaining a great deal of currency and attention: *sustainability* and *resilience*. Sustainability is the broader of the two. It addresses a society's capacity to ensure that environmental integrity, social quality, and economic viability are simultaneously sustained through generations, with each generation not constraining the ability of following generations to continue to depend on, in this case, our water resources. Resilience is more narrowly defined as the ability of a society to recover or reconstruct its systems after a major disruptive event (natural or not) so that natural and infrastructure systems can continue to function. In a world of increasing population and increased exposure to natural and anthropogenic hazards, both sustainability and resilience are concepts important to achieve.

At present, we suggest that insufficient integrated guidance is available to planners regarding:

- what water resource and water infrastructure issues pertain to community planning
- how to engage the water utility community in useful conversations about these issues
- how to engage communities in water-related land planning issues
- how to incorporate the results of these discussions into comprehensive plans

Some very good examples exist in the U.S. of comprehensive plans that have successfully integrated water issues with community and land planning, but the communities often had to develop their own approaches or borrow piecemeal ideas from other communities that had developed their own approaches.

The lack of clear, concise guidance slows the implementation of best practices by communities that both need and desire to address these issues. Such communities in need of improved water management decision making have been identified in every part of the country, each with its own specific issues. The issues are often diverse, complicated, and difficult to resolve, and yet there are commonalities across large sections of the country that can be addressed through improved comprehensive and sustainability plans and improved planning practices.

The general recommendation for improved guidance for comprehensive plan development with respect to water is also informed by APA's Sustaining Places Initiative, which has developed guidance for integrating critical sustainability concepts and practices into local governmental comprehensive plans. This guidance is laid out in the PAS Report *Sustaining Places: Best Practices for Comprehensive Plans.*

FRAMEWORK FOR COMPREHENSIVE PLAN GUIDANCE FOR WATER RESOURCES PLANNING

The basic structure of Sustaining Places Comprehensive Plan supplemental guidance for water should consider the wide array of water resource management issues, including the bulleted issues below. As noted in the introduction, future development of more detailed guidance on water management will need to consider both the basics (for communities that are interested in establishing an initial foundation for their work) and more advanced planning techniques (for communities that are ready for a fully integrated approach). In addition, the suggested concepts are not linear in their application, but rather reflect a systems approach that requires multithread analysis and iterative planning.

The following "touchpoints" are identified for planners in addressing water in a comprehensive, integrated manner within comprehensive plans, or plan supplements.

- **Existing water supplies and distribution systems:** Identify and characterize water supplies (e.g., ground or surface water; local supply or purchased water; drought sensitivity; potential for excessive water withdrawals, or "mining"; sensitivity to structural damages from natural hazards; availability during normal and drought periods; long-term sustainability; quality). Characterize delivery systems (e.g., treatment system capacity and treated water storage; bulk delivery infrastructure and community systems) and storage capacity and capabilities (e.g., days of water in emergency situations). Evaluate infrastructure integrity, interagency and cross-utility coordination and resilient/sustainable systems planning, and level of service for fire protection. Identify existing community, state, and federal regulatory requirements and available best practices that are relevant to the community.
- **Existing wastewater systems and receiving water capacity:** Identify and characterize receiving waters (e.g., ground, surface, estuarine, or saline waters), treatment systems (e.g., treatment system capacity, discharge requirements during normal and drought periods, major interceptor pipelines, community collection systems, infrastructure integrity, sensitivity to structural damages from natural hazards), and limitations on receiving water capacity (e.g., water quality-limited effluent limits, total maximum daily loads). Identify existing community, state, and federal regulatory requirements and available best practices that are relevant to the community.
- **Existing stormwater systems:** Identify major public stormwater system components, receiving waters, and known stream degradation impacts; street flooding problems; relationship to groundwater/aquifer recharge and land subsidence; and water quality issues. Identify existing community, state, and federal regulatory requirements and available best practices that are relevant to the community.
- **Current system demands for water supply and wastewater:** Determine annual and seasonal demands relative to system capacities; existing commitments for future capacity; unusual features of systems demands, such as dominant users and special treatment needs.
- **Evaluate and inform driving forces for water infrastructure needs:** Evaluate the community or regional plans and expectations for land development, population and employment growth, community structure, development standards, etc., that will drive both demand for water services and environmental stresses related to water.
- **Projected demands for water supply and wastewater:** Determine planning horizon; projected population, job, and industrial trends; per capita water consumption trends; estimated annual and seasonal demands relative to system capacities; unusual features of future systems demands, such as dominant users and special treatment needs; and resulting infrastructure needs.
- **Water stresses from existing and projected demands:** Determine the ability of natural systems to provide required supply and effluent assimilation services through the planning period, and establish how existing regulatory systems can mitigate or avoid the stresses and what additional measures are required.
- **Sustainable water systems as part of the community's future vision.** Based on the evaluations of available water resources and their current integrity and stresses, current demands on water resources and their impacts, available infrastructure capacity and constraints, regulatory requirements and best practices, and all other relevant community considerations, develop an integrated vision for the existence, quality, integrity, use, and ben-

efits of water resources and water utility functions within the community and its region.

- **Scenarios to achieve the vision of sustainable water systems:** Assess impacts of future land use and development scenarios on water supply and demand, stormwater generation, water quality, natural hydrologic systems, etc. Establish a conceptual framework for determining which scenarios optimize benefits and costs within the overarching sustainability goal.
- **Comprehensive plan policies and actions to address water supply needs:** Identify methods by which the community can modify its existing or future land-use patterns and densities, building designs, landscaping, and water demands to remain within sustainable levels of water supply with acceptable water quality. Tools may include mitigation and adaptation methods (e.g., water use efficiency, water conservation, beneficial reuse, new or modified water supplies, new or modified drinking water treatment and storage, distribution system requirements, recharge protection or augmentation for surficial aquifer or stream flow protection, incorporation of green stormwater infrastructure and stormwater recharge of aquifers, use of alternative water supplies for nonpotable need).
- **Comprehensive plan policies and actions to address wastewater demands:** Identify methods by which the community can modify its existing or future land-use patterns and densities, building designs, landscaping, and water demands to remain within sustainable levels of wastewater generation, collection, and treatment, including mitigation and adaptation methods (e.g., wastewater generation reductions, beneficial reuse, new or modified wastewater collection and treatment system requirements, control of combined sewer or sanitary sewer overflows, incorporation of green stormwater infrastructure).
- **Comprehensive plan policies and actions to address water impacts:** Identify methods by which the community can modify its existing or future land uses to mitigate past impacts to water supply or quality, or to mitigate or avoid future impacts (e.g., stormwater management, source water protection programs, protection of sensitive water-related land resources, water quality protection, development standards).
- **Comprehensive plan policies that promote regenerative water systems:** Identify opportunities for the recovery of nutrients, energy, and water from sewers and from sewage, wastewater, and water resource recovery facilities; for the use of stormwater and rainwater to replenish groundwater or augment water supplies; and for promotion of regulatory, financial, and community systems to facilitate recovery of resources from the water system.
- **Comprehensive plan policies that promote water as an urban amenity:** Identify areas where water-sensitive urban design principles can be incorporated into the urban space by integrating water features at a range of scales from roadside green infrastructure to large green/blue waterway corridors; consider the incorporation of "ecosystem services" of water features; and identify ways to enhance the presence and value of water within the community.
- **Comprehensive plan policies and actions for stormwater management:** Determine level of service for stormwater management services, including flood protection and water quality management. Identify goals, objectives, and policies to meet level of service requirements.

The APA Water Working Group staff reported to the APA Board of Directors in September 2015 that "the [Sustaining Places] standards are designed as a framework and do not go into great depth or detail on particular planning topics. In addition to regular updates, there is an opportunity to develop more in-depth 'extensions' of or 'plug-ins' to the standards on topics of interest, as a resource for planners."

Each of the six principles, two processes, and two attributes in the Comprehensive Plan Standards for Sustaining Places is supported by a series of best practices that provide more specific guidance to communities on how to incorporate them into their comprehensive plans. Water has a prominent role, both explicitly and implicitly, in these principles. Table A1 (p. 122) identifies linkages between selected best sustaining practices for each principle, process, and attribute, and salient water resource and water utility issues.

CONCLUSION

Water resources and water utility infrastructure are fundamental components of our society, and will become more important over time as competition for resources increase. Our urban and suburban communities and development patterns would fail without adequate attention to resource management. Planners working with their communities should better incorporate these issues within comprehensive plans.

To avoid a constant process of discovery and development, preparation of a national guidance document or system would be useful to hasten the spread of best practices throughout the planning community. Unfortunately, such compiled and focused guidance, based on One Water

TABLE A1. SUSTAINING PLACES BEST PRACTICES: LINKAGES TO WATER RESOURCES AND INFRASTRUCTURE

Sustaining Places Best Practices	Link to Water Resources and Infrastructure
PRINCIPLE 1: LIVABLE BUILT ENVIRONMENT	
1.10 Implement green building design and energy conservation.	Water use efficiency and conservation; wastewater beneficial reuse; rainwater and stormwater capture and use
1.11 Discourage development in hazard zones.	Vulnerability of water supply, wastewater, and stormwater infrastructure to natural hazards; regulation of water utility services for new development in hazard zones
PRINCIPLE 2: HARMONY WITH NATURE	
2.1 Restore, connect, and protect natural habitats and sensitive lands.	Protection and restoration of natural areas that support water supply sources including both ground and surface waters
2.2 Plan for the provision and protection of green infrastructure.	Protection of ground and surface water supply sources; stormwater management measures; protecting water quality in natural systems; protection and restoration of waterways from urban runoff
2.6 Encourage climate change adaptation.	Respond to potential exacerbation of droughts and floods, natural hazards to water infrastructure, increased stormwater runoff, etc.
2.9 Encourage water conservation and plan for a lasting water supply.	Water availability; building design; building retrofit standards; water revenues
2.10 Protect and manage streams, watersheds, and floodplains.	Protection of aquatic ecosystems, recreational uses, and water supply sources from pollution of both ground and surface waters
PRINCIPLE 3: RESILIENT ECONOMY	
3.6 Provide and maintain infrastructure capacity in line with growth or decline demands.	Water infrastructure capacity; facility sizing; revenue trends relative to needs.
3.7 Plan for post-disaster economic recovery.	Ensuring or restoring water infrastructure services during and after natural disasters
PRINCIPLE 4: INTERWOVEN EQUITY	
4.3 Plan for the physical, environmental, and economic improvement of at-risk, distressed, and disadvantaged neighborhoods.	Potential for green infrastructure; access to and level of service for water infrastructure
4.6 Upgrade infrastructure and facilities in older and substandard areas.	Water infrastructure level of service and lifecycle costs
4.8 Protect vulnerable populations from natural hazards.	Maintenance and restoration of water infrastructure services during and after natural disasters
PRINCIPLE 5: HEALTHY COMMUNITY	
5.1 Reduce exposure to toxins and pollutants in the natural and built environments.	Drinking water quality; control of sanitary sewer and combined sewer overflows; stormwater pollution control
5.5 Provide accessible parks, recreation facilities, greenways, and open space near all neighborhoods.	Potential for green infrastructure that provides open space amenities; identification of flood-prone areas that can be incorporated into public amenities
PRINCIPLE 6: RESPONSIBLE REGIONALISM	
6.3 Coordinate local open space plans with regional green infrastructure plans.	Protection of ground and surface water supply sources; management of flood-prone areas

Sustaining Places Best Practices	Link to Water Resources and Infrastructure
6.9 Encourage consistency between local capital improvement programs and regional infrastructure priorities.	Regional water infrastructure capacity; water supply system interconnections and emergency assistance, etc.
PROCESS 7: AUTHENTIC PARTICIPATION	
7.1 Engage stakeholders at all stages in planning process.	Water utility professionals, floodplain managers, and other representatives of the water planning and management community
7.4 Develop alternative scenarios of the future.	Addresing water issues such as supply, demand, and flooding in scenarios reflecting a range of valid possible futures
7.5 Provide ongoing and understandable information for all participants.	Providing information on existing water supply, wastewater, and stormwater systems; projected future demands; stresses such as aging infrastructure and climate change, etc.
PROCESS 8: ACCOUNTABLE IMPLEMENTATION	
8.1 Indicate specific actions for implementation.	Future water supply, wastewater, and stormwater system needs, water quality, floodplain management, etc., and their relationships to land use and other community systems and attributes
8.2 Connect plan implementation to the capital planning process.	Water infrastructure; green infrastructure; land acquisition to protect water supply, quality, and natural floodplain functions, etc.
8.4 Establish interagency and organizational cooperation.	Coordination between community planners and water professionals in implementation
8.5 Identify funding sources for plan implementation.	Funding sources and revenue streams related to water
8.6 Establish implementation indicators, benchmarks, and targets.	Indicators, benchmarks, and targets related to water supply and demand, wastewater, water quality, stormwater, flooding, etc.
ATTRIBUTE 9: CONSISTENT CONTENT	
9.1 Assess strengths, weaknesses, opportunities, and threats.	Existing and future water supply and demand; water infrastructure capacity; projected impacts of climate change, institutional capacity, etc.
9.2 Establish a fact base.	Water supply and wastewater systems; water infrastructure current and projected demands; updated mapping and evaluation of floodplains and other natural hydrological systems, etc.
9.3 Establish a vision of the future. 9.4 Set goals in support of the vision. 9.5 Set objectives in support of the goals. 9.6 Set policies to guide decision making. 9.7 Define actions to carry out the plan.	Addressing water and its connection to other community attributes and systems in the vision, goals, objectives, policies, and actions
ATTRIBUTE 10: COORDINATED CHARACTERISTICS	
10.1 Be comprehensive in the plan's coverage.	Addressing water and its interrelationships with other topics covered by the plan
10.2 Integrate the plan with other local plans and programs.	Water supply and wastewater infrastructure plans; hazard mitigation and resilience plans; climate action plans; sustainability plans, etc.

principles, does not appear to exist at the time of publication of this report. Expanded guidance for integration of water resources and water infrastructure planning into comprehensive plans is needed, and this discussion of possible frameworks and content is offered to help move the discussion forward.

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APPENDIX B: GLOSSARY OF WATER TERMS

This glossary is a standalone resource that includes terms that are used in this PAS report as well as other water-related terms that are useful to know when working with water. These definitions have been drawn and adapted from a number of different sources; each is footnoted with its source, and the list of sources is provided at the end of the glossary.

aqueduct: a pipe, conduit, or channel designed to transport water from a remote source, usually by gravity.[36]

aquifer: a geologic formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.[36]

aquifer, confined: soil or rock below the land surface that is saturated with water, surrounded by layers of impermeable material, and under pressure, so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.[36]

aquifer, unconfined: an aquifer whose upper water surface is at atmospheric pressure, and thus is able to rise and fall.[36]

artificial recharge: a process in which water is put back into groundwater storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.[36]

base flow: sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by groundwater discharges.[36]

blackwater: water from plumbing fixtures containing urine and feces.[5]

Clean Water Act (CWA): the primary federal law that regulates discharges of pollutants into U.S. waters and regulates quality standards for surface waters. Originally enacted in 1948 as the Federal Water Pollution Control Act, the CWA was reorganized and expanded in 1972. The Clean Water Act became the Act's common name with amendments in 1972. Under the CWA, the U.S. Environmental Protection Agency (EPA) implements pollution control programs and sets water quality standards for all contaminants in surface waters. The CWA has made it unlawful to discharge pollutants from a point source into navigable waters unless a permit is obtained. The EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges.[28]

climate change: any significant change in the measures of climate lasting for an extended period of time. Climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.[22]

combined sewer system (CSS): a single-pipe system that collects rainwater runoff, domestic sewage, and industrial wastewater and carries it to a sewage treatment plant, where it is treated and discharged into a water body.[24]

combined sewer overflow (CSO): discharge of untreated stormwater and wastewater from a combined sewer system directly to nearby streams, rivers, and other water bodies that occurs when the volume of stormwater and wastewater exceeds the capacity of the system (e.g., during a storm event).[24]

community water system: a public water system that supplies water to the same population year-round.[27]

conjunctive use: withdrawal by a water purveyor of water from a stream or river when it is plentiful and from ground water rather than the stream or river during periods of lower flows. Also called in-lieu recharge.[5]

connection fees: the charges that a locality, water or sewage company, or utility company imposes to hook up individual residences to the larger infrastructure network.[5]

conservation: activities designed to reduce the demand for water, improve efficiency in use and reduce losses and waste of water, and improve land management practices to conserve water.[1]

contaminant of emerging concern (CEC): a chemical or other substance that has no regulatory standard, has been recently "discovered" in natural streams (often because of improved analytical chemistry detection levels), and potentially causes deleterious effects in aquatic life at environmentally relevant concentrations. CECs include persistent organic pollutants (POPs), pharmaceuticals and personal care products (PPCPs), veterinary medicines, endocrine-disrupting chemicals (EDCs), and nanomaterials.[33]

conveyance loss: water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a groundwater source and be available for further use.[36]

desalination: the removal of salts from saline water to provide fresh water. This method is becoming a more popular way of providing fresh water to populations.[36]

discharge: the volume of water that passes a given location within a given period of time, usually expressed in cubic feet per second.[36]

distillation: a technique used to create potable water from salt water. Seawater is heated to produce steam, which is then condensed to produce water with a low salt concentration.[5]

drainage basin: a land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River, contain thousands of smaller drainage basins. Also called a **watershed**.[36]

drawdown: a lowering of the groundwater surface caused by pumping.[36]

effluent: water that flows from a sewage treatment plant after it has been treated.[36]

erosion: the process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles in the stream.[36]

Environmental Site Design (ESD): an effort to mimic natural systems along the whole stormwater flow path through combined application of a series of design principles throughout the development site. The objective is to replicate forest or natural hydrology and water quality. ESD practices are considered at the earliest stages of design, implemented during construction and sustained in the future as a low-maintenance natural system. Each ESD practice incrementally reduces the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required. Example practices include preserving natural areas, minimizing and disconnecting impervious cover, minimizing land disturbance, conservation (or cluster) design, using vegetated channels and areas to treat stormwater, and incorporating transit, shared parking, and bicycle facilities to allow lower parking ratios. Also called Better Site Design (BSD).[3]

estuary: a place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.[36]

evaporation: the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See **transpiration.**[36]

evapotranspiration: the sum of evaporation and transpiration.[36]

fit-for-purpose water: reuse of water that involves treating "used" water to a quality that is acceptable for the intended reuse while posing the least risk to the user. Examples of reuse include irrigation of specific agriculture (e.g., turf and tree farms, public parks, and sports fields), cement making, household landscapes, toilet flushing, and laundry. Different reuse options require specific levels of water quality, which dictate the types of treatment necessary to achieve those qualities.[37]

flood: an overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: the inundation of land is temporary, and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.[36]

flood, 100-year: a flood level with a 1 percent chance of being equaled or exceeded in any given year (not a flood that occurs once every 100 years).[36]

flood stage: the elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.[36]

floodplain: a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.[36]

floodway: the channel of a river or stream and the parts of the floodplain adjoining the channel that are reasonably required to efficiently carry and discharge the floodwater or flood flow of a river or stream.[36]

freshwater: water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.[36]

graywater: wastewater from clothes washing machines, showers, bathtubs, hand washing, lavatories and sinks, but not toilets or kitchens.[36]

green infrastructure: a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.[23]

groundwater: water that flows or seeps downward and saturates soil or rock, supplying springs and wells; also, water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust.[36]

groundwater recharge: inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.[36]

hydroelectric power plant: a facility where electricity is produced using the power of falling water to turn a generator.[5]

hydroelectric power water use: the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.[36]

hydrogeology: the study of subsurface waters and geologic aspects of surface waters.[34]

hydrologic cycle: the cyclic transfer of water vapor from the earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.[36]

hydrology: the science that deals with water on and beneath the earth's surface.[35]

hydromodification: disruption of the normal flow of a stream, either with too much flow or too little. This can imbalance the ecology of the stream and cause loss of plant and aquatic life.[5]

impermeable layer: a layer of solid material, such as rock or clay, which does not allow water to pass through.[36]

impervious surface: a material which prevents the infiltration or passage of liquid through it. This may apply to roads, streets, parking lots, rooftops, and sidewalks.[14]

infiltration: the flow of water from the land surface into the subsurface.[36]

inflow: the discharge of water into sewer pipes, usually from illegal connections with roof leaders, or illegal cross-connections between sanitary and storm sewers.[5]

injection wells: pipes that extend several thousand feet into rocks bounded by impermeable layers with no contact with aquifers; most commonly used to dispose of hazardous wastes.[5]

inlets: grated openings often found at street corners that collect stormwater runoff from gutters and guide it into storm sewer submains under the street.[5]

irrigation: the controlled application of water for agricultural purposes through man-made systems to supply water requirements not satisfied by rainfall.[36]

Integrated Water Resource Management (IWRM): a process which promotes the coordinated development and management of water, land, and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Also called **One Water**.[8]

land-use/water nexus: the interdependencies of land-use planning, water demand and energy needs. Water is needed to generate energy as hydropower; energy-related mineral extraction and mining, fuel production, and emission controls rely on large amounts of water. In turn a large amount of energy is needed to extract, convey, treat, and deliver potable water, as well as collect, treat, and dispose of wastewater. Variables guiding land use as it related to water and energy include a growing population (directly increasing housing, transit, and commercial needs); increased need for agricultural production to feed more people; the geographical location and consumption of water resources; and climate change.[15]

low-impact development (LID): a stormwater management approach that seeks to manage runoff using distributed and decentralized microscale controls. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Instead of conveying and treating stormwater solely in large end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small-scale landscape practices and design approaches that preserve natural drainage features and patterns.[3]

leachate: water that becomes contaminated by wastes in a landfill.[5]

levee: a natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.[36]

manhole: a small hole through which access may be gained to underground pipes or structures. Often located where pipes change in direction, size, or slope, or where two lines intersect. Also called **utility access port (UAP).**[5]

municipal water system: a water system that has at least five service connections or which regularly serves 25 individuals for 60 days. Also called **public water system**.[36]

municipal wastewater: wastewater composed of household wastes and industrial wastewater from manufacturing and commercial uses, as contrasted with agricultural or rural runoff.[5]

nonpoint source (NPS) pollution: pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, and organic or toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. It occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards and picks up soil particles and pollutants, such as nutrients and pesticides.[36]

National Pollutant Discharge Elimination Program (NPDES): a program authorized by the 1972 Clean Water Act to regulate point-source pollution. It was amended in 1987 to regulate nonpoint source pollution as well.[5]

off-stream storage: the diversion or conveyance of available water into a valley or canyon with little or no aquatic ecosystem and recreational benefit and used as a reservoir.[5]

One Water: a concept also referred to as Integrated Water Resource Management (IWRM). Several water-focused organizations have working definitions of One Water, two of which are provided below:

1. One Water is an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs.[17]
2. The One Water approach considers the urban water cycle as a single integrated system, in which all urban water flows are recognized as potential resources, and the interconnectedness of water supply, groundwater, stormwater and wastewater is optimized, and their combined impact on flooding, water quality, wetlands, watercourses, estuaries and coastal waters is recognized.[10]

overdrafting: a condition in which withdrawal of water from an aquifer or basin exceeds the recharge rate.[5]

pathogen: a disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.[36]

peak flow: the maximum instantaneous discharge of a stream or river at a given location.[36]

perchlorate: a byproduct of the jet- and rocket-fuel industry that has contaminated groundwater supplies in some parts of the country.[5]

per capita use: the average amount of water used per person during a standard time period, generally per day.[36]

permeability: the ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable materials, such as clay, don't allow water to flow freely.[36]

plumbing system: a system within a structure comprising water pipes, drain pipes, ventilation pipes, and natural gas lines for the water heater.[5]

point-source pollution: water pollution coming from a single point, such as a sewage-outflow pipe.[36]

pollutants: substances including dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.[21]

pollutants, toxic: substances that have been defined by the EPA as harmful to animal or plant life, including organics (pesticides, solvents, polychlorinated biphenyls (PCBS), and dioxins) and metals (lead, silver, mercury, copper, chromium, zinc, nickel, and cadmium).[5]

pollution: the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.[21]

precipitation: rain, snow, hail, sleet, dew, and frost.[36]

Principles for Water-Wise Cities: a set of 17 principles structured along four levels of action meant to guide city leaders and stakeholders in a collaborative effort to develop and implement a vision of sustainable urban water practices. Crafted by the International Water Association, these principles establish a framework for how cities can address the water challenges facing cities.[12]

public supply: water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users. Most people's household water is delivered by a public water supplier. The systems have at least 15 service connections (such as households, businesses, or schools) or regularly serve at least 25 individuals daily for at least 60 days out of the year.[36]

recharge: water added to an aquifer; for instance, rainfall that seeps into the ground.[36]

reclaimed water: treated wastewater that is safe and suitable for a purpose that would use other water resources.[19]

recycled water: water that is used more than one time before it passes back into the natural hydrologic system.[36]

reservoir: a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.[36]

resilience: a capability to anticipate, prepare for, respond to, and recover from significant multihazard threats with minimum damage to social well-being, the economy, and the environment.[22]

return flow: that part of a diverted flow that is not consumptively used and returned to its original source or another body of water.[36]

return flow (irrigation): irrigation water that is applied to an area and which is not consumed in evaporation or transpiration and returns to a surface stream or aquifer.[36]

river: a natural stream of water of considerable volume, larger than a brook or creek.[36]

river basin: the drainage area of a river and its tributaries.[16]

runoff: that part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff. Also, the total discharge described above during a specified period of time. Further defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.[36]

Safe Drinking Water Act (SDWA): the federal law that protects public drinking water supplies throughout the nation, originally passed in 1974. Under the SDWA, the EPA sets standards for drinking water quality and works with its partners to ensure they are implementing the various technical and financial programs that keep drinking water safe.[30]

saline water: water that contains significant amounts of dissolved solids. As compared to fresh water (less than 1,000 parts per million (ppm) solids), slightly saline water contains 1,000–3,000 ppm solids, moderately saline water contains 3,000–10,000 ppm solids, and highly saline water contains 10,000–36,000 ppm solids.[36]

sanitary sewer: a system of pipes that collects and transports domestic, commercial, and industrial wastewater and limited amounts of stormwater and infiltrated ground water to treatment facilities for appropriate treatment.[25]

sanitary sewer overflow (SSO): occasional discharges of raw sewage from municipal sanitary sewers, which may be caused by blockages, line breaks, sewer defects that allow stormwater and groundwater to overload the system, power failures, improper sewer design, and vandalism.[25]

sea-level change/sea-level rise: a change in the level of the ocean, both globally and locally, due to changes in the shape of the ocean basins, the total mass of water, or changes in water density. Global warming contributes to sea-level rise through increases in the total mass of water from the melting of land-based snow and ice as well as changes in water density from an increase in ocean water temperatures and salinity changes.[11]

sediment: material in suspension in water or recently deposited from suspension in the waters of streams, lakes, or seas.[36]

sedimentary rock: rock formed of sediment, including sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and rocks formed by or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.[36]

sedimentation tanks: wastewater tanks in which floating wastes are skimmed off and settled solids are removed for disposal.[36]

self-supplied water: water withdrawn from a surface water or groundwater source by a user rather than being obtained from a public supply. An example would be home owners obtaining water from their own wells.[36]

seepage: the slow movement of water through small cracks or pores of a material into or out of a body of surface or subsurface water, or the loss of water by infiltration into the soil from a canal, ditches, laterals, a watercourse, a reservoir, storage facilities, or other body of water, or from a field.[36]

septic tank: a tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry wastewater to a treatment plant. Within the tank, settled sludge is in immediate contact with sewage flowing through the tank and solids are decomposed by anaerobic bacterial action.[36]

settling pond: an open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.[36]

sewage treatment plant: a facility designed to receive wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safety (e.g., greases and fats, human waste, dissolved pollutants, microorganisms) when discharged into receiving streams or bodies of water.[36] See **water resource recovery facility.**

sewer: a system of underground pipes that collects and delivers wastewater to treatment facilities or streams.[36]

sinkhole: a depression in the earth's surface caused by the dissolution of underlying limestone, salt, or gypsum. Drainage is provided through underground channels that may be enlarged by the collapse of a cavern roof.[36]

spring: a water body formed when the side of a hill, a valley bottom, or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water.[36]

storm sewer: a sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers).[36]

stormwater: precipitation that accumulates in natural or constructed storage and stormwater systems during and immediately following a storm event.[14]

stormwater discharge/runoff: Precipitation that does not infiltrate into the ground or evaporate due to impervious land surfaces but instead flows onto adjacent land or water areas and is routed into drain/sewer systems.[16]

stormwater management: techniques that are used to address stormwater runoff.[3]

stream: a general term for a body of flowing water; a natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.[36]

streamflow: the water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.[36]

subsidence: a dropping of the land surface as a result of groundwater being pumped. Cracks and fissures can appear in the land. This is almost always an irreversible process.[36]

surface water: water that is on the earth's surface, such as in a stream, river, lake, or reservoir.[36]

Total Maximum Daily Load (TMDL): the maximum amount of all pollutants taken together that a water body can receive and still meet water quality standards.[5]

transpiration: the process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface through leaf pores. See **evapotranspiration**.[36]

urban runoff: stormwater runoff in urbanized areas where much of the land surface is covered with impervious surfaces. This increases the volume and velocity of stormwater runoff and adds pollutants including metal particles, oil, and chemicals from cars; sewage and pet waste; pesticides; road salt; and sediment.[29]

U.S. Army Corps of Engineers (USACE): a part of the Department of the Army that has both civil and military responsibilities. In civil works, the USACE has authority for approval of dredge and fill permits in navigable waters and tributaries thereof; it enforces wetlands regulations, and constructs and operates a variety of water resources projects, mostly notably levees, dams, and locks. It plays an important role in stormwater management and disaster reduction by providing federal flood protection while also supporting state and local agencies in addressing flood management. [5,16]

utility access port (UAP): see **manhole**.[5]

wastewater: water that has been used in homes, industries, and businesses that is not for reuse unless it is treated.[36]

wastewater treatment, primary: the first stage of the wastewater treatment process, in which mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this stage.[36]

wastewater treatment, secondary: the second stage of the wastewater treatment process, in which biological or chemical-physical processes reduce suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of oxygen-demanding substances and suspended matter. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. Disinfection is the final stage of secondary treatment.[36]

wastewater treatment, tertiary: selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices; the additional treatment of effluent beyond that of primary and secondary treatment methods to obtain a very high quality of effluent. These processes include flocculation basins, clarifiers, filters, and chlorine basins or ozone or ultraviolet radiation processes.[36]

wastewater treatment system, centralized: a managed system consisting of collection sewers and a single treatment plant used to collect and treat wastewater from an entire service area.[31]

wastewater treatment system, decentralized: an on-site or clustered system used to collect, treat, and disperse or reclaim wastewater from a small community.[31]

wastewater treatment system, package(d) plant: a premanufactured treatment facility used to treat wastewater in small communities or on individual properties.[32]

wastewater treatment return flow: water returned to the environment by wastewater treatment facilities.[36]

water, nonpotable: water that is unsafe for human consumption. It does not have the safe qualities of drinking water, but can still be used for other purposes.[18]

water, potable: water of a quality suitable for drinking.[36]

water balance: an accounting of the inflow to, outflow from, and storage in a hydrologic unit, such as a drainage basin aquifer, soil zone, lake, reservoir, or irrigation project. Also called hydrologic budget.[13]

water cycle: the circuit of water movement from the oceans, to the atmosphere, to the earth, and back to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.[36]

water neutral: a state in which the negative externalities of the water footprint of a good, service, individual consumer, community, or business have been reduced and offset. Water neutrality is achieved when all that is "reasonably possible" should have been done to reduce the existing water footprint and the impacts of the residual water footprint are offset by making a "reasonable investment" in establishing or supporting projects that aim at the sustainable and equitable use of water.[9]

water-neutral development: new development in which the projected water demand of is offset with on-site and off-site water efficiency measures to neutralize the impact on overall service area demands.[4]

water-neutral growth: growth in which the projected water demand of new development is offset with on-site and off-site water efficiency measures.[4]

water offset: the projected demand of new water connections (or new development) being offset by on-site and off-site water conservation efforts. This terminology is used to describe the mitigation of the water demand associated with new development. Offsets can refer to actions such as finding new supply or letting agricultural land go fallow. A seemingly effective way to allow for new growth while maintaining overall service area demands, water demand offset policies require that developers ensure that construction of new developments does not result in an increase in water demands.[4]

water lines: pipes that convey water throughout a network. The largest pipes in a water system are called feeder mains and can be up to 18 inches in diameter. Branch mains lead off the feeder mains. Service lines or pipes link the branch mains to the user and can be two inches in diameter.[5]

water quality: a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.[36]

water reclamation/recycling: the reuse of wastewater (usually municipal) in ways including groundwater recharge, agricultural irrigation, landscape irrigation for golf courses and parks, or use in decorative water bodies.[5]

water resource recovery facility (WRRF): a term intended to replace "wastewater treatment plant" and other conventional names (e.g., sewage plant) for such facilities. Initiated by the Water Environment Federation, the change in name reflects the paradigm shift in the water sector, focusing on resource recovery and the products and benefits of treatment rather than solely the waste coming into the facilities.[7]

water rights, riparian: the rights of an owner whose land abuts water. They originated in English common law and fall into three categories: natural flow doctrine, which allows all riparian owners equal rights to use water for domestic purposes; reasonable use doctrine, which allows domestic and commercial use of water for productive purposes that does not unduly interfere with others' use; and prior appropriation doctrine, applied in most arid western states, which grants a superior right to the first user of the water.[6]

water table: the top of the water surface in the saturated part of an aquifer.[36]

water use: water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface water and groundwater sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.[36]

water use, commercial: water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as city/county water departments, and self-supplied sources, such as local wells.[36]

water use, domestic: water used for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. About 85 percent of domestic water is delivered to homes by public-supplied sources, such as city/county water departments, while about 15 percent of the U.S. population supplies its own water, mainly from wells.[36]

water use, industrial: water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, 80 percent of water for industrial uses comes from self-supplied sources, such as local wells or withdrawal points in a river, but some water comes from public-supplied sources, such as city/county water departments.[36]

water use, public: water supplied from a public water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.[36]

water utility: a facility that provides a safe water supply for domestic, industrial, commercial, and some agricultural uses. They can vary in size and many are publicly owned.[2]

watershed: the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds such as the Mississippi River basin contain thousands of smaller watersheds. See **drainage basin**.[36]

well: a bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension, whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.[36]

wholesaler: an entity that purchases water from the federal and state government and sells it to local entities such as cities, smaller water districts, or private water companies.[5]

withdrawal: water removed from a groundwater or surface water source for use.[36]

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