FAILURE TO ACT

THE ECONOMIC IMPACT OF CURRENT INVESTMENT TRENDS IN WATER AND WASTEWATER TREATMENT INFRASTRUCTURE ★★★★

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

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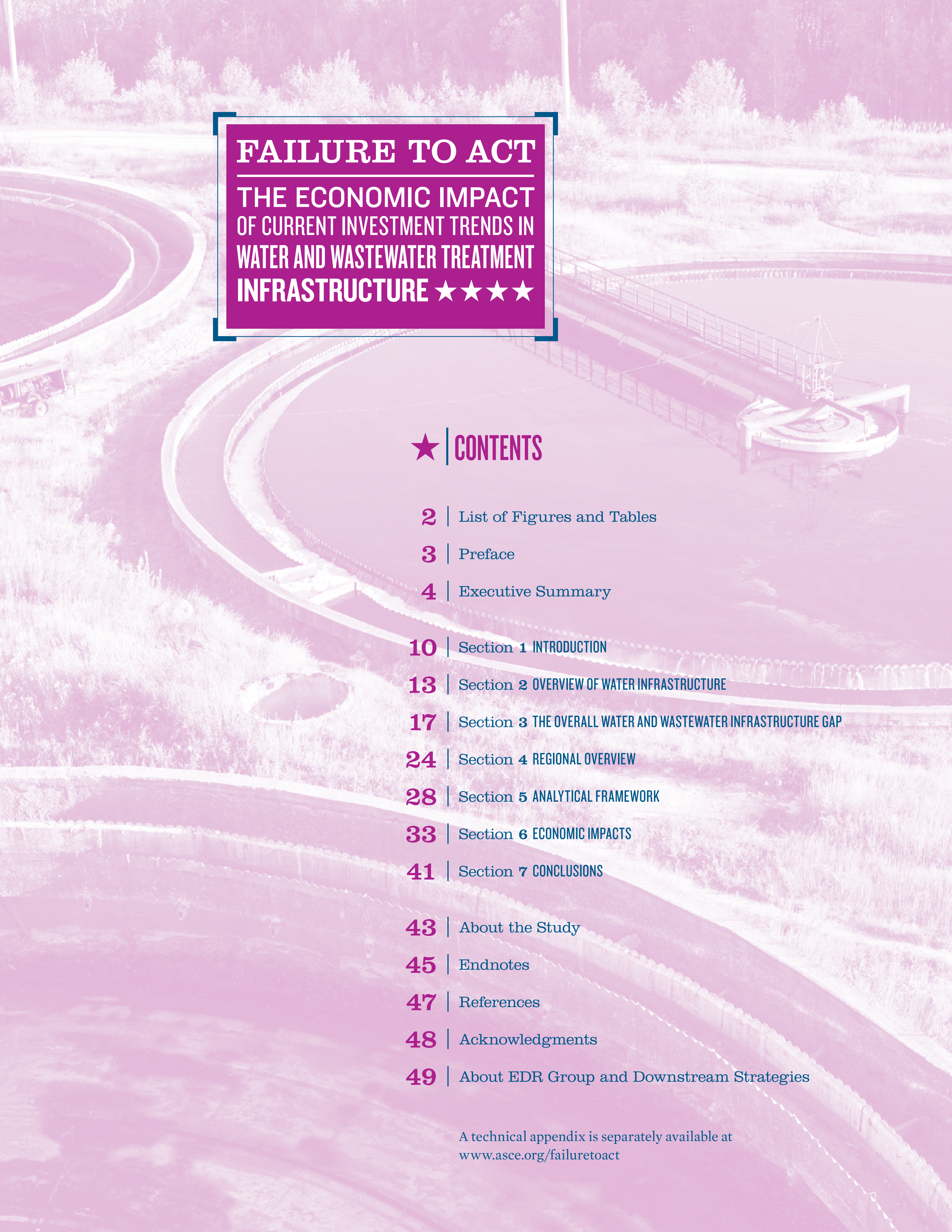

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★ PREFACE

The purpose of the *Failure to Act* report series is to provide an objective analysis of the economic implications for the United States of its continued underinvestment in infrastructure. The four reports in the series will assess the implications of the present trends in infrastructure investment for the productivity of industries, national competitiveness, and the costs for households.

Every four years, the American Society of Civil Engineers (ASCE) publishes *The Report Card for America's Infrastructure*, which grades the current state of 15 national infrastructure categories on a scale of A through F. ASCE's 2009 *Report Card* gave the nation's wastewater and drinking-water infrastructure a D−. The present report answers the question of how the condition of the U.S. infrastructure system affects economic performance. In other words, how does a D− affect America's economic future?

The focus of this report is on the pipes, treatment plants, pumping stations, and other infrastructure that make up the nation's public drinking-water and wastewater systems. Most public water and wastewater systems are owned and operated by local or regional government agencies. Drinking-water systems may also be privately owned and operated under contract with public agencies. In accordance with the definitions used by the U.S. Environmental Protection Agency (EPA), in the pages that follow we consider both types of systems to be "public." Moreover, this report analyzes two types of infrastructure needs:

1. building new infrastructure to service increasing populations and expanded economic activity; and
2. maintaining or rebuilding existing infrastructure that needs repair or replacement.

This is the second report in ASCE's *Failure to Act* series. The first report, *Failure to Act: The Economic Impact of Current Investment Trends in Surface Transportation Infrastructure*, encompasses highways, bridges, rail, and transit. Subsequent reports will address energy transmission, as well as airports and marine ports.

EXECUTIVE SUMMARY

Of all the infrastructure types, water is the most fundamental to life, and is irreplaceable for drinking, cooking, and bathing. Farms in many regions cannot grow crops without irrigation. Government offices, hospitals, restaurants, hotels, and other commercial establishments cannot operate without clean water. Moreover, many industries—food and chemical manufacturing and power plants, for example—could not operate without the clean water that is a component of finished products or that is used for industrial processes or cooling. Drinking-water systems collect source water from rivers and lakes, remove pollutants, and distribute safe water. Wastewater systems collect used water and sewage, remove contaminants, and discharge clean water back into the nation's rivers and lakes for future use. Wet weather investments, such as sanitary sewer overflows, prevent various types of pollutants like sewage, heavy metals, or fertilizer from lawns from ever reaching the waterways.

However, the delivery of water in the United States is decentralized and strained. Nearly 170,000 public drinking-water systems are located across the U.S. Of these systems, 54,000 are community water systems that collectively serve more than 264 million people. The remaining 114,000 are non-community water systems, such as those for campgrounds and schools. Significantly, more than half of public drinking-water systems serve fewer than 500 people.

As the U.S. population has increased, the percentage served by public water systems has also increased. Each year new water lines are constructed to connect more distant dwellers to centralized systems, continuing to add users to aging systems. Although new pipes are being added to expand service areas, drinking-water systems degrade over time, with the useful life of component parts ranging from 15 to 95 years.

Particularly in the country's older cities, much of the drinking-water infrastructure is old and in need of replacement. Failures in drinking-water infrastructure can result in water disruptions, impediments to emergency response, and damage to other types of essential infrastructure. In extreme situations caused by failing infrastructure or drought, water shortages may result in unsanitary conditions, increasing the likelihood of public health issues.

The United States has far fewer public wastewater systems than drinking-water systems—approximately 14,780 wastewater treatment facilities and 19,739 wastewater pipe systems as of 2008.[1] In 2002, 98 percent of publicly owned treatment systems were municipally owned.[2] Although access to centralized treatment systems is widespread, the condition of many of these systems is also poor, with aging pipes and inadequate capacity leading to the discharge of an estimated 900 billion gallons of untreated sewage each year.[3]

The EPA estimated the cost of the capital investment that is required to maintain and upgrade drinking-water and wastewater treatment systems across the U.S. in 2010 as $91 billion. However, only $36 billion of this $91 billion needed was funded, leaving a capital funding gap of nearly $55 billion.

Water infrastructure in the United States is clearly aging, and investment is not able to keep up with the need. This study's findings indicate that investment needs will continue to escalate. As shown in Table 1, if current trends persist, the investment required will amount to $126 billion by 2020, and the anticipated capital funding gap will be $84 billion. Moreover, by 2040, the needs for capital investment will amount to $195 billion and the funding gap will have escalated to $144 billion, unless strategies to address the gap are implemented in the intervening years to alter these trends.

Effects on Expenses

Even with increased conservation and cost-effective development of other efficiency methods, the growing gap between capital needs to maintain drinking-water and wastewater treatment infrastructure and investments to meet those needs will likely result in unreliable water service and inadequate wastewater treatment.

Because capital spending has not been keeping pace with needs, the resulting gap will only widen through 2040. As a result, pipes will leak, the construction of the new facilities required to meet stringent environmental standards will be delayed, addressing the gap will become increasingly more expensive, and waters will be polluted.

This analysis assumes that the mounting costs to businesses and households will take the form of:

- ★ Doing nothing and living with water shortages, and higher rates (rationing through price increases); or major outlays by businesses and households, including expenditures incurred by moving to where infrastructure is still reliable, purchasing and installing equipment to conserve water or recycle water, and increasing reliance on self-supplied water and/or wastewater treatment (i.e., installing individual wells and septic waste systems when municipal facilities and services are not available options), and
- ★ Incurring increased medical costs to address increases in water-borne illnesses due to unreliable delivery and wastewater treatment services.

These responses to failing public infrastructure will vary by location, household characteristics, and size and type of business. Expenditures due to moving, or from installing and operating new capital equipment for "self-supply," are estimated for households, commercial establishments, and manufacturers. These costs are estimated at $35,000 per household and $500,000 to $1 million for businesses, depending on size and water requirement, and are amortized over 20 years. Although these expenditures are based on the costs associated with self-supply, the costs are used to represent outlays by some households and businesses in response to unreliable water delivery and wastewater treatment services. This study does not assume that companies or households move outside of the multistate region where they are now located. However, movement

TABLE 1 ★ **Annual Capital Gap for Water Infrastructure in 2010, 2020, and 2040** *(billions of 2010 dollars)*

YEAR	SPENDING	NEED	GAP
2010	36.4	91.2	54.8
2020	41.5	125.9	84.4
2040	51.7	195.4	143.7

SOURCES Needs calculated from EPA (1997a, 1997b, 2001, 2003, 2005, 2008, 2009, 2010). Spending calculated from CBO (2010) and USCB (2011a, 2011b).

across regional boundaries and relocation of businesses outside of the U.S. is certainly a response that may be triggered by decreasing reliability of public water and sewer systems. Households and businesses that do not self-supply are assumed to absorb the higher costs that are a consequence of disruptions in water delivery and wastewater treatment due to worsening infrastructure. The assumption for this category is that these households and businesses will pay the $84 billion associated with the 2020 capital gap ($144 billion by 2040) in terms of higher rate costs over and above the baseline projected rates for water and wastewater treatment.

Water-borne illnesses will exact a price in additional household medical expenditures and labor productivity due to sick time used. The EPA and the Centers for Disease Control and Prevention have tracked the 30-year incidence of water-borne illnesses across the U.S., categorized the type of illnesses, and developed a monetary burden for those cases. That burden is distributed partially to households (29 percent), as out-of-pocket fees for doctor or emergency room visits, and other illness-related expenses leaving less for a household to spend on other purchases, and mainly to employers (71 percent), due to lost labor productivity resulting from absenteeism. The monetary burden from contamination affecting the public-provision systems over the historical interval was $255 million.

Overall Summary of Costs

The sum of estimated expenses to households and businesses due to unreliable water delivery and wastewater treatment is shown in Table 2. By 2020, the total costs to businesses due to unreliable infrastructure will be $147 billion while that number will be $59 billion for households. The total impact of increased costs and drop in income will reduce the standard of living for families by almost $900 per year by 2020.

Effects on the National Economy

By 2020, the predicted deficit for sustaining water delivery and wastewater treatment infrastructure will be $84 billion. This may lead to $206 billion in increased costs for businesses and households between now and 2020. In a worst case scenario, the U.S. will lose nearly 700,000 jobs by 2020. Unless the infrastructure deficit is addressed by 2040, 1.4 million jobs will be at risk in addition to what is otherwise anticipated for that year.

The impacts of these infrastructure-related job losses will be spread throughout the economy in low-wage, middle-wage and high-wage jobs. In 2020, almost 500,000 jobs will be threatened in sectors that have been traditional employers of people without extensive formal educations or of entry-level workers.[4] Conversely, in generally accepted high-end sectors of the economy, 184,000 jobs will be at risk.[5]

The impacts on jobs are a result of costs to businesses and households managing unreliable water delivery and wastewater treatment services. As shown in Table 3, between now and 2020, the cumulative loss in business sales will be $734 billion and the cumulative loss to the nation's economy will be $416 billion in GDP. Impacts are expected to continue to worsen. In the year 2040 alone, the impact will be $481 billion in lost business sales and $252 billion in lost GDP.[6] Moreover, the situation is expected to worsen as the gap between needs and investment continues to grow over time. Average annual losses in GDP are estimated to be $42 billion from 2011 to 2020 and $185 million from 2021 to 2040.[7]

The Role of Sustainable Practices

In all likelihood, businesses and households will be forced to adjust to unreliable water delivery and wastewater treatment service by strengthening sustainable practices employed in production and daily water use. The solutions already being put forward and implemented in the United States and abroad include voluntary limitations or imposed regulations governing the demand for water, as well as technologies

The impacts on jobs are a result of costs to businesses and households managing unreliable water delivery and wastewater treatment services. The situation is expected to worsen as the gap between needs and investment continues to grow over time.

TABLE 2 ★ Estimated Costs for U.S. Households and Businesses due to Unreliable Water and Wastewater Infrastructure *(billions of 2010 dollars)*

SECTOR	COSTS, 2011–20		COSTS, 2021–40		COSTS, 2011–40	
	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL
Households	$59	$6	$557	$28	$616	$21
Businesses	$147	$15	$1,487	$74	$1,634	$54
TOTALS	**$206**	**$21**	**$2,044**	**$102**	**$2,250**	**$75**

NOTE Numbers may not add due to rounding.

SOURCES EDR Group based on interviews, establishment counts, and sizes by sector from *County Business Patterns*, population forecasts of the U.S. Census, and forecasts of establishments and households provided by the INFORUM Group of the University of Maryland.

TABLE 3 ★ Effects on Total U.S. Business Sales and GDP due to Declining Water Delivery and Wastewater Treatment Infrastructure Systems, 2011–40

(billions of 2010 dollars unless noted)

YEAR	BUSINESS SALES	GDP
Losses in the Year 2020	–$140	–$81
Losses in the Year 2040	–$481	–$252
Average Annual Losses 2011–2020	–$73	–$42
Average Annual Losses 2011–2040	–$251	–$137
Cumulative Losses 2011–2020	–$734	–$416
Cumulative Losses 2011–2040	–$7.5 Trillion	–$4.1 Trillion

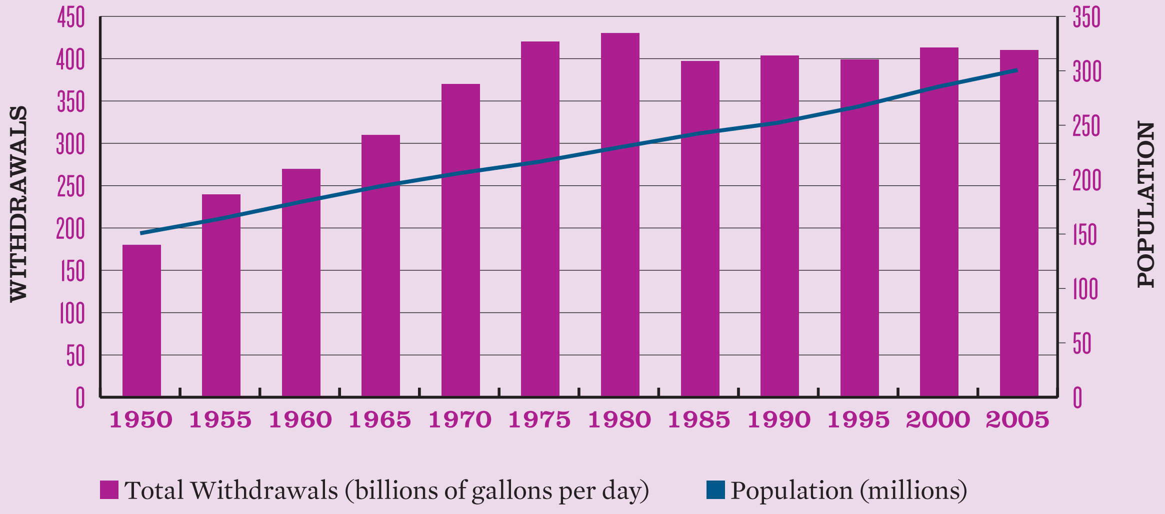
NOTE Losses in business sales and GDP reflect impacts in a given year against total national business sales and GDP in that year. These measures do not indicate declines from 2010 levels.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011 that recycle water for industrial and residential purposes (e.g., using recycled shower water for watering lawns). These types of policies have reduced the demand for water and wastewater, and, therefore have lessened the impacts on existing infrastructure. The most recent Clean Watersheds Needs Survey (EPA 2010) incorporates new technologies and approaches highlighted for wastewater and stormwater: advanced treatment, reclaimed wastewater, and green infrastructure. In contrast, the most recent Drinking Water Needs Survey (EPA 2009) does not include new technologies and approaches, such as separate potable and nonpotable water and increasing efficiencies.

American businesses and households have been using water more efficiently, and they can continue to improve their efficiency during the coming decades. As shown in Figure 1, though the U.S. population has continued to grow steadily since the mid-1970s, total water use has been level. Overall, U.S. per capita water use peaked in the mid-1970s, with current levels being the lowest since the 1950s. This trend is due to increases in the efficiency of industrial and agricultural water use and is reflected in an increase in the economic productivity of water. These trends in industrial water use can be explained by a number of factors. For example, several water-intensive industries, such as primary metal manufacturing and paper manufacturing, have declined in the U.S., thereby reducing water withdrawals. Other industries have faced more stringent water quality standards under the Clean Water Act, which may have led to the implementation of technologies or practices that save water.[8]

Nationally, water use in the home has remained stable since the 1980s. Efficiency and conservation efforts have reduced per capita household consumption in some states and regions. Domestic water use has become more

FIGURE 1 ★ **Water Use and Population in the United States, 1950–2005**



SOURCE U.S. Geological Survey.

efficient through the use of new technologies such as water-efficient toilets that use one-third of the water of older toilets. In addition, new technologies and approaches may reduce future water infrastructure needs. For example, many cities have recently adopted green infrastructure approaches to wet weather overflow management. Green roofs, grassy swales, and rain gardens, for example, are used to capture and reuse rain to mimic natural water systems. Such techniques often provide financial savings to communities.

Nevertheless, demand management and sustainable practices cannot solve the problem alone. These efforts are countered by increasing populations in hot and arid regions of the country—including the Southwest, Rocky Mountains, and Far West—where there is greater domestic demand for outdoor water use.[9]

In this study, a second scenario was run, which assumed that there would be a general adjustment by businesses and households as the capital gap worsened. In this scenario, negative economic impacts mount for about 25 years—roughly 2011–35, though at a slower pace than the earlier scenario—and then abate as increasing numbers of households and businesses adjust to the reality of deficient infrastructure, including net losses of 538,000 jobs by 2020 and 615,000 jobs by 2040. In this scenario, job losses peak at 800,000 to 830,000 in the years 2030–32.

In addition, GDP would be expected to fall by $65 billion in 2020 and $115 billion in 2040. The lowest points in the decline in GDP would be in 2029–38, when losses would exceed $120 billion annually. After-tax personal income losses under this scenario are $87 billion in 2020 and $141 billion in 2040, which represents a rebound from $156 billion to $160 billion in annual losses in the years 2030–34.

The Objectives and Limits of This Study

The purpose of this study is limited to presenting the economic consequences of the continuing underinvestment in America's water, wastewater, and wet weather management systems. It does not address the availability or shortages of water as a natural resource or the cost of developing and harnessing new water supplies. Joining water delivery and wastewater treatment infrastructure with the costs of developing new water supplies is an appropriate and important subject for a more extensive follow-up study. This report assumes that the current regulatory environment will remain in place and no changes to current regulations will occur. Finally, this work is not intended to propose or imply prescriptive policy changes. However, many organizations and interest groups, including ASCE, continue to engage with policy makers at all levels of government to seek solutions to the nation's infrastructure problems.

Conclusion

Well-maintained public drinking water and wastewater infrastructure is critical for public health, strong businesses, and clean rivers and aquifers. Up to this moment American households and businesses have never had to contemplate how much they are willing to pay for water if it becomes hard to obtain.

This report documents that capital spending has not been keeping pace with needs for water infrastructure, and if these trends continue, the resulting gap will only widen through 2040. As a result, pipes will leak, new facilities required to meet stringent environmental goals will be delayed, O&M will become more expensive, and waters will be polluted.

There are multiple ways to partially offset these negative consequences. Possible preventive measures include spending more on existing technologies, investing to develop new technologies and then implementing them, and changing patterns in where and how we live. All these solutions involve costs. Separately or in combination, these solutions will require actions on national, regional, or private levels, and will not occur automatically.

1 INTRODUCTION

The analysis presented in this report illustrates how deficiencies in water delivery, wastewater treatment, and wet weather management infrastructure affect the U.S. economy and will continue to do so in the future. The report seeks to highlight not only how deficient water systems impose costs on households and businesses but also how these costs affect the productivity and competitiveness of industries, along with the well-being of households.

The report includes the following topics:

- ★ an overview of water delivery and wastewater treatment infrastructure,
- ★ water demand by region and the segmentation of consumers,
- ★ the shortfall in infrastructure investment,
- ★ the regional implications of this shortfall,
- ★ an overview of the methodology employed to assess economic performance, and
- ★ the implications of the shortfall in infrastructure investment for national economic performance.

The final sections include conclusions, a discussion of opportunities for future research, the sources and methodology used, and acknowledgments.

The basis for the economic analysis is documentation provided by the EPA in studies and databases developed from 1995 through 2010; research by industry groups, such as the American Water Works Association and the National Association of Water Companies; and scholarship by and interviews with engineers and other experts on water and sewers. The need to maintain the existing water delivery, wastewater treatment, and related systems have significant implications for industry competitiveness and performance, and also the standards of living of households.

1.1 The Objectives and Limits of this Study

The purpose of this study is limited to presenting the economic consequences of a continuing trend of underinvestment in America's water and wastewater systems. It does not address the availability or shortages of water as a natural resource, or the cost of developing and harnessing new water supplies, and it is not intended to propose or imply prescriptive policy changes.

Water and wastewater capital spending by federal, state, and local governments has increased consistently since 1956. It is difficult to predict future levels of capital spending because a wide range of factors will exert an influence over the coming decades. Spending will be impacted by the degree to which infrastructure actually fails, or is predicted to fail, in the near future. In addition, capital spending will rise to meet requirements from new laws and regulations. Regional growth differences in future population and economic activity will also impact the allocation of future capital spending. Additionally, funding trends are strongly influenced by political will. Without attempting to model the numerous complicated factors listed above, a linear projection based on historical data provides a reasonable long-term trend that is consistent with past patterns.

The most important challenge in assessing the economic consequences of unreliable water and wastewater service is that economic data and tools to manipulate those data are not readily available. Given this limited information, assumptions are required to weigh the responses of businesses and households when faced with deteriorating water and sewer service due to failing infrastructure.

Alternatives faced by consuming households and businesses are not feasible on a national level. One or more of these alternatives may be viable for individual companies or households, depending on the location and scale of services needed. These alternatives are, however, unrealistic as levers to alter system capacity and reliability issues nationwide. Today, alternatives are summarized by:

- ★ Adopting further sustainable practices through changes in activity processes, or installation of new equipment;[10]

- ★ Doing nothing—and living with water delivery disruptions and increased incidence of contamination due to unreliable delivery and wastewater treatment services and higher rates (rationing through price increases);

- ★ Significantly increasing reliance on "self-supply" for water supply and/or wastewater treatment (i.e., building individual wells and septic waste systems when municipal facilities and services are not available options); and

- ★ Moving to where water and wastewater services are not hindered by failing infrastructure, or move to an area where self-supply is permitted and practicable;

The effectiveness of these responses to failing public infrastructure will vary by location, size, and type of business. For example, private well and septic installations are not very likely to occur in cities, due to environmental and regulatory factors. Moreover, water supply conditions vary widely by location. For example, in most of California it is virtually impossible to self-supply water, but it is possible to self-supply wastewater treatment. In addition to today's technology, conservation can address a portion of the supply problem, but by itself it is not a societal solution to the broader problem of aging and the declining performance of municipal infrastructure.

All these options, however, generate added costs for households and business establishments. For the purposes of this study, the cost of self-supply is estimated for households, commercial establishments, and manufacturers, and is used as a basis to estimate the range of added costs that might be incurred by any of these other alternatives.

In addition to today's technology, conservation can address a portion of the supply problem, but by itself it is not a societal solution to the broader problem of aging and the declining performance of municipal infrastructure.

Households and businesses that would or could not self-supply (or move, or obtain water-conserving equipment) are assumed to absorb the higher costs that are a consequence of disruptions in water delivery and wastewater treatment due to worsening infrastructure. These costs are assumed to be the size of the capital funding gap, which under present investment trends is expected to reach $144 billion by 2040, unless it is addressed earlier. The underlying assumption for this cost is that the prices of water and wastewater treatment will increase as services need to be rationed to stretch the effectiveness of the infrastructure in overcoming the capital gap. Using the gap to reflect higher costs reflects the concept of rationing by price.

Summary data and expert interviews were used to construct national and multistate regional estimates of costs. Key sources include analyses conducted by the EPA and other research to estimate the capital funding gap and demand by sector and region; the American Water Works Association's 2010 Water and Wastewater Rate Survey, which is a sampling of utility data by size and user class; and interviews to broadly approximate the capital and operations and maintenance costs of private systems.

As this study is limited to the economic consequences of current investment trends, it does not include the potential economic impacts and benefits of construction to close the gap between trends and identified needs. An analysis that includes the economic impacts of construction and how new investment will affect economic performance will vary depending on the mix of solutions that are implemented.

2 OVERVIEW OF WATER INFRASTRUCTURE

2.1 Drinking-Water

Nearly 170,000 public drinking-water systems are found across the United States. Of these, 54,000 are community water systems that collectively serve more than 264 million people. Community water systems are those that serve more than 25 people a day, all year round. The remaining 114,000 systems are non-community water systems, such as those for campgrounds and schools. Only 43 percent of community water systems are publicly owned; 33 percent are private, and the balance are maintained by entities whose primary purpose is something other than water provision.[11]

As shown in Figure 2, the number of people who supply their own water using domestic wells and springs has remained steady since 1965. However, as the population has increased, the percentage of the population served by public systems has increased. This increase was about 3 percent per five years from 1950 to 1965, but since the publicly supplied population reached 80 percent, the increase has slowed to about 1 percent per five years.

This trend is largely explained by a migration to cities—the rural population was 36 percent of the total in 1950 but dropped to 16 percent by 2010. Additionally, each year new water lines are constructed, connecting more distant dwellers to centralized systems.

Although new pipes are being added to expand service areas, drinking-water systems degrade over time, with the useful life of component parts ranging from 15 to 95 years (Table 4). Especially in the country's older cities, much of the drinking-water infrastructure is old and in need of replacement. Failures in drinking-water infrastructure can result in water disruptions, impediments to emergency response, and damage to other types of infrastructure.[12] In extreme situations, water shortages, whether caused by failing infrastructure or by drought, may result in unsanitary conditions, leading to public health concerns. Broken water mains can damage roadways and structures and hinder fire-control efforts. Unscheduled repair work to address emergency pipe failures may cause additional disruptions to transportation and commerce.

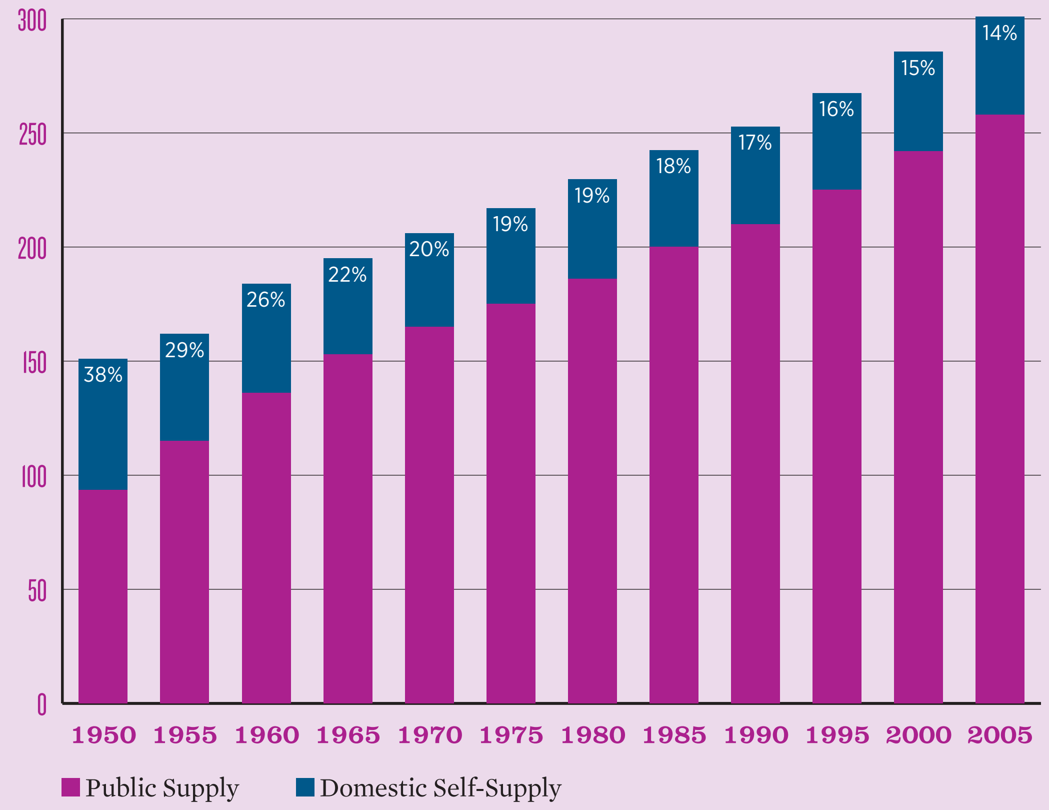
2.2 Wastewater

There are fewer public wastewater systems than drinking-water systems. In 2008, 14,780 wastewater treatment facilities and 19,739 wastewater pipe systems were operational across the U.S.[13] In 2002, 98 percent of publicly owned treatment works were municipally owned.[14]

Although access to centralized treatment is widespread (Figure 3), the condition of many of these systems is poor, with aging pipes and inadequate capacity leading to the discharge of an estimated 900 billion gallons of untreated sewage each year.[15]

Before about 1950, it was a common practice to construct systems that directed wet weather runoff into combined sewer systems, mixing discharges known as wet weather overflows (WWOs) with sanitary sewage. Many of these combined systems are still in use today. When

FIGURE 2 ★ **U.S. Population Served by Public Drinking-Water and by Self-Supply, 1950–2005** *(millions)*



SOURCES MacKichan (1951, 1957); MacKichan and Kammerer (1961); Murray (1968); Murray and Reeves (1972, 1977); Solley, Chase, and Mann (1983); Solley, Merk, and Pierce (1988); Solley, Pierce, and Perlman (1993, 1998); Hutson et al. (2004); Kenny et al. (2009).

Especially in the country's older cities, much of the drinking-water infrastructure is old and in need of replacement. Failures in drinking-water infrastructure can result in water disruptions, impediments to emergency response, and damage to other types of infrastructure.

TABLE 4 ★ The Useful Lives of Drinking-Water System Components

COMPONENT	USEFUL LIFE (YEARS)
Reservoirs and dams	50–80
Treatment plants—concrete structures	60–70
Treatment plants—mechanical and electrical	15–25
Trunk mains	65–95
Pumping stations—concrete structures	60–70
Pumping stations—mechanical and electrical	25
Distribution	60–95

SOURCE EPA (2002, table 2-1).

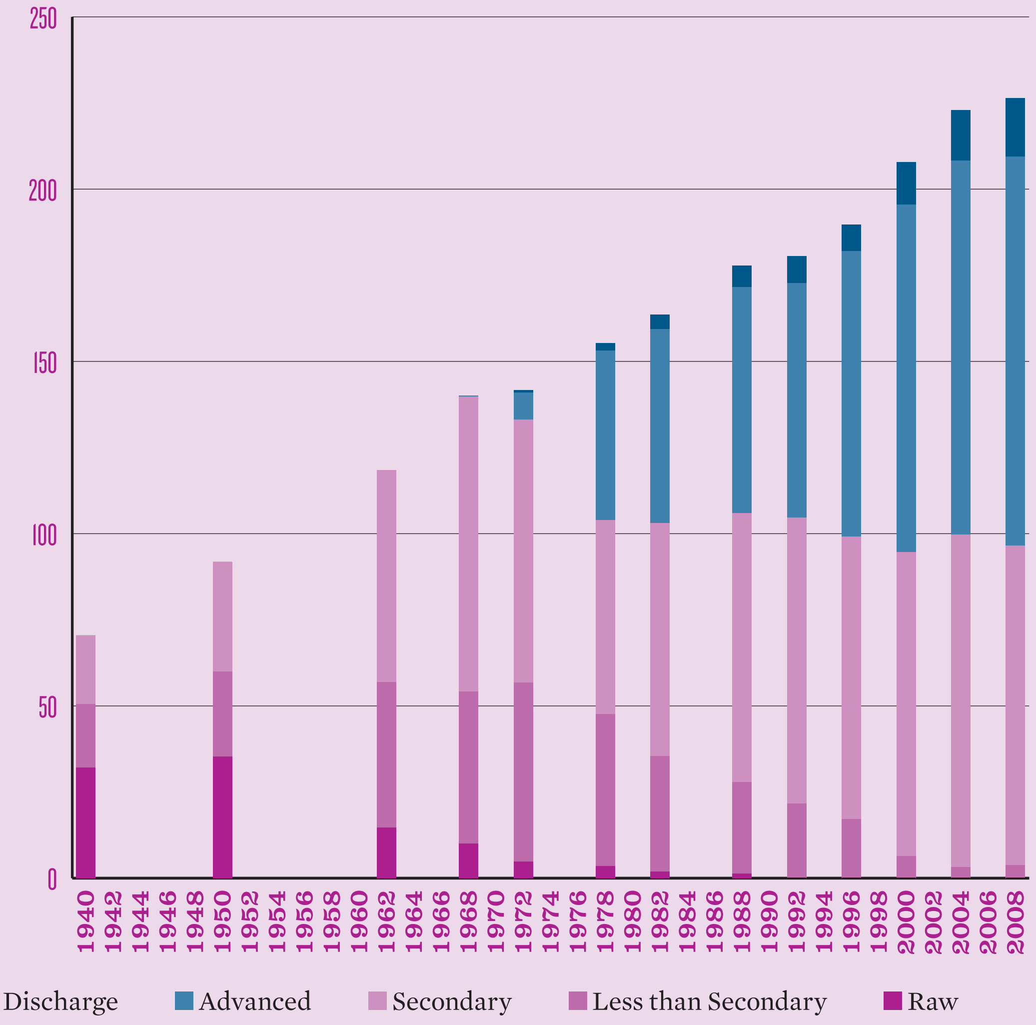
TABLE 5 ★ The Useful Lives of Wastewater System Components

COMPONENT	USEFUL LIFE (YEARS)
Collections	80–100
Treatment plants—concrete structures	50
Treatment plants—mechanical and electrical	15–25
Force mains	25
Pumping stations—concrete structures	50
Pumping stations-mechanical and electrical	15
Interceptors	90–100

SOURCE EPA (2002, table 2-1).

aggravated by heavy rain and snowmelt, increased runoff overwhelms the sewer system, resulting in the release of the combined sewage and stormwater directly into streams through WWOs. In addition, WWOs also result in the discharge of untreated sewage, but due to aging infrastructure rather than by design. During wet weather, WWOs allow groundwater to seep into pipes, potentially causing a system overload. As more systems approach and surpass their effective life spans (Table 5), WWO events become more common.

FIGURE 3 ★ U.S. Population Served by Publicly Owned Water Treatment Works, 1940–2008 *(millions)*



NOTE In addition to the population served by publicly owned treatment works, this figure also shows population with raw sewage discharges. This figure does not show population served by onsite wastewater treatment systems.

SOURCES EPA 2010, figure ES-2, which references U.S. Public Health Service and EPA Clean Watersheds Needs Surveys.

3

THE OVERALL WATER AND WASTEWATER INFRASTRUCTURE GAP

The 30-year capital needs for maintaining and expanding the United States' water delivery systems, wastewater treatment plants, and sanitary and storm sewer systems range from approximately $91 billion in 2010, to $126 billion in 2020, to $195 billion by 2040. These estimates are considerably higher than previous ones—because they account for escalated costs, a previous underreporting of local needs by communities, an extension of analysis from 20 to 30 years of needs, and a more detailed study of the needs to address raw sewage being discharged from combined sewage overflows.

These estimates are primarily drawn from the following calculations of the EPA:

★ National drinking-water needs (DWNs) over 20 years, which the agency has updated every 4 years from 1995 through 2007. The DWNs are based on water quality problems, or water-quality-related public health problems that existed when the reports were released, or that were expected to occur within the next 20 years. For example, the needs identified in the 2007 DWNs are those expected from 2007 through 2026.[16]

★ National clean watershed needs over 20 years, which the agency has updated every 4 years from 1996 through 2008. Figure 6 shows these progressing 20-year need estimates. The 20-year need for a given year refers to the amount required for investment over the next 20 years. For example, the 2004 value indicates that the capital need in the years 2004–23 would total $200 billion.[17]

As documented by EPA, 20-year capital needs for water distribution have increased dramatically since 1995. Capital stock needs for drinking-water are largely to address pipes (transmission and distribution lines), treatment systems, storage, and source.[18] The pipes that constitute the transmission and distribution network cover more than half the needs for drinking-water infrastructure. EPA (2002) applies a simple aging model to pipes (normal distribution) in the 20 cities studied by the American Water Works Association. According to this model, the peak replacement need percentage will occur between 2030 and 2040.

Clean watershed needs (CWNs) are based on water quality problems, water-quality-related public health problems that existed on January 1 of the CWNs' date, or that were expected to occur within the next 20 years. For example, the needs identified in the 2008 CWNs are those expected from 2008 through 2027. Of the other sectors, WWOs constitute the largest portion of the wastewater and wet weather needs; the need for WWOs has remained relatively constant since 1996. In contrast, several types of needs have increased considerably. Both categories related to the treatment plants themselves—secondary treatment and advanced wastewater treatment—have rising needs. The needs related to the construction of new pipes are also rising. The needs for wet weather handling increased dramatically between 2004 and 2008, likely reflecting the new Phase 2 MS4 requirements that began to take effect across the country in the early 2000s.

3.1 Capital Needs, 2010–40

For drinking-water, wastewater, and wet weather management, Figure 4 presents past and projected spending and the capital gap that is likely to occur should future spending follow this path. As shown in Table 6, the overall capital gap for water infrastructure—which includes drinking-water, wastewater, and wet weather—is already significant: $54.8 billion in 2010. If spending increases at the modest but historically consistent rate shown in Figure 4, the gap will increase to $84.4 billion by 2020 and $143.7 billion by 2040 (in constant 2010 dollars).[19]

Additional factors may result in additional costs in the future, which are not considered in this gap analysis. These may include the consequences of climate change—water shortages, flood damage to infrastructure, and influxes of saltwater in near-coast aquifers, and also the need to construct and operate more technologically advanced and energy-intensive treatment facilities—wastewater recycling, the removal of newly regulated contaminants, and desalination.[20]

The gap analysis for routine operations and maintenance (O&M) needs indicates that if O&M spending continues to increase at a rate similar to the past, spending should keep pace with needs, and no gap should develop. This is an unsurprising outcome, given that O&M needs are generally funded through user fees and rate increases that are introduced to cover rising O&M costs. This result is also consistent with the EPA's gap analysis, which found that consistent small increases in rates would be generally sufficient to pay for increasing O&M needs.[21]

TABLE 6 ★ Overall Annual Capital Gap for Water Infrastructure in 2010, 2020, and 2040 *(2010 dollars in billions)*

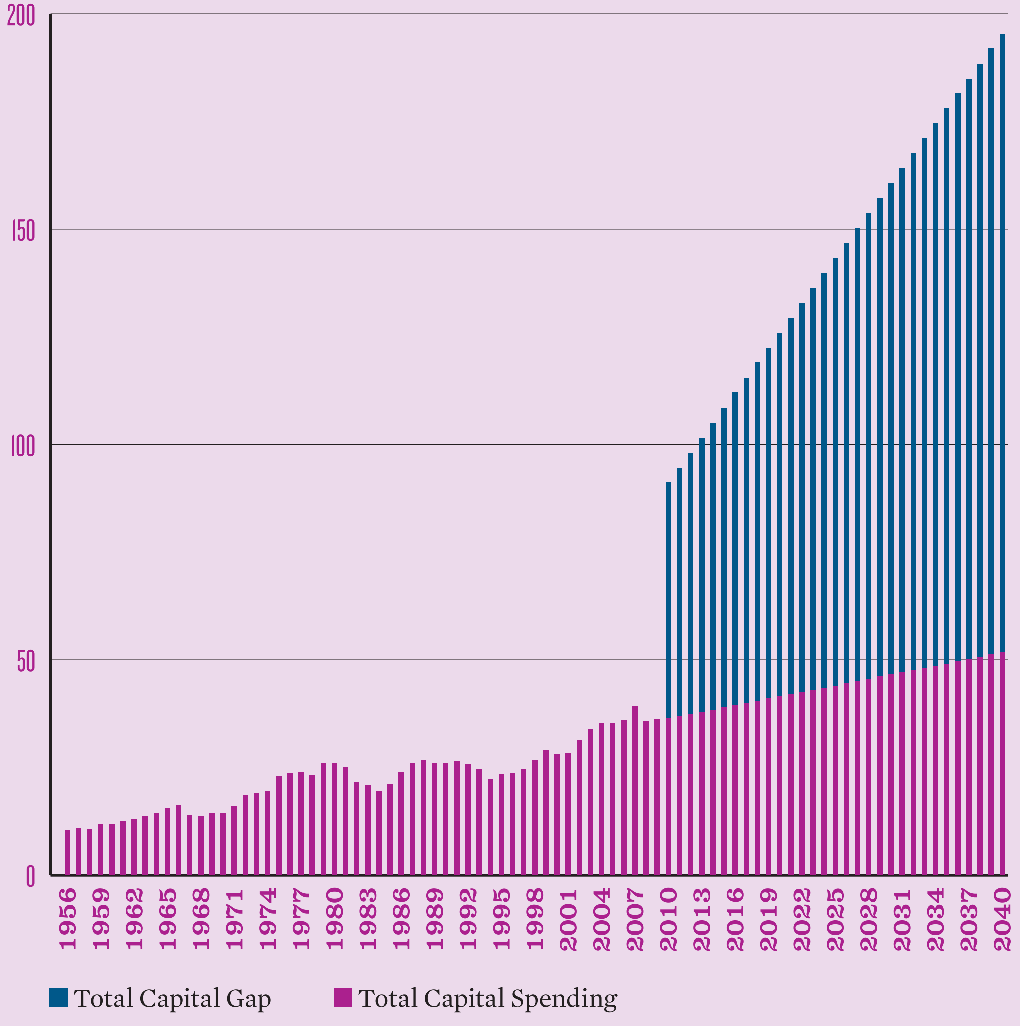
YEAR	SPENDING	NEED	GAP
2010	36.4	91.2	54.8
2020	41.5	125.9	84.4
2040	51.7	195.4	143.7

SOURCES Needs calculated from EPA (1997a, 1997b, 2001, 2003, 2005, 2008, 2009, 2010). Spending calculated from CBO (2010) and USCB (2011a, 2011b). Consumer price index adjustment from BLS (2011).

However, a special burden will be placed on households and businesses in cities that have experienced population declines during the last half-century.

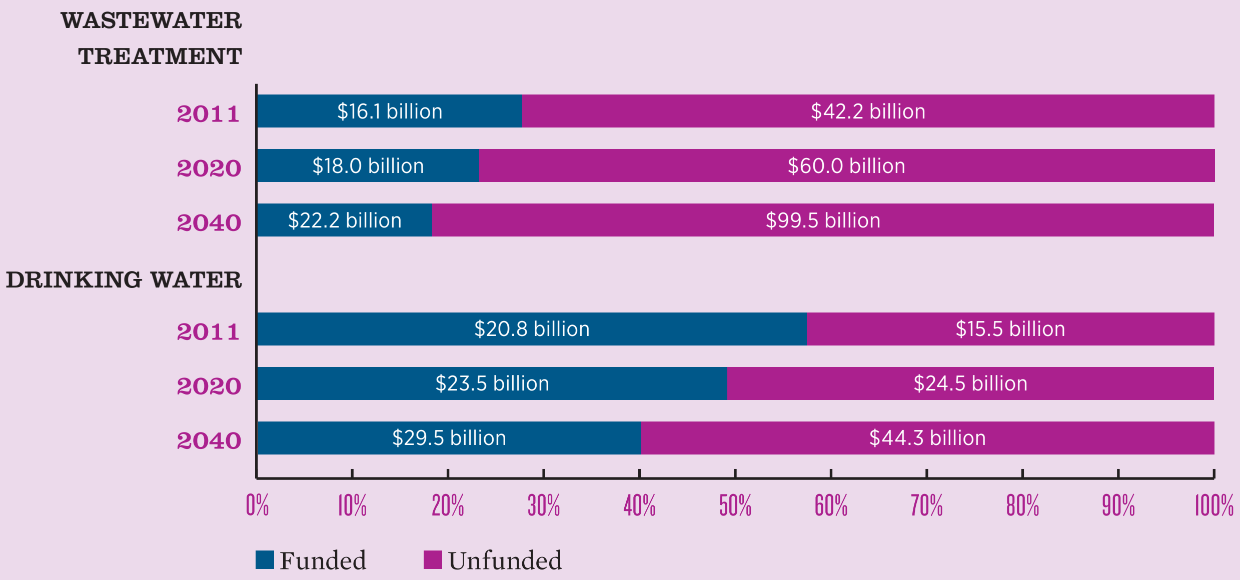
O&M expenditures for both drinking-water and wastewater treatment infrastructure have increased steadily over the last several decades, with spending increasing more rapidly in the recent past. The American Water Works Association (AWWA) has named this the Dawn of the Replacement Era, with the wave of increased spending predicted to last 30 years or more.[22] The earliest pipes installed in the late 19th century have an average life span of about 120 years,

FIGURE 4 ★ **Overall Capital Investment Gap for U.S. Water Infrastructure, 1956–2040** *(billions of 2010 dollars)*



SOURCES Needs calculated from EPA (1997a, 1997b, 2001, 2003, 2005, 2008, 2009, 2010). Spending calculated from CBO (2010) and USCB (2011a, 2011b). Consumer price index adjustment from BLS (2011). Projections by Downstream Strategies and EDR Group.

FIGURE 5 ★ **Expected Wastewater Treatment and Drinking-Water Infrastructure Needs and Investments in the U.S., 2011, 2020 and 2040**
(billions of 2010 dollars)



SOURCES Needs calculated from EPA (1997a, 1997b, 2001, 2003, 2005, 2008, 2009, 2010). Spending calculated from CBO (2010) and USCB (2011a, 2011b). Consumer price index adjustment from BLS (2011). Projections by Downstream Strategies and EDR Group.

but pipes installed after World War II have a shorter life span—about 75 years. For this reason, several generations of pipe will reach the end of their usable life within a couple of decades. Water mains must be replaced regardless of the number of current users, and because O&M needs are fulfilled by taxpayers, a smaller population translates to higher per capita replacement costs. Also, small and rural water utilities will experience higher-than-average per capita replacement costs due to the impact of a lack of economies of scale.[23]

Figure 5 shows the difference in needs, expected investments, and expected gaps for drinking-water and wastewater treatment for 2010, 2020, and 2040. Total needs for drinking-water delivery infrastructure are estimated to have been $35 billion in 2010, and escalate to $48 billion by 2020 and $74 billion by 2040 (all values are in 2010 dollars). Although more than half of drinking-water needs were funded in 2010 (58 percent of the total need), the dollars expected to be invested fall to under 50 percent of the total need by 2020 and to 40 percent by 2040. In looking at the wastewater treatment infrastructure, the estimate of total need in 2010 is $40 billion, escalating to $78 billion in 2020 and to nearly $122 billion by 2040. However, in 2010, less than 30 percent of wastewater infrastructure needs were met, and this ratio of investment to total need is expected to fall to 23 percent by 2020 and to 18 percent by 2040.

Overall, under present consumption trends and technologies, the U.S. will need $126 billion in investment for water and wastewater treatment infrastructure by 2020, and $196 billion by 2040. However, based on current investment

TABLE 7 ★ **Changes in U.S. Capital Spending by Federal, State, and Local Governments for Water Delivery and Wastewater Treatment, 1995–2040**

YEAR OR CHANGE		SPENDING	NEEDS
Water delivery	1995[A]	$13	$17
	2007[A]	$21	$33
	% change, 1995–2007	64	94
	2040[B]	$29	$74
	% change, 2007–40	40	121
Wastewater treatment	1996[A]	$11	$24
	2008[A]	$15	$52
	% change, 1996–2008	43	115
	2040[B]	$22	$122
	% change, 2008–40	43	136

NOTE Percentages may not calculate due to rounding.

[A] Historical.
[B] Trends-extended projection.

SOURCES EPA 1995 to 2008 and trends expended projections from 2007 (water) and 2008 (wastewater) through 2040, calculated by Downstream Strategies.

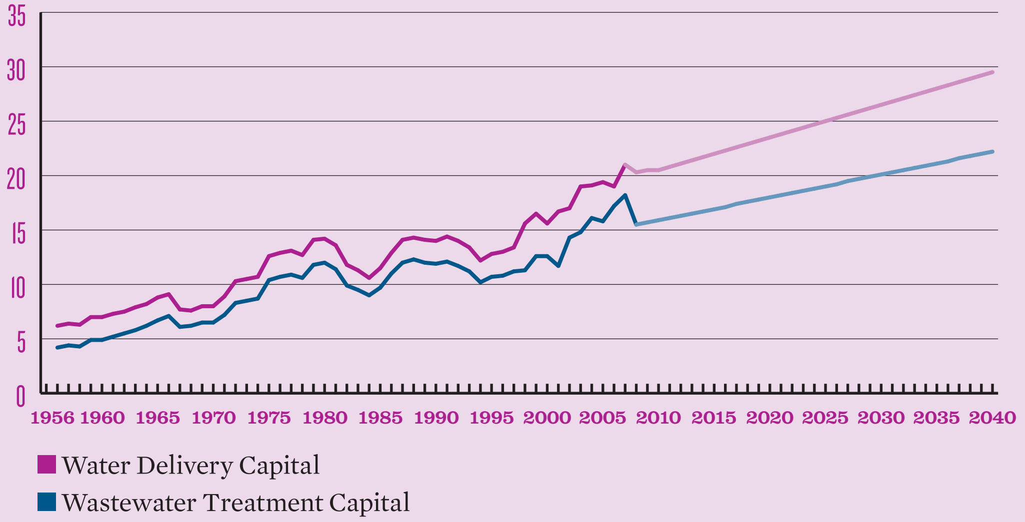
patterns, only 33 cents on the dollar will be funded in 2020, falling to 26 cents by 2040.

EPA documents historical capital spending and trends in four-year time spans for water delivery investments (1995–2007) and wastewater treatment infrastructure (1996–2008). In constant 2010 dollars, historical trends show federal, state, and local government investments in water delivery rising by 64 percent from 1995 to 2007 and in wastewater treatment systems by 43 percent from 1996 to 2008. However, given the aging of current infrastructure coupled with national population growth, total capital needs increased by 94 percent for drinking-water and 115 percent for wastewater treatment during the same periods. As shown in Table 7, this gap is expected to be further exacerbated by 2040.

On a trends-extended basis, capital spending for water delivery and wastewater treatment infrastructure is expected to continually increase from now to 2040. In constant 2010 value, the data available from the mid-1950s show that capital spending for water delivery has grown from $6 billion in 1956, to $21 billion in 2007.[16] Similarly, capital spending for wastewater treatment infrastructure was $4 billion in 1956 and $18 billion in 2007. These trends imply an investment of $30 billion for drinking-water and $22 billion for wastewater by 2040. Figures 6 and 7 illustrate the historical and trends extended extrapolations of water and wastewater treatment infrastructure.

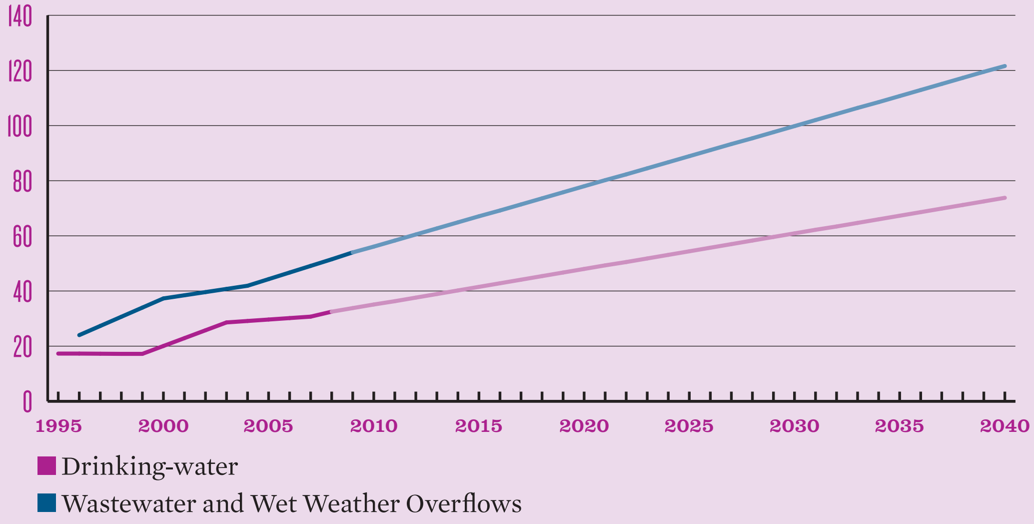
Although capital investment in upgraded water and wastewater treatment infrastructure is expected to increase through 2040, needs,

FIGURE 6 ★ **Spending by Federal, State, and Local Governments, 1956–2040**
(billions of 2010 dollars)



SOURCES EPA to 2007 (water) and 2008 (wastewater), trend-line projection from 2007 (water) and 2008 (wastewater) through 2040 calculated by Downstream Strategies.

FIGURE 7 ★ **Annual Capital Needs, 1995–2040** *(billions of 2010 dollars)*



SOURCES EPA to 2008 (water) and 2009 (wastewater and wet weather), Trend-line projection from 2008 (water) and 2009 (wastewater and wet weather) through 2040 calculated by Downstream Strategies.

and therefore the capital spending gap is expected to grow at a faster rate than spending over the coming 30 years.

3.2 Comparison of the Gap to the National Economy

The gap between expected capital needs and expenditures for water delivery and wastewater treatment infrastructure is expected to grow faster than growth in employment, income, and GDP. This is true, even before accounting for macroeconomic impacts from a shortfall in water and wastewater infrastructure investment, not to mention the needs to address failing infrastructure in surface transportation, energy transmission services, marine ports, and airports. As shown in Table 8, the water and wastewater treatment infrastructure investment gap grows at faster rates than income or GDP, whether in total values or weighted by population. The growth of the gap will place increasingly greater strains on households and industries between today and 2040.

TABLE 8 ★ **Comparative Changes of the Water and Wastewater Treatment Capital Spending Gap and the U.S. Economy in 2010, 2020, and 2040**

MEASURE	ANNUAL VALUE (2010 DOLLARS)			PERCENT CHANGE		
	2010	2020	2040	2010–20	2020–40	2010–40
AGGREGATE						
Water infrastructure gap (billions)	$54.8	$84.4	$143.7	54	70	162
U.S. GDP (billions)	$14,613	$19,066	$28,453	30	49	95
Personal income (billions)	$6,446	$9,236	$14,581	43	58	126
WEIGHTED						
Gap per capita	$177	$248	$354	40	43	100
Gap per household	$464	$645	$916	39	42	97
Per capita income	$20,795	$27,085	$35,913	30	33	73
Per worker income	$49,655	$61,853	$84,749	25	37	71
GDP per capita	$47,139	$55,911	$70,080	19	25	49
GDP per worker	$112,561	$127,680	$165,380	13	30	47

NOTE “Aggregate measures” are displayed in billions of 2010 dollars. However, “weighted measures” are shown in single 2010 dollars and are not rounded.

SOURCES Moodys.com for projections for employment, GDP, and personal income. Population and household had are guided by the projections of the Social Security Administration and were aggregated by the INFORUM research unit of the University of Maryland.

4 | REGIONAL OVERVIEW

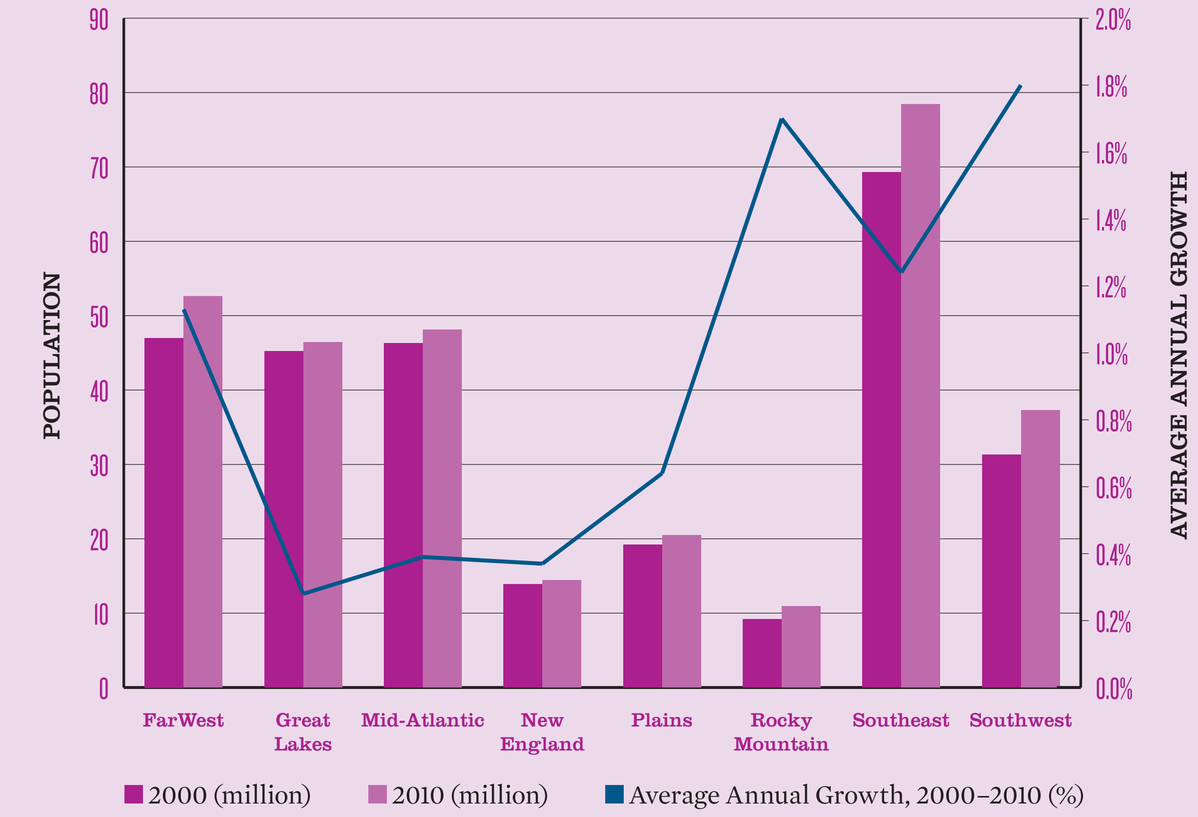
4.1 Building New Infrastructure

The need for new water infrastructure in the United States will generally parallel increases in population and economic activity, unless new needs are addressed by increasing the efficiency of existing systems. As shown in Figures 8 and 9, population and economic activity (measured as gross regional product) are growing fastest in the nation's Far West, Rocky Mountains, Southeast, and Southwest regions. A fifth region, the Mid-Atlantic, has also experienced rapid economic growth. Therefore, these regions are expected to be significantly impacted due to the expansion needs for existing water, sewer, and wet weather management systems.

4.2 Maintaining the Existing Infrastructure

Every four years, the EPA compiles needs assessments for drinking-water and wastewater infrastructure. These assessments are instructive in helping to identify which regions are most in need of investments to repair or replace existing infrastructure.

FIGURE 8 ★ U.S. Population Growth by Region, 2000–2010



SOURCE USCB (2000, 2010).

Figure 10 summarizes the most recent drinking-water needs survey, which compiles needs over the next 20 years. Needs are greater than $1,000 per person in five regions: Far West, Great Lakes, Mid-Atlantic, Plains, and Southwest.

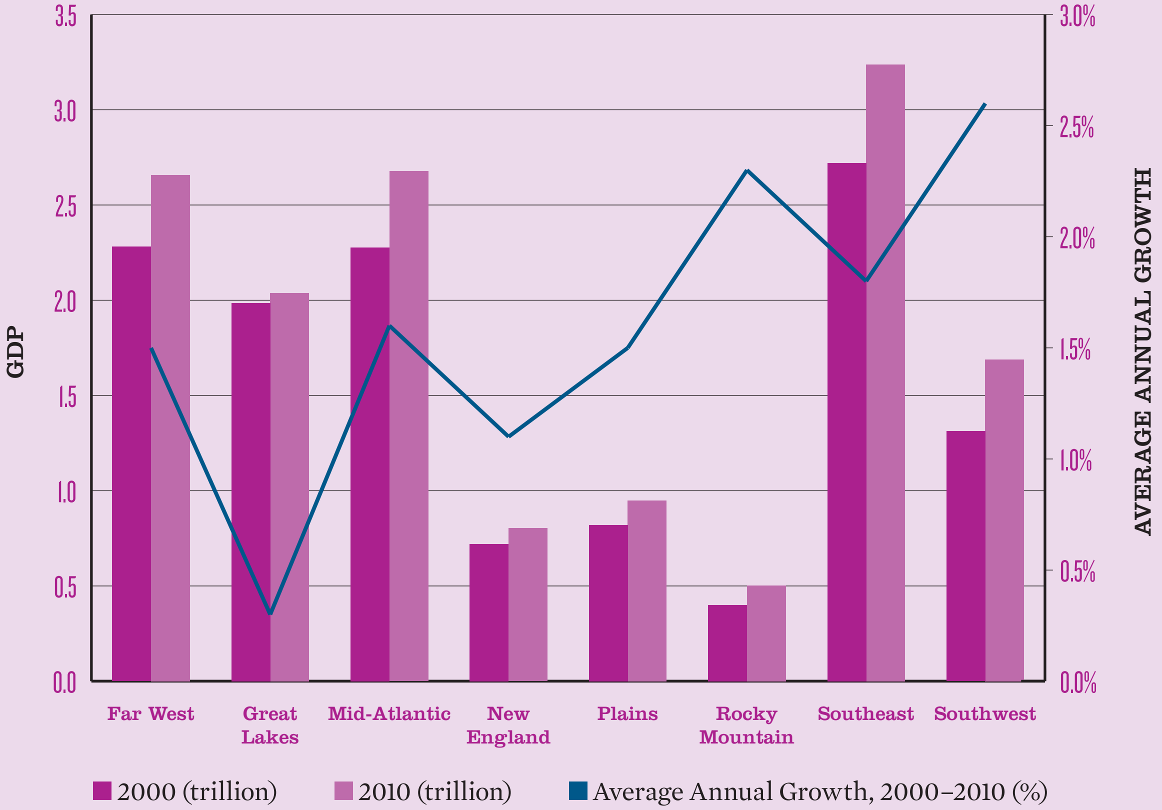
As shown in Figure 10, the Mid-Atlantic region has particularly high per capita needs to address wastewater and wet weather needs. Other regions with needs greater than $800 per person include the Far West, Great Lakes, New England, and Plains.

The Great Lakes and Mid-Atlantic regions have particularly large needs to address wet weather management to prevent raw sewage from discharging into streams, lakes, and the Atlantic Ocean. More than 80 percent of the total projected WWO needs during the next 20 years will occur within these two regions.

As summarized in Table 9, the Far West, Mid-Atlantic, and Southwest regions have significant concerns for both building new water infrastructure to support population and economic growth, and also for maintaining existing infrastructure. All other regions have concerns regarding one or the other category—building new or maintaining existing infrastructure.

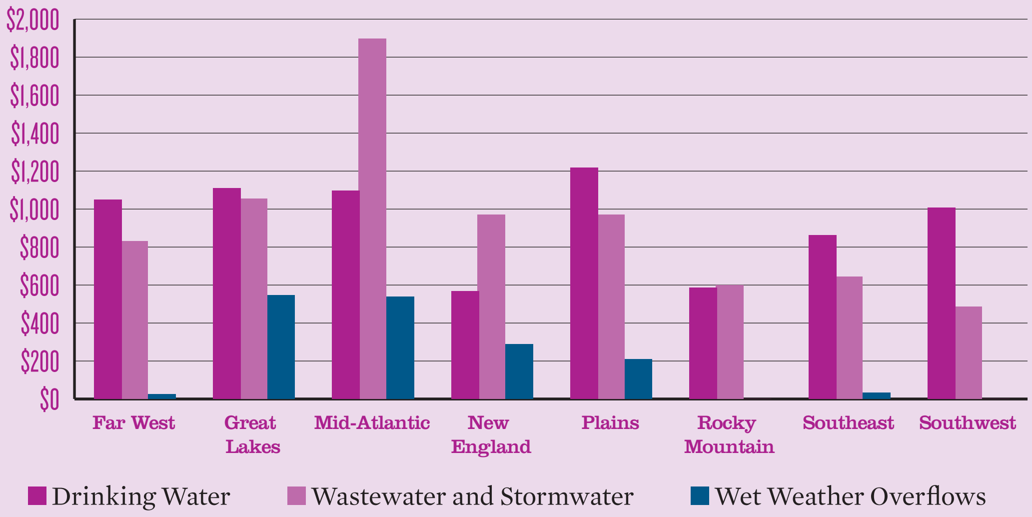
Population and economic activity are growing fastest in the nation's Far West, Rocky Mountains, Southeast, and Southwest regions. A fifth region, the Mid-Atlantic, has also experienced rapid economic growth.

FIGURE 9 ★ **Gross Regional Product Growth, 2000–2010**



SOURCES GDP from BEA (2011). Consumer price index adjustment from BLS (2011).

FIGURE 10 ★ Per Capita 20-Year Needs by Region



SOURCES EPA (2009, 2010). Population from USCB (2010).

TABLE 9 ★ Regional Concerns Regarding Building New or Maintaining the Existing Water Infrastructure

REGION	BUILDING NEW INFRASTRUCTURE	MAINTAINING EXISTING DRINKING-WATER INFRASTRUCTURE	MAINTAINING EXISTING WASTEWATER AND WET WEATHER INFRASTRUCTURE
Far West	X	X	X
Great Lakes		X	X
Mid-Atlantic	X	X	X
New England			X
Plains		X	X
Rocky Mountains	X		
Southeast	X		
Southwest	X	X	

NOTE Regions are agglomerations of states and therefore issued faced by individual states, cities or substate areas are subsumed in the overall regional totals. For example, building new infrastructure is identified as a need in the Rocky Mountain Region. Yet in metro areas like Denver the greatest expenditure will be in replacing and updating existing infrastructure.

SOURCES Synthesis by Downstream Strategies and EDR Group based on figures 8–10 and associated discussion.

5 | ANALYTICAL FRAMEWORK

5.1 The Funding Gap

The first step is comparing the two alternative scenarios, to calculate the funding gap between what would be needed to maintain the U.S. water and sewer infrastructure and operating systems to meet anticipated future needs, and what is expected to be spent given current investment trends. This chapter describes the analytical process for calculating the 2010–40 funding gap.

In summary, the gap between needs and investment in water and sewer infrastructure is $55 billion in 2010 and is expected to grow to $144 billion (in 2010 dollars) by 2040 if present trends in investment and demand by households and businesses continue.

5.2 Costs Incurred by Households and Businesses

The second step is to identify the costs incurred by households and businesses during the 2010–40 period if current investment trends prevail and the nation's water and sewer facilities degrade in performance and capacity. Our analysis of these consequences is based on combining the following factors:

- ★ Average rates for water and sewer service and past trends of rate changes;
- ★ Estimates of operation and maintenance charges for self-supply systems;
- ★ Number of households dependent on public water systems;
- ★ Adjustments for multiple households and business establishments on a single parcel;
- ★ Number of establishments by size and type (*commercial, industrial*) that do not self-supply; and
- ★ Estimates for capital costs for consuming households and businesses to self-supply water and sewer services.

Using these factors and the related assumptions, by 2020 the approximate $84 billion forecast *annual* deficit for sustaining water delivery and wastewater treatment infrastructure may lead to $38 billion in costs for businesses and households in that year and more than $200 billion in cumulative costs from 2011 (Table 2). With the continued growth of the gap to $144 billion by 2040, costs accruing to businesses and households may be an additional $200 billion that year and by 2040 amount to a cumulative total exceeding $2 trillion. Key analysis and assumptions are noted below.

Private Water and Sewer Alternatives

Digging a well and installing a septic system is one option for a household and business to respond to inadequate infrastructure, although it is not a reasonable response for every location (e.g., a city or a location without water, or places where legal regulations prohibit some or all private options) or a choice that every business or household that could do so would pick. Other possible responses include moving a household or business to a place with adequate water and wastewater treatment services, and purchasing and installing equipment that will conserve water. For the purpose of this study, we use the customer's response of privatizing as a stand-in for all possible responses under the premise that all possible responses incur costs, and the cost of privatization is a reasonable proxy for other adjustments.

The rate of annual self-supply response is assumed to track the annual growth in the water and wastewater investment gap. Thus, as the gap worsens our scenario shows an increasing number of businesses and households hedging against the costs associated with deteriorating water delivery and wastewater treatment and reliability of services.

Self-supply costs differ by countless factors. Some depend on location—including the proximity of the water source and the scale of construction required to tap the source—and on local regulations. Other factors are related to the amount of water and the size of the septic systems desired. Related to this is the size of a housing unit, including different scales of single-family homes and multifamily developments. For commercial and industrial use, the type and size of the business must be taken into account, as well as whether the business physically stands alone or is in an office building or retail mall.

We developed overarching assumptions about the cost of self-supply through a series of consultations with design-build firms and civil engineers independent of ASCE. For commercial and industrial sectors, onetime capital costs

TABLE 2 ★ Estimated Costs for U.S. Households and Businesses due to Unreliable Water and Wastewater Infrastructure *(billions of 2010 dollars)*

SECTOR	COSTS, 2011–20		COSTS, 2021–40		COSTS, 2011–40	
	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL
Households	$59	$6	$557	$28	$616	$21
Businesses	$147	$15	$1,487	$74	$1,634	$54
TOTALS	**$206**	**$21**	**$2,044**	**$102**	**$2,250**	**$75**

NOTE Numbers may not add due to rounding.

SOURCES EDR Group based on interviews, establishment counts, and sizes by sector from *County Business Patterns*, population forecasts of the U.S. Census, and forecasts of establishments and households provided by the INFORUM Group of the University of Maryland.

range from $500,000 to more than $1.5 million, though for this study such costs were capped at $1 million and were assumed to be at the lower end of the scale for all except the largest business establishments in the U.S. For households, digging a well was estimated at a typical range of $8,000 to $10,000, and installing a septic system was estimated between $25,000 and $50,000.[24] Private costs for annual operation and maintenance were estimated by interviewees at running at about $45,000 for commercial and industrial use, and $1,000 for households.[25]

It should be mentioned that new technologies and approaches may reduce future water infrastructure needs. For example, many cities have recently adopted green infrastructure approaches to wet weather overflow management. Green roofs, grassy swales, and rain gardens, for example, are used to infiltrate, evapotranspire, and capture and reuse rain to mimic natural water systems. Such techniques often provide financial savings to communities.

Average Water Rates

The *2010 Water and Wastewater Survey* by the American Water Works Association reported water and wastewater rates for 308 water utilities and 228 wastewater utilities by size of utility and millions of gallons per day consumed by users. Five classes of residential ranges and four classes of commercial and industrial ranges were identified. We averaged the rates and charges for residential, commercial, and industrial customers nationally and by multistate region according to the location and size of each utility.

Number of Businesses and Households

Our data on the number of business establishments by size and region were taken from *U.S. County Business Patterns* and aggregated by commercial and industrial classifications. The most recent data available are for 2009, and these data were projected to 2040 based on employment projects by sector obtained from Moodys.com. Household projections were provided by the INFORUM Research Unit of the University of Maryland and were guided by projections from the Social Security Administration.

Costs among Industries and Households

The most recent national analysis by sector based on U.S. Geological Survey data was conducted in 1995 and shows that households account for 56 percent of public water demand, commercial sectors account for 17 percent, industrial sectors account for 12 percent, and public uses and losses make up the remaining 15 percent. Ten years later, the analysis was completed without this degree of detail, but it shows that households draw 58 percent of water nationally, which was similar to the 1995 findings. If the cost of water rises due to deficient infrastructure, the question is how costs will be spread across the economy. We started with the base of demand across broadly defined sectors: 56 percent households, 17 percent commercial establishments, and 12 percent industrial establishments. We then made an assumption that households, which are made up of voters, will insist that costs be assigned to businesses, following the pattern of many communities that have dual property tax rates and dual utility rates—one for households, and one for businesses. For this analysis, future costs are allocated to households at 33 percent, the commercial sector at 24 percent, and the industrial sector at 28 percent. The significant increase in the industrial sector's share is based on the list of key water dependent industries, which are all industrial, and 28 of the top 30 water-intensive sectors, including the top 20, are industrial.[26]

The Incidence of Waterborne Illnesses

Deficiencies in the systems used for the public-provision of drinking water and the handling of wastewater and stormwater can trigger bacterial and viral outbreaks. The EPA and the Centers for Disease Control and Prevention have tracked the 30-year[27] incidence of water-borne illnesses across the U.S., categorized the type of illness, and have developed a monetary burden for those cases. Based on the annual percentage increase in the capital spending gap projected through

2040, the monetary burden for water-borne illness is estimated to be $413 million for 2011–20 and $1.3 billion for 2021–40.[28] To put these costs in perspective, by 2040 the U.S. per capita cumulative impacts of water-borne illnesses in the face of an increasing infrastructure gap are estimated to be $4.89 and to fluctuate between $.11 and $.21 per year from 2011 to 2040. A World Health Organization report estimates that the per capita worldwide effects of water-borne illnesses will be $98 in 2015.[29]

Adjustments for Multiple Households and Business Establishments on Single Parcels

The findings discussed above were adjusted to reflect multiple housing units and business establishments on single parcels based on national data. According to the data reported by the U.S. Census Bureau's "2005–2009 American Community Survey," roughly 128 million housing units are placed on 100 million parcels. Therefore, the household impacts were discounted by 21.5 percent.

In addition, the U.S. Energy Information Administration (EIA) calculated that 705,000 office buildings in the U.S. contain a total of 1.6 million establishments, an average of 2.3 per building. This is slightly more than the average number of establishments in other types of commercial buildings (1.7 per building) and retail (1.8 per building). Nevertheless, a large majority (70 percent) of office buildings have only one establishment. To be cautious, the office ratio of 2.3 was used for this analysis, and commercial establishments were discounted by 56.5 percent.[30] Using the EIA average of 1.7 would produce a lower reduction of establishments (e.g., using the 1.7 average would result in a reduction rate of 41 percent).

The Broader Effects on the Nation's Economy

The final step is to calculate how these costs ultimately affect the nation's economy. First, the added costs of failing to adequately invest in water and sewer infrastructure were allocated to industries and sectors of the economy based on water reliance and usage rates. Then the LIFT (Long-term Inter-industry Forecasting Tool) economic model was used to calculate how these added household and business costs will, over time, ultimately affect expenditure patterns and business productivity among industries, leading to changes in the nation's competitiveness and economic growth. The results are provided as long-term changes in jobs and income in the U.S. The LIFT model is a national policy and impact forecasting system developed by INFORUM, a research center within the Department of Economics at the University of Maryland, College Park.

5.3 Water-Intensive Industries

This section examines sectors of the U.S. economy that are most dependent on public water/wastewater infrastructure. Morikawa et al. (2007) lists 11 industry sectors that are highly dependent on water resources or vulnerable to water risks. These are not necessarily the eleven most water-intensive industries across the U.S. but are industries that most rely on dependable clean water supply. There is overlap in the water-intensive and water-dependent analyses presented (chemicals, beverages, food processing, but notably core industries of automobile manufacturing, biotechnology/pharmaceuticals and electronics are classified as among the most water dependent sectors in the U.S. economy. These are key industrial sectors of the national economy, and include:

- ★ Apparel
- ★ Automobile.
- ★ Beverage.
- ★ Biotech/Pharmaceutical
- ★ Chemical,
- ★ Forest Products,
- ★ Food Manufacturing,
- ★ High-technology/Electronics,
- ★ Metal/Mining,
- ★ Refining, and
- ★ Utilities.

TABLE 10 ★ Top Water-Intensive Industries in the U.S. *(direct water use per dollar output)*

INDUSTRY	GALLONS/$ OUTPUT
Paint & coating manufacturing	123
Alkalies & chlorine manufacturing	38
Paperboard mills	36
Wineries	34
Pesticide & other agricultural chemical manufacturing	30
Synthetic dye & pigment manufacturing	27
Adhesive manufacturing	21
Industrial gas manufacturing	21
Distilleries	14
Poultry processing	14
Next 20 most intensive sectors	128

SOURCE Blackhurst et al. (2010) Supplemental Materials. Note: These estimates include self-supplied water and water purchased from private water and sewer systems, but do not include water purchased from government-owned systems. Estimates exclude agricultural, mining, and electrical power generation sectors, which are primarily self-supplied.

On the other hand, Blackhurst et al. (2010) estimate water withdrawals for 426 sectors in the U.S. economy. They start with USGS data from 2000, and first disaggregate the public supply sector. Household deliveries from public supply are subtracted from total public supply, and the remaining water is allocated to 379 economic sectors based on their share of purchases from the "water, sewage and other systems" sector.[31] For sectors with unreported data, the authors use comparable rates for similar service sectors. The authors then add in self-supplied industrial withdrawals for 30 sectors in the following industries: food, textile, wood, paper, petroleum, chemical, plastic, and primary metals. Blackhurst's findings conclude that 15 of the 20 most water-intensive sectors, measured by direct water use per dollar of output, are comprised of agricultural, mining or power generation industries and, therefore, likely rely on self-supplied water and wastewater services.

Table 10 illustrates the 10 most water-intensive sectors other than agricultural, mining, and electric power generation sectors, which together account for preponderance large proportion of self-supplied water. A wide range of industries are water-dependent. The top two sectors, as well as several others, are within the chemical industry. It is important to note that this includes estimates of both publicly supplied and self-supplied water, and therefore, does not provide a direct estimate of the sectors that most rely on public water infrastructure.

6 ECONOMIC IMPACTS

Negative impacts on the U.S. economy are a result of businesses and households managing unreliable water delivery and wastewater treatment services, which in turn result from a lack of investment in the national water network. Strategies such as relocation, investing in conservation technologies, and self-supplying services can create costs that reduce business income (and, as a consequence, productivity and wages). Costs associated with water-borne illnesses and higher utility rates divert income from other uses.

The report has examined these effects in two ways. First, the report assumes that households and businesses do not adjust behavior or implement technologies beyond what is being done today, and that new conservation methods and technologies are not implemented. However, in a second approach, businesses and households are assumed to adjust to unreliable water delivery and wastewater treatment service by strengthening their conservation efforts in production and daily water use.

6.1 Current Circumstances

Overview

Unless investment increases in water infrastructure or technology/conservation solutions change, the following economic outcomes are expected:

- ★ About $734 billion in business sales will be lost cumulatively in the next 10 years, from 2011 to 2020.
- ★ By 2040, the total will amount to $7.5 trillion over 30 years.
- ★ The loss of business sales will include $416 billion in GDP from 2011 to 2020, representing the actual productivity in the U.S.
- ★ By 2040, the cumulative lost GDP will exceed $4 trillion (Table 3).

TABLE 3 ★ Effects on Total U.S. Business Sales and GDP due to Declining Water Delivery and Wastewater Treatment Infrastructure Systems, 2011–40

(billions of 2010 dollars unless noted)

YEAR	BUSINESS SALES	GDP
Losses in the Year 2020	– $140	– $81
Losses in the Year 2040	– $481	– $252
Average Annual Losses 2011–2020	– $73	– $42
Average Annual Losses 2011–2040	– $251	– $137
Cumulative Losses 2011–2020	– $734	– $416
Cumulative Losses 2011–2040	– $7.5 Trillion	– $4.1 Trillion

NOTE Losses in business sales and GDP reflect impacts in a given year against total national business sales and GDP in that year. These measures do not indicate declines from 2010 levels.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011

TABLE 11 ★ Effects on Total U.S. Jobs and Personal Income Due to Declining Water Delivery and Wastewater Treatment Infrastructure Systems, 2011–40

(billions of 2010 dollars, unless noted)

YEAR	JOBS (ROUNDED TO 100,000)	DISPOSABLE PERSONAL INCOME (BILLIONS OF 2010 DOLLARS)	DISPOSABLE PERSONAL INCOME PER CAPITA (2010 DOLLARS)	DISPOSABLE PERSONAL INCOME PER HOUSEHOLD (2010 DOLLARS)
Average annual losses, 2011–20	– 400,000	– $54	– $200	– $400
Average annual losses, 2021–40	– 1,200,000	– $222	– $600	– $1,500
Average annual losses, 2011–40	– 900,000	– $166	– $500	– $1,200
Cumulative losses, 2011–20	N.A.	– $541	– $1,700	– $4,300
Cumulative losses, 2021–40	N.A.	– $4,440	– $11,800	– $30,700
Cumulative losses, 2011-40	N.A.	– $4,981	– $13,900	– $36,000

NOTE Losses in jobs and income reflect impacts in a given year against total national jobs and income in that year. These measures do not indicate declines from 2010 levels. Total disposable personal income is in billions of 2010 dollars. Per capital and per household averages are in 2010 dollars rounded to the nearest $100. N.A. = not applicable.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011.

As shown in Table 11, these losses in business sales and GDP will lead to job and personal income declines. On average, annual jobs losses will be 367,000 each year from during 2011 to 2020, and more than 900,000 jobs annually would be lost during the 30-year span from 2011 to 2040. Job losses are expected to be 669,000 by 2020 and reach 1.4 million by 2040. Overall, disposable personal income will decrease by a total of $541 billion from 2011 to 2020, at an average of $54 billion per year, and total nearly $5 trillion from 2011 to 2040, which is an annual

On average, annual jobs losses will be 367,000 each year from during 2011 to 2020, and more than 900,000 jobs annually would be lost during the 30-year span from 2011 to 2040.

TABLE 12 ★ Potential Employment Impacts as a Consequence of Failing Water and Wastewater Infrastructure, 2020 and 2040

SECTOR	2020	2040
Agricultural services and food products	– 10,000	– 28,000
Construction	– 71,000	– 151,000
Knowledge sector services (excluding medical services)[A]	– 159,000	– 381,000
Medical services	– 15,000	223,000
Mining and refining	– 1,000	– 3,000
Retail trade	– 199,000	– 425,000
Restaurants, bars, and hotels	– 63,000	– 175,000
Technology/electronics manufacturing	– 4,000	– 11,000
Transportation equipment	– 6,000	– 23,000
Transportation services	– 16,000	– 51,000
Utilities	– 9,000	– 29,000
Wholesale trade	– 32,000	– 83,000
Other services and entertainment	– 36,000	– 123,000
Other manufacturing	– 48,000	– 117,000
TOTAL	**– 669,000**	**– 1,377,000**

[A] Knowledge sector services generally includes the medical sector. However, due to the potential of an increase in water-borne illnesses bought on by decaying infrastructure, the demand for medical services may increase, and therefore the impacts are displayed separately.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011.

average of $166 billion per year in lost income for 30 years. By 2020, the impact is expected to be almost $900 per household in terms of lost income and out of pocket expenses for costs associated with deficient infrastructure.

Given current levels of investment, capital investment needs, and demand trends, along with the deterioration of the water delivery and wastewater treatment infrastructure, this scenario could cost the U.S. nearly 700,000 jobs in 2020 and 1.4 million jobs over what is otherwise forecast for 2040.

The three sectors that will lose the greatest number of jobs are retail, restaurants and bars, and construction, resulting from a combination of less disposable income, increased water costs, and the increasing costs of water-based goods. In addition, retail impacts are likely due to higher intermediate-input prices, and less discretionary spending by households because they have health costs due to contaminated systems. Construction impacts can be traced to a general income decline among households and corporations, and the added costs of construction materials that require water either in factories or on construction sites. This is in the context of the overall economy showing almost $481 million less industrial output and $300 million less disposable personal income in 2040 (in 2010 dollars).

The impacts of these infrastructure-related job losses will be spread throughout the economy in low-wage, middle-wage and high-wage jobs. In 2020, almost 500,000 jobs will be threatened in sectors that have been traditional employers of people without extensive formal educations or entry-level workers.[32] Conversely, in generally accepted high-end sectors of the economy, 184,000 jobs will be at risk.[33] Unless the infrastructure gap is addressed, by 2040 its impacts will put at risk almost 1.2 million jobs within basic sectors, while a relatively stable net amount of 192,000 jobs in knowledge-based industries may be jeopardized. In this latter grouping, approximately 415,000 jobs will be threatened; however, medical services are expected to grow between 2020 and 2040 due to increasing outlays to fight water-borne illnesses.[34]

Although assigning industries to high education categories is a generalization, the impact will clearly be felt across sectors.

The impacts on jobs are a result of costs to businesses and households managing unreliable water delivery and wastewater treatment services. Between now and 2020, the cumulative loss in business sales will be $734 billion and the cumulative loss to the nation's economy will be $416 billion in GDP (Table 3). Impacts are expected to continue to worsen. In the year 2040 alone, the impact will be $481 billion in lost business sales and $252 billion in lost GDP.[35] Moreover, the situation is expected to worsen as the gap between needs and investment continues to grow over time. Average annual losses in GDP are estimated to be $42 billion from 2011 to 2020 and $185 million from 2021 to 2040.

Exports

By 2020, exports are likely to show a loss of approximately $6 billion compared with expected export levels, which represents an almost 4 percent decrease in business sales compared with estimates (see Table 13). By 2040, the loss of exports, which represent international business sales, will be a significant portion of the economic impacts that stem from the funding gap in water delivery and wastewater treatment infrastructure. Export losses are expected to increase steadily from 2011 to 2040. However, by 2040, the level of lost export dollars is expected to rise to almost $77 billion, which represents approximately 16 percent of the lost total national business sales. By 2040, exports will be lost in 65 of the 91 traded sectors. In contrast to domestic economic impacts, export losses will be heavily felt in the technology and manufacturing sectors—including aerospace, instruments, and drugs—and also in the associated finance and professional services sectors. This ripple effect illustrates the increasing rate of export chemical product losses from 2011 through 2040. Table 14 profiles losses by sector in 2040.

TABLE 13 ★ Cumulative Losses of U.S. Exports *(billions of 2010 dollars)*

PERIOD OF LOSSES	CUMULATIVE EXPORT LOSSES	ANNUAL AVERAGE EXPORT LOSSES
2011–20	–$20	–$2
2021–40	–$807	–$40
2011–40	–$828	–$28

NOTE Losses reflect impacts in a given year against total national export projections. These measures do not indicate declines from 2010 levels.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011.

TABLE 14 ★ Potential U.S. Export Reductions by 2040 *(billions of 2010 dollars)*

SECTOR	EXPORT DOLLARS LOST (PREDICTED FOR 2040)
Aerospace	–$10.7
Finance and insurance	–$8.3
Equipment and machinery	–$6.1
Wholesale trade	–$5.9
Instruments	–$4.7
Agricultural and food products	–$4.2
Plastics and rubber products	–$3.6
Chemical and drug products	–$3.0
Air transportation	–$2.6
Professional services	–$2.2
SUBTOTAL	**–$51.5**
Other sectors	–$25.2
TOTAL	**–$76.7**

NOTE Losses reflect impacts in a given year against total national export projections for 2040. These measures do not indicate declines from 2010 levels.

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011.

A strict “trends-extended” hypothesis shows declines that proceed much faster after 2020, as infrastructure worsens and the general approaches of households and businesses are to cut back on spending and investing due to the increasingly high cost of reliable delivery and sewer services.

TABLE 15 ★ Comparison of Potential Scenarios *(billions of 2010 dollars)*

LOSSES	ADJUSTED	STRICT TRENDS
Jobs, 2020	538,000	669,000
Jobs, 2040	615,000	1,377,000
GDP, 2020	$65	$81
GDP, 2040	$115	$252
Business sales, 2020	$115	$140
Business sales, 2040	$229	$481
Disposable personal income, 2020	$87	$106
Disposable personal income, 2040	$141	$292
ANNUAL AVERAGES, 2011–20		
Jobs	319,000	367,000
GDP	$36	$42
Business sales	$64	$73
Disposable personal income	$48	$54
ANNUAL AVERAGES, 2021–40		
Jobs	720,000	1,195,000
GDP	$111	$185
Business sales	$208	$340
Disposable personal income	$138	$222

SOURCES EDR Group and LIFT model, University of Maryland, INFORUM Group, 2011.

6.2 The Role of Sustainable Practices

It is possible that businesses and households can partially account for unreliable water delivery and wastewater treatment services by increasing their conservation efforts in production and daily water use. Improved conservation through changes in behavior, innovative production methods, and the utilization of technology is a realistic prospect in the face of rising costs.

In this study, a second impact analysis assumes that there would be a general adjustment by businesses and households as the capital gap worsened, which would mean that:

- ★ Impacts show net losses of 538,000 jobs by 2020 and 615,000 by 2040. In this circumstance, job losses would peak at 830,000 in the years 2030–32.
- ★ Business sales as a measure of total economic activity would be expected to fall by $115 billion in 2020, and $229 billion by 2040; in the years 2032–34, output decline is forecast to decline by more than $240 billion per year under this scenario.
- ★ GDP would be expected to fall by $65 billion in 2020, and $115 billion in 2040. The lowest points in the decline in GDP would be in 2029–38, when losses would exceed $120 billion annually.
- ★ After-tax personal income losses under this scenario would be $87 billion in 2020 and $141 billion in 2040. At its worst, annual losses in the years 2030–34 are estimated to range from $156 billion to $160 billion.

Table 15 compares the two impact assumptions. A strict "trends-extended" hypothesis shows declines that proceed much faster after 2020, as infrastructure worsens and the general approaches of households and businesses are to cut back on spending and investing due to the increasingly high cost of reliable delivery and sewer services when common infrastructure is growing increasingly unreliable. "Mitigated" trends extended show slightly lower impacts than the stricter scenario through 2020 and a slight upswing in all measures beginning in the mid-2030s to 2040 as households and businesses adjust to the long-term unreliability of water delivery and wastewater treatment infrastructure.

6.3 Innovative Approaches to Water Delivery and Wastewater Treatment

Innovative approaches to tomorrow's water infrastructure may not look the same as today. Today's new or envisioned technologies and approaches may become routine with advances in science and regulatory frameworks or needs. In this section, several types of new and emerging technologies and approaches are described that may impact drinking-water, wastewater, and wet weather management infrastructure, and therefore affect the size of the capital gap of failing to invest in current systems.

Separate Potable and Nonpotable Water

A large portion of public supply water is used for watering lawns, flushing toilets, and washing clothes. These uses do not require potable water, but in most localities, all publicly supplied water is treated to meet federal drinking-water standards. It is becoming cost-effective for municipalities to construct separate lines for potable and nonpotable uses as water becomes scarcer and treatment more costly. In Tampa, for example, customers are offered the option of hooking up to a reclaimed water system for lawn irrigation. In serviced neighborhoods, customers must pay a connection fee, but the usage fee for reclaimed water is 40 to 80 percent less than for treated water, depending on the volume used.

Advanced Treatment of Wastewater

The "advanced" treatment of wastewater denotes treatment that is more stringent than secondary treatment or produces a significant reduction in biochemical oxygen demand, nitrogen,

Today's new or envisioned technologies and approaches may become routine with advances in science and regulatory frameworks or needs.

phosphorous, ammonia, metals, or synthetic organic compounds.[36]

The Chesapeake Bay—which receives pollutants from Maryland, Virginia, and Delaware and from as far away as Pennsylvania, New York, and West Virginia—provides an example of a regulatory driver for advanced wastewater treatment. The bay is impaired, and a total maximum daily load cleanup plan has been developed that outlines reductions in nitrogen, phosphorus, and sediment levels that must be met across the watershed in order to return the bay to health. More stringent nitrogen and phosphorus limitations at wastewater treatment plants will be critical in implementing this clean-up plan and ensuring that algae blooms and dead zones, where fish and shellfish cannot survive, no longer occur.

Reclaimed Wastewater

In areas of water scarcity, it is sometimes reasonable to divert wastewater treatment plant effluent for beneficial uses such as irrigation, industrial use, and thermoelectric cooling, instead of releasing the effluent into rivers or aquifers. In this way, a "new" water source is tapped.

In its recent surveys, the EPA has documented needs among the 50 states for building distribution systems for this reclaimed, or recycled, water. Such needs were reported by 20 states in 2008, which is up from 15 states in 2004. Based on reported needs, California and Florida lead the nation in recycled water systems, while the largest percentage growth over the two reporting cycles occurred in Texas and North Carolina.[37] Recycled wastewater is being used for irrigation, thermoelectric cooling, and even to recharge aquifers that source public water supplies.

Green Infrastructure

In natural systems, most precipitation is absorbed or infiltrated into the ground, where it replenishes aquifers, nourishes plants, and supplies water to nearby streams during low flows. This process is important for the long-term maintenance of drinking-water supplies. Green infrastructure provides several techniques that mimic natural systems by providing infiltration and capturing mechanisms for wet weather runoff, including green roofs, grassy swales, permeable pavement, and rain barrels.

Desalination

Although a response to water-supply shortages and not a type of water delivery, desalination is important because of the scale of investment required for its development. Desalination removes salt and minerals from seawater or brackish groundwater, making it fit to drink. As with other alternative water technologies, desalination in the U.S. is most prevalent in Florida, Texas, and California. Desalination is an old idea, but its modern manifestation requires vast amounts of energy and a technology that has not yet been perfected. Desalination of brackish groundwater is occurring in Yuma and El Paso, while examples of coastal desalination plants include Monterey Bay, California, and Tampa Bay.

Water Hauling

One extreme and logistically challenging strategy to address water deficiencies in delivery systems and supply is water-hauling, which is the practice of supplying water to households and businesses by truck delivery. Although this practice is part of everyday life in many nations, in the U.S. it is mostly limited to cases of extreme droughts and large natural disasters, or routinely to fill swimming pools.

7 | CONCLUSIONS

The Diamond-Water Paradox is taught in many introductory economics courses. The paradox is that although water is much more central to life than diamonds, diamonds are more expensive than water.[38] Up to this moment, American households and businesses have never had to contemplate how much they would be willing to pay for water if it were to become hard to obtain. Economic analyses have not contemplated the impacts of exceptionally high costs for water and wastewater treatment on the national economy.

Water infrastructure is distinct in its commitment to public safety. For example, if the transportation infrastructure breaks down, travel will be slow and the slowdown will mean that businesses and households will incur costs, but travelers will still be able to get to their destinations. Water, however, is vital, and if it is not available, essential life activities cannot be sustained. Although water may be conserved, it must be obtainable. A well-maintained public drinking-water and wastewater infrastructure is critical for public health, strong businesses, and clean rivers and aquifers. However, as documented in this report, capital spending has not been keeping pace with needs, and if these trends continue, the resulting gap will only widen through 2040. As a result, pipes will leak, new facilities required to meet stringent environmental goals will be delayed, operations and maintenance will become more expensive, and sources of water will become polluted.

Funding to close the gap can come from multiple sources. Federal grants and loans have played crucial roles in building water infrastructure over the decades. Despite recent federal deficits, infrastructure spending can both create short-term construction jobs and improve the foundation upon which the nation's economy rests.

Yet federal funding is not the only answer; since the mid-1970s, money from local and state governments has represented an increasing percentage of public drinking-water and wastewater investment—rising to more than 95 percent in recent years.[39]

Because some water systems are now privatized (approximately 10 percent of the 170,000 public-serving drinking-water systems), private capital may become increasingly important. But whether a system is government owned or private, households and businesses still ultimately foot the bill; thus, setting rates at levels sufficient to maintain and upgrade infrastructure is critical. If rates increase too much, however, more low-income residents would face financial hardship.

There are multiple ways to prevent these negative consequences described in this report. Possible preventive measures include spending more on existing technologies, investing to develop and then implement new technologies, and changing patterns in where and how we live. All these solutions involve costs. Separately or in combination, these solutions will require action at the national, regional, and private levels, and will not occur automatically.

7.1 Opportunities for Future Research

This study has examined the economic implications of the United States' failure to meet its future needs for water delivery and wastewater treatment infrastructure, but that is only part of the story. If we want to assure that households and businesses will continue to receive access to affordable and safe water in the future, then there are also needs to maintain and grow available resources such as dams, aquifers, and other water supply sources. Three of the nation's four regions with high population growth—the Far West, Rocky Mountain, and Southwest—include virtually all its desert lands and most of its semiarid regions. Deserts and semiarid regions receive less than 20 inches of rain per year, and have evaporation rates that exceed precipitation rates. In these water-scarce regions, water is often drawn from deep underground aquifers or piped in from wetter climes. Therefore, one area of focus for future research will be to refine estimates of the availability and cost to access additional water sources, particularly as technology continues to develop.

A related focus for future research would be to examine how climate change may affect water supplies. Future climate change can alter the timing and extent of snow and rain seasons, affecting reservoirs and exacerbating drought conditions in arid climates. Additionally, extended storms may overextend wet weather system overflows in place.

A third area for future research would attempt to develop data on how households and businesses react to the loss of reliable water services and the costs to adjust. Tools that could be employed in a study include a survey to examine how businesses and households have reacted to breakdowns in water delivery and costs that have been incurred to date. To be most effective, this type of survey effort should be segmented by household income and industry sector—the latter to separate water-dependent industries from other industries. A second tool would be to fully develop a national database of water and sewer systems that includes a historical national profile of water delivery and cross-tabulated by gallons per day, costs, geography, customer market, and age of the system (or state of good repair).

Our research validates a widely accepted premise that the age of the water and wastewater treatment infrastructure is a major problem in maintaining reliable service. The disaggregation of water delivery and treatment systems is a barrier to developing a comprehensive national study of the age of pipes and their remaining useful life. However, given the aging infrastructure, particularly in the older urban areas of the Northeast, Mid-Atlantic, and Midwest, older water systems that are not being replaced or substantially upgraded appear to be critical points for infrastructure failure. In this context, a comprehensive national study is needed as the first step toward implementing a methodical, preventive capital investment plan.

★ ABOUT THE STUDY

This study illustrates scenarios of what could happen to the national economy if households and businesses must pay a premium for reliable water delivery and wastewater treatment, using current trends of water demand, infrastructure needs, investment and available information about strategies that are available to guarantee reliability. The analysis approach compares three scenarios:

- ★ The implied base case in which sufficient investment is made to maintain water and sewer infrastructure systems to meet anticipated future needs, and

- ★ Two scenarios in which current investment trends lead to a growing gap between the performance of our nation's water and sewer systems and anticipated needs.

These latter scenarios consider "gross impacts" and not "net impacts" of water consumers' strategies to contend with unreliable water delivery and wastewater treatment services. Economic impacts for purchases of technologies not yet invented or widely employed, and impacts from more money being diverted to moving companies, digging wells and producing and installing septic systems were not measured due to the difficulty of estimating the costs required to pursue these various alternatives. Once the nature of potential water conservation technologies are explored, as well as behavioral modeling of water consumers' responses, an extension of this analysis could include those spending effects as well.

Capital needs and expenditures for drinking water and wastewater treatment infrastructure are based on federal government data sources. In particular, EPA's drinking water needs surveys, clean watersheds needs surveys, and gap analysis provide key information about the scale and types of needs by state and the growth in these needs over time. The U.S. Congressional Budget Office (CBO) and the Census Bureau provide key historical public spending data, and the Census Bureau also provides important data on private capital expenditures on water infrastructure. Future trends in infrastructure needs and spending are based on a continuation of past trends, and were validated by a literature review and expert interviews.

This economic analysis is primarily based on two data sets developed by EPA, interviews and literature. Key sources and assumptions include:

- ★ Twenty-year forecasts of infrastructure needs and funds for water and wastewater treatment infrastructure published by EPA. The last study was published in 2007 for water and 2008 for wastewater. The data was projected on a straight-line to 2040 based on trends of local, state and federal spending and needs from 1995 to 2007 for water and 1996 to 2008 for wastewater. See Chapter 3 for more detail.

- ★ Studies of the U.S. Geological Survey identify water demand by region, and type of customer as measured by millions of gallons per day (MGD). See Chapter 4 for more detail.

- ★ The added costs that will be increasingly incurred by households and businesses in future years, in response to increasingly unreliable water delivery and wastewater treatment services. This includes costs associated with self-supply of services, relocation and/or conservation. See Chapter 6 for more detail.

Several adjustments were applied to results of the Drinking-water and Clean Watersheds Needs Surveys. This approach follows the lead of EPA, which made similar adjustments in its 2002 gap analysis:

- ★ The needs were adjusted to constant 2010 dollars;

- ★ Underreporting across all segments of drinking-water infrastructure was addressed by adding an underreporting adjustment, which is calculated by multiplying the total of the other sectors by a factor of 0.74;[40]

- ★ The estimated need for wet weather management each year was increased by a factor of 7.94, which is the factor calculated by EPA (2002) in its gap analysis for this line item;[41] and

- ★ The underreporting across all segments of wastewater treatment, sanitary sewers and combined sewer overflows was addressed by adding an underreporting adjustment, which is calculated by multiplying the total of the other water treatment sectors by a factor of 0.73.[42]

The economic analysis process has three steps:

1. Through comparison of the two alternative scenarios, we calculate the added costs incurred by households and businesses due to increasingly inadequate infrastructure. This is done on a year-by-year basis.
2. Those added costs are distributed amongst households and various sectors of the economy in accordance with their location and water/sewer use patterns.
3. An economic model of our nation's economy is used to calculate how households' income and expenditure patterns, as well as business productivity, is affected and lead to changes in our nation's competitiveness and economic growth. The results are provided in terms of long-term changes in jobs and income in the U.S. This sequence makes use of the LIFT model, a national policy and impact forecasting system developed by INFORUM—a research center within the Department of Economics at the University of Maryland, College Park.

The four step process for threading the incurred costs through the LIFT model is summarized below:

1. Costs
    a. Convert costs by sector using a amortization rate of .05 (20 years)
    b. Add operation and maintenance costs
    c. Allocate costs by broad segments across appropriate LIFT production sectors and households using LIFT Input-Output (IO) coefficients. Costs based on estimates of self-supply investment in lieu of data for moving and/or conservation costs.
2. Costs of paying higher public system rates.
    a. Convert all quantities to prices using baseline forecast GDP deflator
    b. Allocate increased public sector costs by broad segment across appropriate LIFT production sectors and households using LIFT IO coefficients.
3. Compute cost/price shocks
    a. For each production sector, compute net increase in commodity prices implied by cost shocks calculated in steps 1 and 2. For household sector, compute net increase in water and sewer personal consumption expenditure (PCE) deflator implied by cost increases. These price increments are inputted to the LIFT alternative simulation as multiplicative add factors on commodity and PCE prices.
4. Health and Labor Productivity Implications of Poor Systems
    a. Using additive add factors, apply real expenditure increases in medical service to LIFT PCE service sectors (e.g. physician, hospitals, and other medical services). Deduct equivalent amount from all other PCE spending.
    a. Add cost of lost days directly to the aggregate wage index. This allocates the costs across sectors proportional to total cost of labor in each sector. Cost increase will show up in prices (not as additional employment).

ENDNOTES

1. EPA 2010.

2. EPA 2002.

3. EPA 2004, as cited by ASCE 2009.

4. Agriculture and food products, restaurants, bars and hotels, transportation services, retail trade; wholesale trade, utilities, construction, mining, and refining, other services and entertainment, and other manufacturing.

5. Transportation equipment manufacturing, knowledge sector services, medical services, and technology and instrument manufacturing.

6. Assigning industries to high education dependent or no education dependent is, of course, a generalization. Retail and wholesale operations include MBAs and computer programmers, while hospitals include orderlies and technology companies employ janitors. Observations of the discussion above were made on the basis of a preponderance of occupations in industries that drive the industries and the nature of the product or service that is produced.

7. "Business sales" is being used to represent economic output, which is gross economic activity, including businesses sales, production added to inventory or destroyed, and budget expenditures for nonprofit and public sector organizations. "GDP" or "value added," are the economic activities that occur in the U.S. and is a better indication of domestic productivity. For example, a car assembled and sold in the U.S. might include parts manufactured in Europe or Asia. In this example, the cost of foreign made parts and the transportation costs to transport those parts to the U.S. are part of the price of the car and would be included in the sale price of the car (business sales). However, GDP includes only the domestic assembly, whatever parts are manufactured in the U.S., transportation costs that originate in the U.S., and activities associated with the sale (or consignment to inventory/demolition) of the car.

8. Kenny et al. (2009).

9. Pacific Institute (2009); USCB (2000, 2010).

10. Overall, per capita water use is already down in the U.S. It had peaked in the mid-1970s, and current levels are now the lowest since the 1950s. This trend is due to increases in the efficiency of industrial and agricultural water use and is reflected by an increase in the economic productivity of water (Pacific Institute 2009). In contrast, per capita water use in the home has remained stable since the 1980s (Kenny et al. 2009). Efficiency and conservation have reduced per capita household consumption in some states and regions, but these efforts have been countered by increasing populations in hot and arid regions of the country—including the Southwest, Rocky Mountains, and Far West—where there is greater domestic demand for outdoor water use (Pacific Institute 2009; USCB 2000, 2010).

11. EPA 2002.

12. ASCE 2009b.

13. EPA 2010.

14. EPA 2002.

15. EPA 2004, as cited by ASCE 2009a.

16. In our analysis, we calculate capital spending separately for federal, state, and local governments and for privatized systems. Government expenditures are available since 1956; however, privatized capital expenditures are only available starting in 1998. Both are projected into the future using a simple continuation of past trends, and the sum represents total capital spending for drinking-water infrastructure across the U.S. Drinking-water capital spending by federal, state, and local governments has increased consistently since 1956. Drinking-water capital spending by privatized systems is much smaller, and averaged between 12 and 16 percent of the total between 1998 and 2007. It is difficult to predict future levels of capital spending because a wide range of factors will play unpredictable rolls during the coming decades. Spending will be impacted by the degree to which infrastructure actually fails or is predicted to fail in the near future. In addition, capital spending will rise to meet requirements from new laws and regulations. Demographic changes like population increases, and economic changes like expanding local economies, will also impact future capital spending in particular regions.

17. Thirty-year needs are estimated by fitting a straight-line projection based on historical spending data and needs data that are documented, and spending and 20-year needs data projected by the EPA.

18. The "source" category includes needs for constructing or rehabilitating surface water intakes, raw water pumping facilities, drilled wells, and spring collectors. Neither the "storage" nor "source" category includes raw water reservoirs or dams.

19. Although data on spending are available from the mid-1950s, total needs are documented from the mid-1990s. The "gap" is [total needs–total spending].

20. Anderson 2010.

21. EPA 2002.

22. AWWA 2001.

23. AWWA 2001.

24. Capital costs were assumed to be amortized over 20 years.

25. Very little information about moving is readily available about costs of business relocation because costs are specific to the type and size of each business, and most information available concern state payments, which are often capped or address specific portions of costs. For example, an FHWA study reports payments and expenses due to the displacement of 68 businesses in Providence, Rhode Island caused by the realignment of I-195 and the construction of a new bridge over the Providence River. These businesses varied in size from one-person proprietorships to a 50+ employee manufacturing business. All of the businesses were categorized as small businesses for purposes of their eligibility for reestablishment benefits. Costs of relocation within Rhode Island ranged from $1,000 to $1.1 million in $2010 (Federal Highway Administration, National Business Relocation Study, April 2002, Report No. FHWA-EP-02-030). Elsewhere, in 2010, Perdue Agribusiness headquarters received $1.74 million from the Delaware Strategic Fund for construction costs and relocation expenses entailed from moving from Maryland (Daily Times of Salisbury, November 9, 2011).

In 2006, Inc Magazine profiles a factory relocation at a net cost of $6.5 million ($7.0 million in 2010 dollars), including expenses associated with relocation of personnel and equipment, hiring and training new workers, and cost of land and construction minus proceeds from sale of pervious facility. Out of pocket expenditures for household relocations are based on distance and the amount of labor household members put into the move. Actual moving expenses are roughly $5,000–$10,000 based on various “move calculators on the web”, assuming minimal labor provided by household members, and not factoring other costs of relocation (e.g., job and housing search, and personal transportation).

26. According to U.S. Geological Survey staff, “The difficulty in estimating how much of the ‘other’ use is for public services are that reporting requirements, if any, vary from state to state. Also there are many differences in how completely utilities can keep track of unbilled water. Typical public uses reported by cities in the sample included landscape watering, utility and interdepartmental usage, water treatment, and accounted-for losses. In many cities these uses represented only a small percentage of the net use, but in a few it was more than 10 percent.” These issues make it difficult to split “other” to public sector use and losses that could be attributed ultimately to taxpayers. Also, losses from faulty pipes may leak into the ground and not require wastewater treatment.

27. From 1971 to 2000 for all sources of water, including drinking and wastewater systems.

28. This aspect of the analysis does not take into account the incremental aging of the pipe network by 2020 (45 years) and 2040 (50 years) compared to the system as of 1970 (22 years)

29. Hutton, Guy and Haller, Laurence, Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level Water: Sanitation and Health Protection of the Human Environment, World Health Organization, Geneva, 2004. EDR Group inflated dollars from 2000 to 2010 value.

30. To determine the number of buildings for 100 commercial establishments, divide 100 by 2.3; the product is 43.5. Therefore, we assume 43.5 buildings for every 100 commercial establishments, and reduce total establishments by 56.5 percent.

31. This sector, however, describes purchases from private water and sewage systems and does not include purchases from government-owned systems.

32. Agriculture and food products, restaurants, bars and hotels, transportation services, retail trade; wholesale trade, utilities, construction, mining and refining, other services and entertainment, and other manufacturing.

33. Transportation equipment manufacturing, knowledge sector services, medical services, and technology and instrument manufacturing.

34. Assigning industries to high education dependent or no education dependent is, of course, a generalization. Retail and wholesale operations include MBAs and computer programmers, while hospitals include orderlies and technology companies employ janitors. Observations of the discussion above were made on the basis of a preponderance of occupations in industries that drive the industries and the nature of the product or service that is produced.

35. In this example, the cost of foreign made parts and the transportation costs to transport those parts to the U.S. are part of the price of the car and would be included in the sale price of the car (business sales). However, GDP includes only the domestic assembly, whatever parts are manufactured in the U.S., transportation costs that originate in the U.S., and activities associated with the sale (or consignment to inventory/demolition) of the car.

36. EPA 2010.

37. EPA 2010.

38. Smith 1965.

39. CBO 2010.

40. EPA (1997a, 2001, 2005, 2009). EPA explicitly recognized that they needed to perform an underreporting adjustment for drinking-water. In its gap analysis, USEPA (2002) accounted for underreporting by increasing its total point estimate of capital needs from the 1997 Clean Watersheds Need Survey from $157.2 to $274 billion (in 2001 $). This increases the original estimate by this factor of 0.74.

41. Based on a new USEPA (2002) found that the true SSO needs in 1996 were $92.1 billion rather than the $11.6 billion in the 1996 Clean Watersheds Need Survey (in 2001 $). We assume that the Clean Watersheds Need Surveys released since 1996 are also underestimated by this factor of 7.94.

42. In its gap analysis, USEPA (2002) accounted for underreporting by increasing its total point estimate of capital needs from the 1996 Clean Watersheds Need Survey from $224.5 to $388 billion (in 2001 $). This increases the original estimate by this factor of 0.73.

★ REFERENCES

Anderson, Richard F. 2010. *Trends in local government expenditures on public water and wastewater services and infrastructure: Past, present and future*. Washington: U.S. Conference of Mayors and Mayors' Water Council.

ASCE (American Society of Civil Engineers). 2009a. 2009 infrastructure fact sheet, water and environment, facts about wastewater. www.infrastructurereportcard.org/fact-sheet/wastewater.

—. 2009b. 2009 infrastructure fact sheet, water and environment, facts about drinking-water. www.infrastructurereportcard.org/fact-sheet/drinking-water.

AWWA (American Water Works Association). 2001. Dawn of the replacement era: Reinvesting in drinking-water infrastructure. May.

Barber, Nancy. 2011a. Hydrologist, Georgia Water Science Center Office, U.S. Geological Survey. Personal communication with author Hansen. June 7.

—. 2011b. Hydrologist, Georgia Water Science Center Office, U.S. Geological Survey. Personal communication with author Hansen. August 2.

BEA (Bureau of Economic Analysis). 2011. Gross domestic product by state: All industry total, 1997–2010. U.S. Department of Commerce. Data downloaded through www.bea.gov/regional/index.htm.

Blackhurst, Michael, Chris Hendrickson, and Jordi Sels i Vidal. 2010. Direct and indirect water withdrawals for U.S. industrial sectors. *Environ. Sci. Technol.* 44:2126-30.

BLS (Bureau of Labor Statistics). 2011. Consumer price index history table, U.S. Department of Labor ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt Accessed July 12, 2011

CBO (Congressional Budget Office). 2010. Public spending on transportation and water infrastructure: Supplemental tables. www.cbo.gov/ftpdocs/119xx/doc11940/SupplementalTables.xls.

EPA (U.S. Environmental Protection Agency). 1997a. Drinking-water infrastructure needs survey: First report to Congress. Office of Water. EPA-812-R-97-001. January.

—. 1997b. 1996 clean water needs survey report to Congress. Office of Water. EPA-832-R-97-003. September.

—. 2001. Drinking-water infrastructure needs survey: Second report to Congress (1999). Office of Water. EPA-816-R-01-004. February.

—. 2002. The clean water and drinking-water infrastructure gap analysis. Office of Water (4606M). EPA-816-R-02-020 September.

—. 2003. Clean watersheds needs survey 2000 report to Congress. Office of Water. EPA-832-R-03-001. August.

—. 2005. Drinking-water infrastructure needs survey and assessment: Third report to Congress (2003). Office of Water. EPA-816-R-05-001. June.

—. 2008. Clean watersheds needs survey 2004 report to Congress. Office of Water. EPA-832-R-08-003. January.

—. 2009. Drinking-water infrastructure needs survey and assessment: Fourth report to Congress (2007). Office of Water. EPA-816-R-09-001. February.

—. 2010. Clean watersheds needs survey 2008 report to Congress. EPA-832-R-10-002.

Gordon, Emily, Jeremy Hays, Ethan Pollack, Daniel Sanchez, and Jason Walsh, with Matthew Lewis. 2011. *Water Works: Rebuilding Infrastructure, Creating Jobs, and Greening the Environment*. Washington and Oakland: American Rivers, Economic Policy Institute, and Pacific Institute. www.pacinst.org/reports/water_works.pdf.

GRWS (Groundwater Replenishment System). 2011. Groundwater Replenishment System. www.gwrsystem.com/home.html.

Hanak, Ellen, Jay Lund, Ariel Dinar, Brian Gray, Richard Howitt, Jeffrey Mount, Peter Moyle, and Barton "Buzz" Thompson. 2011. *Managing California's water: From conflict to reconciliation*. San Francisco: Public Policy Institute of California.

Hutton, Guy, and Laurence Haller. 2004. *Evaluation of the costs and benefits of water and sanitation improvements at the global level water: Sanitation and health protection of the human environment*. Geneva: World Health Organization.

Hutson, Susan S., Nancy L. Barber; Joan F. Kenny, Kristin S. Linsey, Deborah S. Lumia, and Molly A. Maupin. 2004. Estimated use of water in the United States in 2000. U.S. Geological Survey Circular 1268. (Revised February 2005.)

Kenny, Joan F., Nancy L. Barber, Susan S. Hutson, Kristin S. Linsey, John K. Lovelace, and Molly A. Maupin. 2009. Estimated use of water in the United States in 2005. U.S. Geological Survey Circular 1344.

MacKichan, K. A. 1951. Estimated use of water in the United States, 1950. U.S. Geological Survey Circular 115.

—. 1957. Estimated use of water in the United States, 1955. U.S. Geological Survey Circular 398.

MacKichan, K. A., and J. C. Kammerer. 1961. Estimated Use of Water in the United States, 1960. U.S. Geological Survey Circular 456.

Morikawa, Mari, Jason Morrison, and Peter Gleick. 2007. *Corporate reporting on water: A review of eleven global industries*. Oakland: Pacific Institute.

Murray, Charles Richard. 1968. Estimated use of water in the United States, 1965. U.S. Geological Survey Circular 556.

Murray, Charles Richard, and E. Bodette Reeves. 1972. Estimated use of water in the United States in 1970. U.S. Geological Survey Circular 676.

—. 1977. Estimated use of water in the United States in 1975. U.S. Geological Survey Circular 765.

Seager, Richard, Alexandrina Tzanova, and Jennifer Nakamura. 2009. Drought in the southeastern United States: Causes, variability over the last millennium, and the potential for future hydro climate change. *Journal of Climate* 22:5021-45.

Seckler, David, Upali Amarasinghe, David Molden, Radhika de Silva, and Randolph Barker. 1998. *World water demand and supply, 1990 to 2025: Scenarios and issues*. Research Report 19. Colombo: International Water Management Institute. www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB019/REPORT19.PDF

Smith, Adam. *The Wealth of Nations*. Edited by Edwin Cannan, New York, 1965, p. 28.

Solley, Wayne B., Edith B. Chase, and William B. Mann IV. 1983. Estimated use of water in the United States in 1980. U.S. Geological Survey Circular 1001.

Solley, Wayne B., Charles F. Merk, and Robert R. Pierce. 1988. Estimated use of water in the United States in 1985. U.S. Geological Survey Circular 1004.

Solley, Wayne B., Robert R. Pierce, and Howard A. Perlman. 1993. Estimated use of water in the United States in 1990. U.S. Geological Survey Circular 1081.

—. 1998. Estimated use of water in the United States in 1995. U.S. Geological Survey Circular 1200.

USCB (U.S. Census Bureau). 2001. P001: Total population. 2001 Census Summary File 1. Downloaded via http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml.

—. 2010. P1: Total population. 2010 Census Summary File 1. Downloaded via http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml Accessed September 23, 2011.

—. 2011a. 2009 Annual capital expenditures survey, tables 4a and 4b. Downloaded via www.census.gov/econ/aces/xls/2009/full_report.html Accessed September 23, 2011.

—. 2011b. Annual capital expenditures survey (1994-2008). Downloaded via www.census.gov/econ/aces/historic_releases_ace.html Accessed September 23, 2011.

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