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Water Use Trends
in the United States

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by Kristina Donnelly and Heather Cooley

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Introduction

Since 1950, the United States Geological Survey (USGS) has collected and released data on national water use every five years for each state, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. In November 2014, the USGS released water-use estimates for 2010. These data are collected from a variety of sources, including from national data sets, state agencies, questionnaires, and local contacts (Maupin et al. 2014). They include estimates of withdrawals of freshwater and saline water from groundwater and surface-water sources and water use by sector. Using these data and historic data from several other sources, this paper reviews national water-use trends, going as far back as 1900 in some cases. For this analysis, we use the term "water use" to refer to the amount of water withdrawn from the ground or diverted from a surface-water source for use.[1,2]

Our analysis finds that we have made considerable progress in managing the nation's water, with total water use less than it was in 1970, despite continued population and economic growth. Indeed, every sector, from agriculture to thermoelectric power generation, shows reductions in water use. National water use, however, remains high, and many freshwater systems are under stress from overuse. Moreover, climate change will exacerbate existing water resource challenges, affecting the supply, demand, and quality of the nation's water resources. In order to address these challenges, we must continue and even expand efforts to improve water-use efficiency in our homes, businesses, industries, and on our nation's farms.

[1] Here, water use includes consumptive and non-consumptive uses. We do not make a distinction between consumptive and non-consumptive use because USGS no longer provides these data.

[2] All numbers in the report are rounded to two significant figures.

Total Water Use

According to data from the USGS, national water use has declined over the last three decades and experienced a major drop between 2005 and 2010.[3] Total water use, which includes both freshwater and saline water, peaked in 1980 at 440 billion gallons per day (bgd) before falling to 400 bgd in 1985 (Figure 1). Between 1985 and 2005, water use remained relatively flat, but by 2010, total water use declined to 350 bgd, lower than it was in 1970.

Reductions in total water use were achieved despite overall national economic gains and an increase in total population. As a result, per capita water use has also been falling since reaching a peak of 1,900 gallons per capita per day (gpcd) in 1980. In 2010, per capita use was 1,100 gpcd, down 17% from 2005 levels and the single largest decline in any five-year period. Figure 2 shows the "economic productivity" of water in the United States from 1900 to 2010, i.e., the inflation-adjusted gross domestic product (GDP) for every 100 gallons of water used. Between 1900 and 1980, the U.S. experienced only a modest increase in the economic productivity of water, and by 1980, $4.00 of GDP was produced per hundred gallons of water used. Since that time, economic productivity has increased dramatically. Indeed, during the most recent period (2005–2010), economic productivity increased by 20% to $11.00 per 100 gallons of water. These results show that the U.S. now produces far more wealth with far less water than at any time in the past.

Throughout the period of record, freshwater has represented the majority (85%) of national

[3] Unless otherwise specified, the geographic extent of the data are as follows: 1950 represents the lower 48 states, D.C., and Hawaii; 1955 represents the lower 48 states and D.C.; 1960 and 1975–2010 represent all 50 states, D.C., Puerto Rico, and U.S. Virgin Islands; 1965–1970 represent all 50 states, D.C., and Puerto Rico.

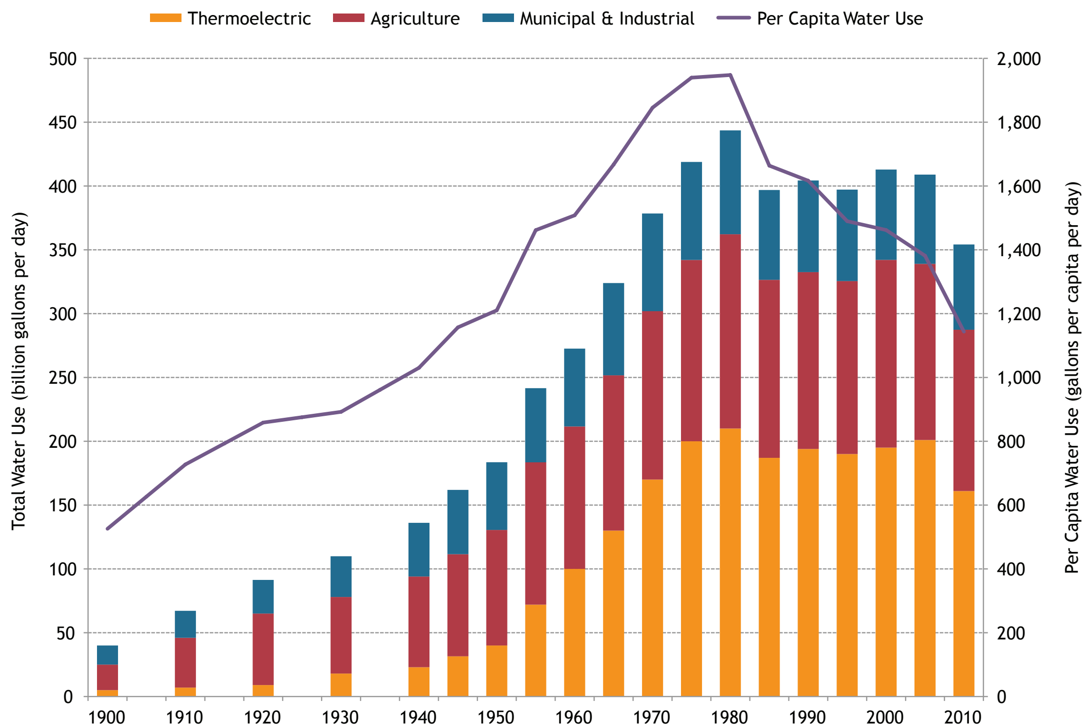

Figure 1. Total Water Use (Freshwater and Saline Water), by Sector (1900-2010)

Notes: Municipal and Industrial (M&I) includes public supply, self-supplied residential, self-supplied industrial, mining, and self-supplied commercial (self-supplied commercial was not calculated in 2000–2010). Agriculture includes aquaculture (1985–2010 only), livestock, and irrigation. Between 1900 and 1945, the M&I category includes water for livestock and dairy.

Sources: Data for 1900–1945 from the Council on Environmental Quality (CEQ) (1991). Data for 1950–2010 from USGS (2014a). Population data from Williamson (2015).

water withdrawals and use. In 2010, agriculture and thermoelectric power were each about 40% of freshwater use, with the remaining 20% withdrawn by the M&I sector (Figure 3). Freshwater use, however, has changed dramatically over time, with particularly large increases in water withdrawals for thermoelectric power. For example, in 1955, total freshwater use was 230 bgd, of which 27% (60 bgd) was for thermoelectric power, 49% (110 bgd) for agriculture, and 23% (52 bgd) for the municipal and industrial (M&I) sector. Between 1955 and 1980 (when U.S. freshwater use peaked), agricultural and M&I water use increased at about the same rate as population (38%), while water use for thermoelectric power increased by 150%.

Freshwater use remained relatively constant over the next two decades, but, between 2005 and 2010, freshwater use dropped by 13%. Thermoelectric power, which represented about one-third of total freshwater use in 2010, was responsible for nearly two-thirds of the overall reductions. We explore this sector and others in the following sections.

Water Use for Thermoelectric Power Generation

Water requirements for thermoelectric power production are substantial, representing the single largest use of water — both fresh and saline — in the United States. Thermoelectric power plants, which can be powered by fossil,

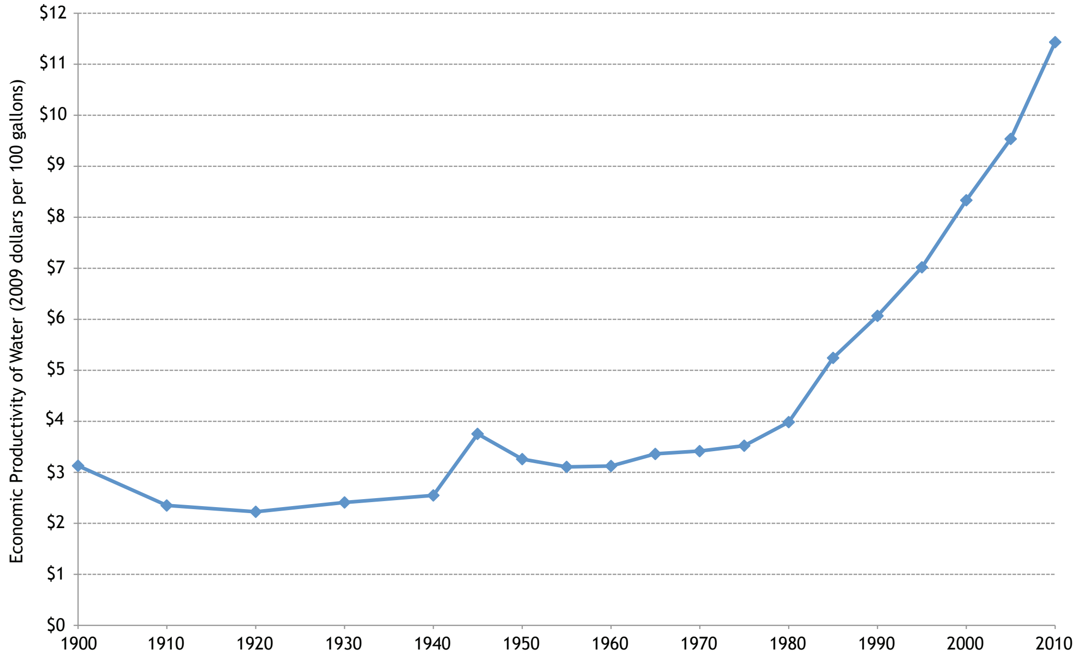

Figure 2. Economic Productivity of Water (1900-2010)

Sources: Data for 1900–1945 from CEQ (1991). Data for 1950–2010 from USGS (2014a). Population data from Williamson (2015).

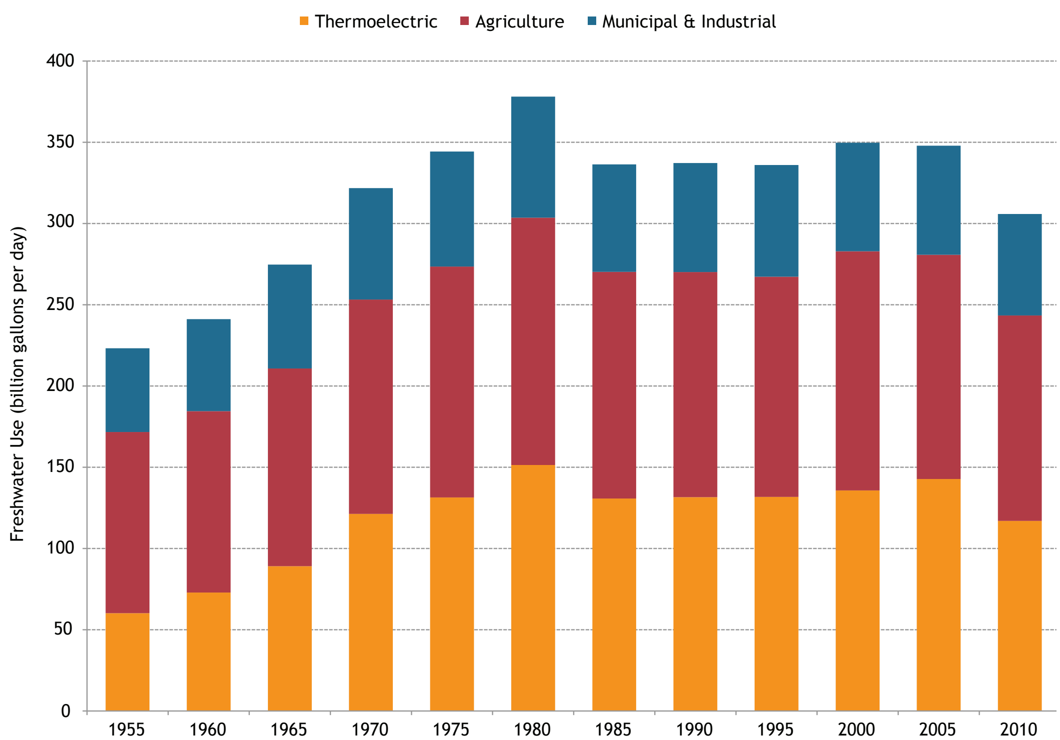

Figure 3. Total Freshwater Use, by Sector (1955-2010)

Notes: Municipal and industrial includes public supply, self-supplied residential, self-supplied industrial, mining (1985-2010 only), and self-supplied commercial (self-supplied commercial was not calculated in 2000-2010). Agriculture includes aquaculture (1985–2010 only), livestock, and irrigation.

Sources: Data for 1955–1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States*, which are published along with each data release: MacKichan (1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Data for 1985–2010 from USGS (2014b).

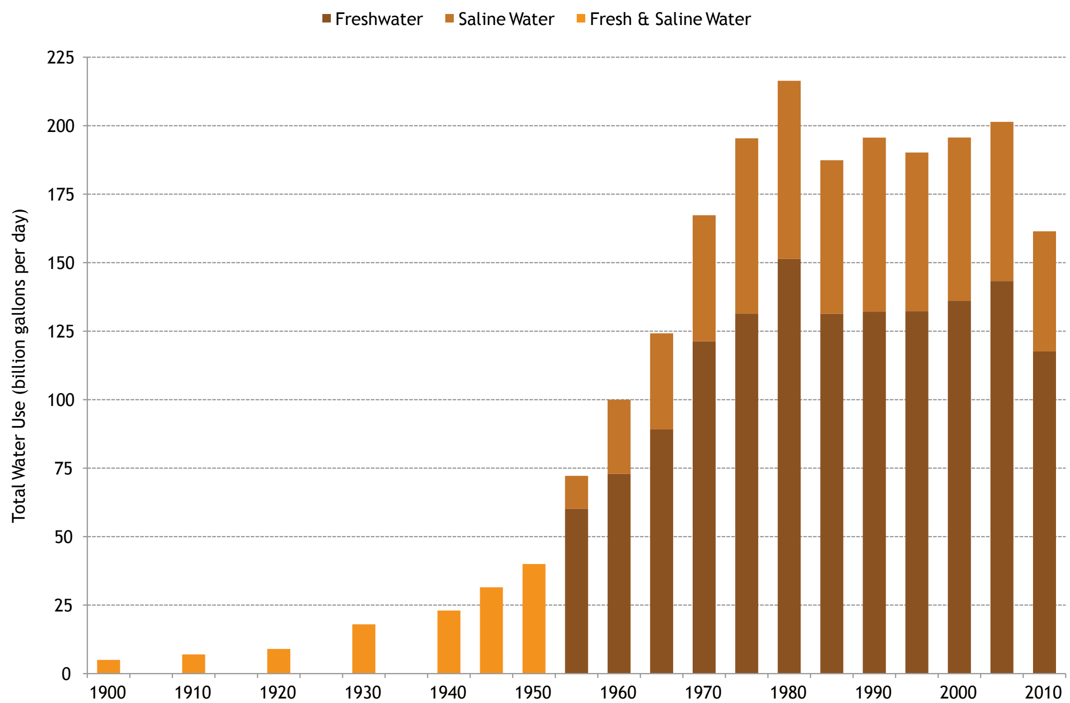

Figure 4. Water Use for Thermoelectric Power Generation, by Type (1900-2010)

Sources: Data for 1900–1950 from CEQ (1991). Data for 1955–1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States,* which are published along with each data release: MacKichan (1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Data for 1985–2010 from USGS (2014b).

geothermal, nuclear, and biomass fuels, use water for cooling purposes and for makeup water that replenishes boiler water lost through evaporation. In 2010, thermoelectric power plants withdrew 160 bgd, nearly all of which was surface water (Figure 4). Nearly three-quarters of the total amount of water withdrawn by thermoelectric power plants in 2010 is freshwater, and the remainder is saline water. The use of saline water is largely confined to coastal regions, as nearly all of this water was withdrawn from the ocean.

Both total water use and freshwater use for thermoelectric power plants are less than they were in 1970. This represents an important reversal of a 25-year trend of increasing water use for producing energy. Total and freshwater use for thermoelectric power plants peaked in 1980 (Solley et al. 1983) at 220 and 150 bgd, respectively. In 1985, water use declined but then increased in nearly every five-year period through 2005.[4] The 20% reduction during the most recent period (2005–2010) represents a significant shift in national water use for thermoelectric power plants, which the USGS attributes to upgrades to intakes and cooling systems, as well as the closure of power plants using water-intensive once-through cooling systems (Maupin et al. 2014).

[4] According to the USGS, the decline in thermoelectric water withdrawals between 1980 and 1985 reflects both reductions in withdrawals as well as more realistic estimates. However, it is not possible to quantify how much of the decline is attributable to either (Solley et al. 1988).

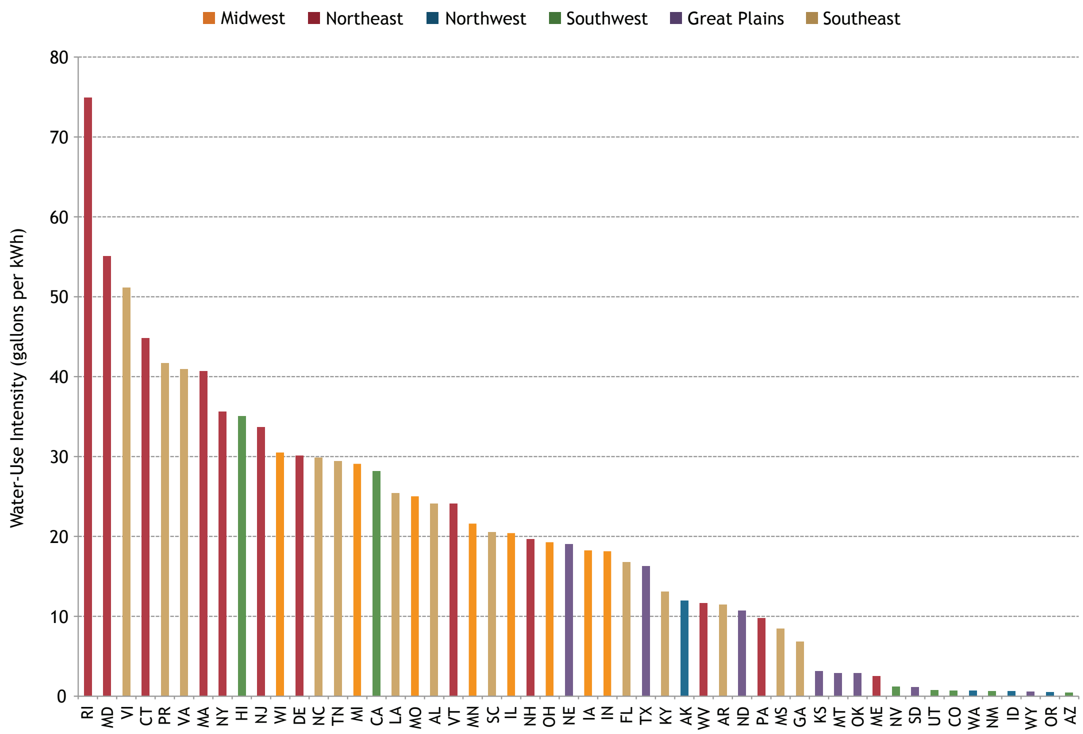

Figure 5. Water-Use Intensity for Thermoelectric Power Generation, by State (2010)
Source: USGS (2014b)

On average, thermoelectric power plants in the United States use 19 gallons of water (both fresh and saline) for every kWh generated in 2010. The water intensity of thermoelectric power production, however, varies tremendously across the U.S, ranging from 0.4 gallons per kWh in Arizona to 75 gallons per kWh in Rhode Island (Figure 5). This variation is primarily driven by the type of cooling system employed, with states that rely on once-through cooling using far more water per unit of energy produced than states using recirculating or dry cooling. Overall, by 2010, the U.S. reduced the water-use intensity of thermoelectric power production by 41% since 1985 and 18% since 2005, with the largest reductions in the Northwest and Southwest. Despite these improvements, thermoelectric power plants still represent the single largest use of water in the United States. Water use could be further reduced by accelerating water and energy efficiency improvements, the development and deployment of less water-intensive renewable energy systems, the adoption of recirculating- and dry-cooling systems (Cooley et al. 2011).

Water Use for the Municipal and Industrial Sector

Municipal and industrial (M&I) water use represents the amount of water withdrawn to meet the needs of cities, towns, and small communities. This includes water used in homes for both indoor and outdoor needs (e.g., cleaning, bathing, cooking, and maintaining gardens and landscapes), as well as water used in the commercial, industrial, and mining sectors to produce the goods and services society desires. M&I water use also includes water used by institutions, such as schools, municipalities, prisons, and government agencies, as well as water losses due to system leakage, theft, hydrant flushing, and unmetered connections.

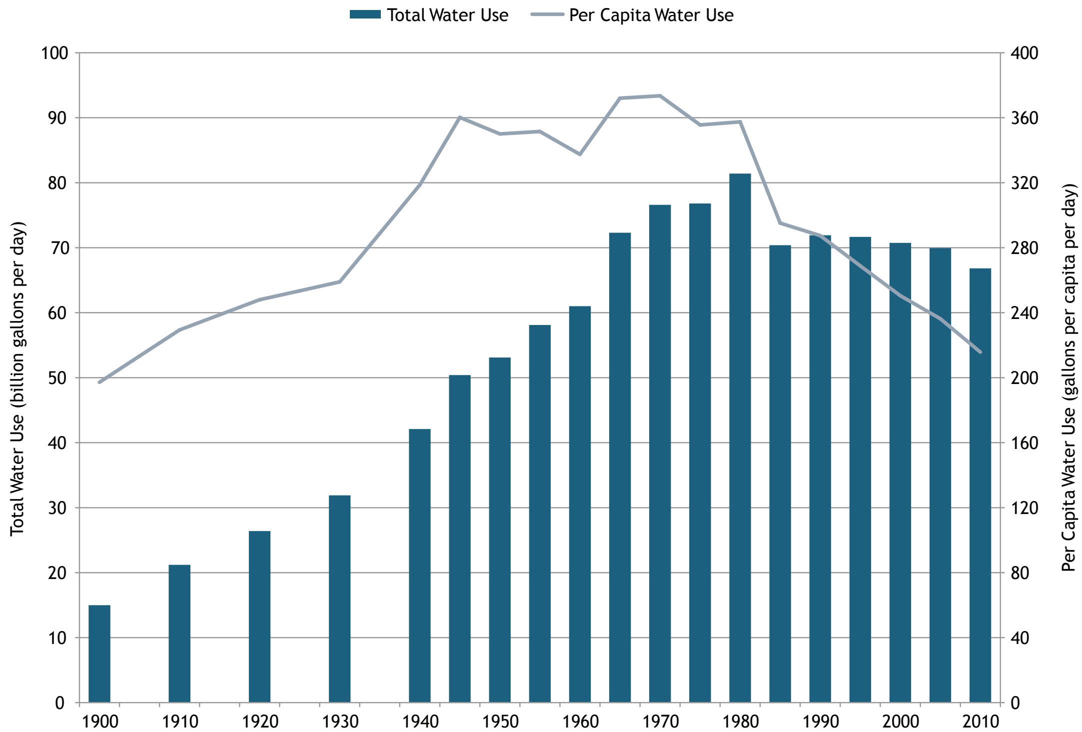

Figure 6. Total and Per Capita Water Use for the Municipal and Industrial Sector (1900–2010)

Notes: Self-supplied commercial was not calculated in 2000, 2005, or 2010, which would account for some of the reduction in use that occurred during that period. In addition, USGS documentation notes that water-use estimates for self-supplied industrial use were more realistic in 1985 than in 1980 and would account for some of the reduction between these years (Solley et al. 1988). M&I water use from 1900–1945 also includes water for livestock and dairies. Some years include public supply deliveries to thermoelectric; although it was not possible to exclude these deliveries for all years, the years for which data are available suggest that this use was relatively very small. D.C. was excluded from the analysis due to lack of data.

Sources: 1900–1945 data from CEQ (1991). 1950–2010 data from USGS (2014a). Population data from Williamson (2015).

In 2010, M&I water use in the United States totaled 67 bgd, or 19% of total national water use. During much of the 20th century, M&I water use increased as the population grew, reaching a record high of 81 bgd in 1980 (Figure 6). This trend reversed in 1985, after which total water use for M&I began to level off and then decline despite continued growth. During the most recent period (2005–2010), M&I water use decreased by 4%, despite a 4% increase in both population and GDP. As a result, per capita water use has declined in every five-year period over the last three decades, from 360 gpcd in 1980 to 220 gpcd in 2010.

Reductions in M&I per capita water demand were driven by two major factors. First, the economy shifted from one dominated by water-intensive manufacturing to a less water-intensive service-oriented economy. Second, numerous federal, state, and local policies and actions have facilitated water-efficiency improvements. For example, the National Energy Policy Act of 1992 established efficiency standards for all toilets, urinals, kitchen and lavatory faucets, and showerheads manufactured after Jan. 1, 1994. Subsequent legislation established additional standards for products not included in the original act, including clothes washers, dishwashers, and

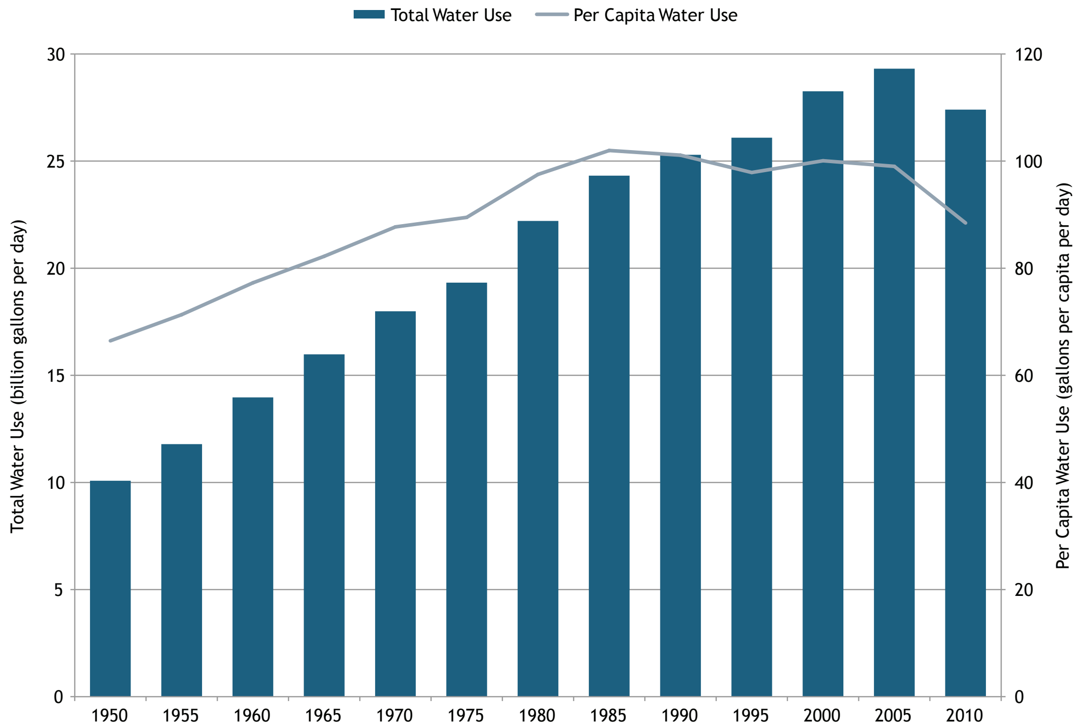

Figure 7. Total and Per Capita Water Use for the Residential Sector (1950–2010)

Notes: The publicly available USGS data only estimate residential water use for 1985-2010 (excluding 2000). Residential water use for 1960–1980 included public use and losses. In the years available, about 57% of the public supply went to residential use. For the years in which residential water-use data were not available (1950–1980 & 2000), we multiplied the total public supply by 57% and added it to self-supplied residential. D.C. was excluded from the analysis due to lack of data.

Sources: Data for 1950–1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States,* which are published along with each data release: MacKichan (1951 and 1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Data for 1985-2010 from USGS (2014b). Population data from Williamson (2015).

a number of commercial products. More recently, the Environmental Protection Agency (EPA) developed the WaterSense program, a voluntary labeling program modeled after the EnergyStar program, to help customers identify and purchase efficient appliances. Products bearing the WaterSense label use less water than required under the national plumbing standards.

Water Use for the Residential Sector

Residential water use is a subset of M&I water use that includes household water use, including for drinking, bathing, washing clothes and dishes, flushing toilets, and landscaping. Residential water can be supplied by private well or spring or delivered by a public supplier. Between 1950 and 2005, total residential water use in the U.S. steadily increased, reaching 29 bgd in 2005 (Figure 7). Between 1985 and 2005, national per capita water use remained steady at about 100 gpcd. In most parts of the U.S., household per capita water use declined due to efficiency improvements; however, these efficiency improvements were offset by population growth

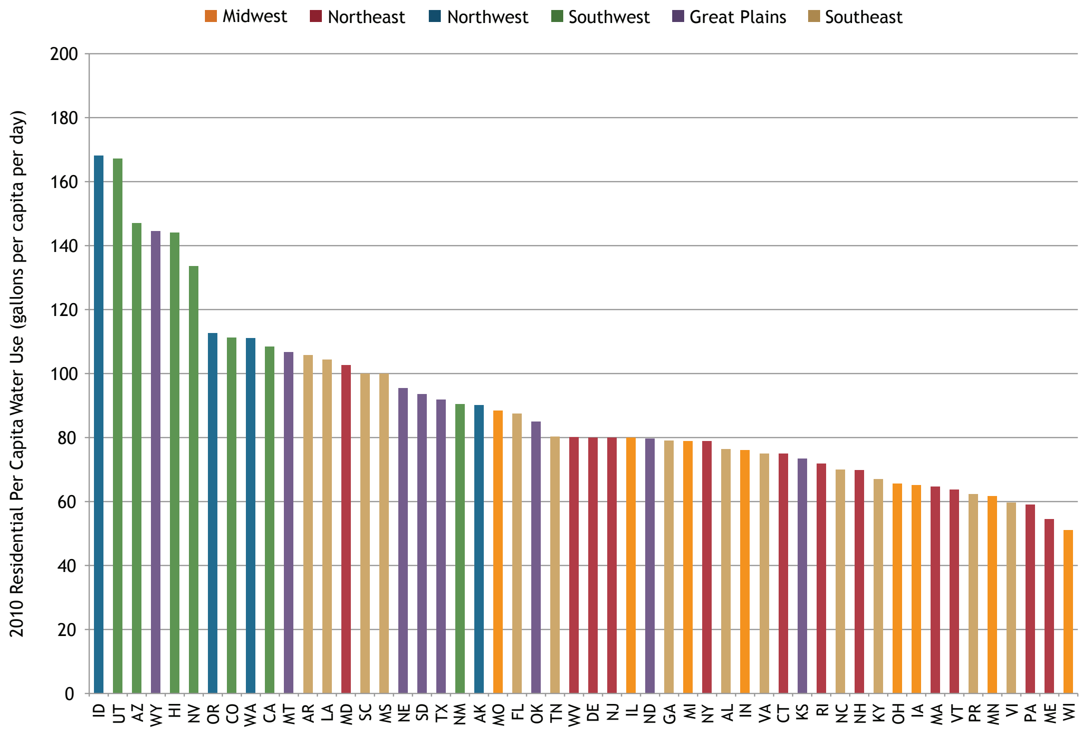

Figure 8. Residential Per Capita Water Use, by State (2010)
Source: USGS (2014b)

in the hottest, driest parts of the U.S., where per capita water use is relatively high. Then, between 2005 and 2010, residential water use declined by 7%, or 2 bgd, despite continued population growth, reducing per capita water use to 88 gpcd in 2010. Household per capita water use declined in a majority of U.S. states between 2005 and 2010, with the largest overall reductions in per capita use occurring in Nevada, Texas, and Nebraska. Nationwide, household per capita water use in 2010 ranged from a low of 50 gpcd in Wisconsin to 170 gpcd in Idaho (Figure 8).

Water Use for Irrigation

Water use for agricultural irrigation has followed a pattern similar to other water-use categories. Total water use for irrigation increased through much of the 20th century, as did irrigated acreage (Figure 9). Water use for irrigation peaked in 1980 at 150 bgd and has declined in nearly every period since.[5] By 2010, water use for irrigation was 120 bgd, its lowest level in more than 40 years. Yet, irrigated acreage has continued to increase, with 62 million acres irrigated in 2010, the most land irrigated at any time in U.S. history.

As a result, the water intensity of U.S. agriculture, as measured by irrigation depth, has declined markedly over the past 60 years (Figure 10). In 1950, an average of 4.0 feet of water was applied to U.S. farmland. By 2010, the irrigation depth had declined to 2.1 feet. Reductions in

[5] Irrigation water use includes water applied by an irrigation system to sustain plant growth in all agricultural and horticultural practices, as well as water that is used for pre-irrigation, frost protection, application of chemicals, weed control, field preparation, crop cooling, harvesting, dust suppression, and leaching salts from the root zone.

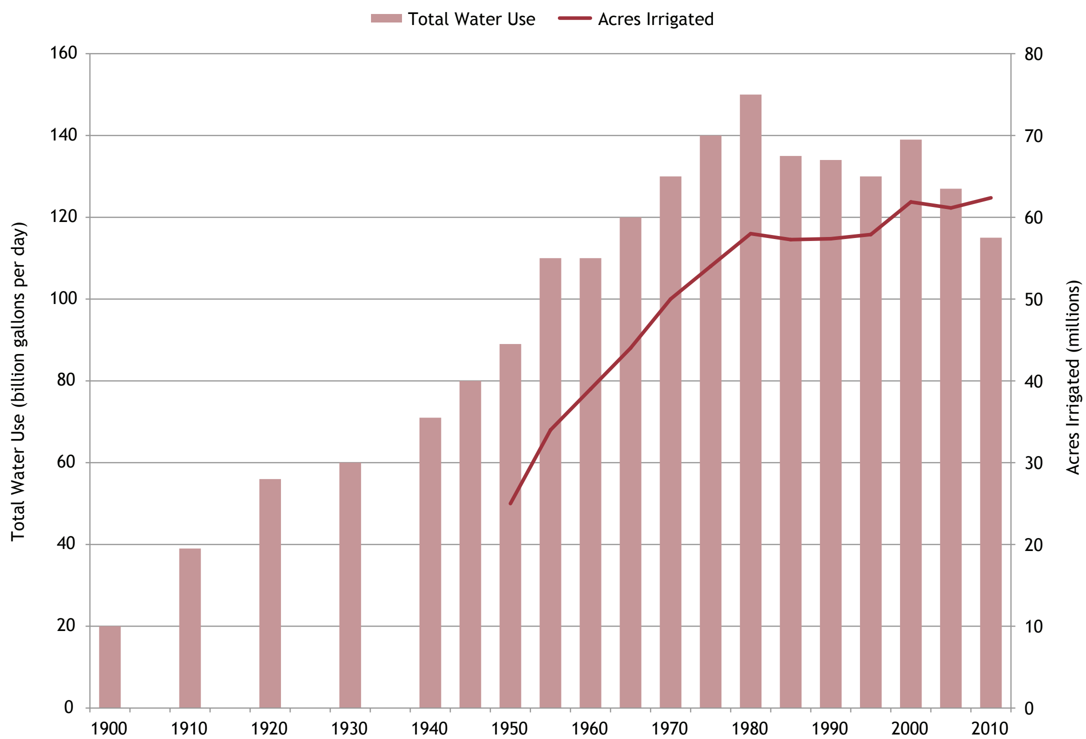

Figure 9. Freshwater Use for Irrigation (1900-2010) and Acres Irrigated (1950-2010)
Sources: Data for 1900–1945 from CEQ (1991). Acreage data for 1950–1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States,* which are published along with each data release: MacKichan (1951 and 1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Acreage data for 1985–2010 from USGS (2014b). Water-use data for 1950–2010 from USGS (2014a).

water intensity could be due to several factors, including shifting to less water-intensive crops, as well as improvements in irrigation technologies and practices. For example, since 1985, the acreage irrigated by surface flooding — the least efficient irrigation method — has declined, while the acreage irrigated by sprinkler and micro-irrigation methods has increased (Figure 11).

Conclusions

National water use has shown marked reductions in recent years. Total water use in the U.S. in 2010 is lower than it was in 1970, despite continued economic and population growth. This is evident in continued reductions in per capita water use, which was lower in 2010 than it was in 1945. Likewise, the economic productivity of water (dollars of gross domestic product per unit of water used) is higher than it has ever been, nearly tripling over the past three decades, from only $4.00 in 1980 (in 2009 dollars) to more than $11.00 (in 2009 dollars) of GDP per hundred gallons used. These results show that the U.S. now produces far more wealth with far less water than at any time in the past.

Thermoelectric power plants represent the single largest use of water — both fresh and saline — in the United States. Thermoelectric power plants, which can be powered by fossil, geothermal, nuclear, and biomass fuels or the sun, use water for cooling purposes and for makeup water that replenishes boiler water lost through evaporation.

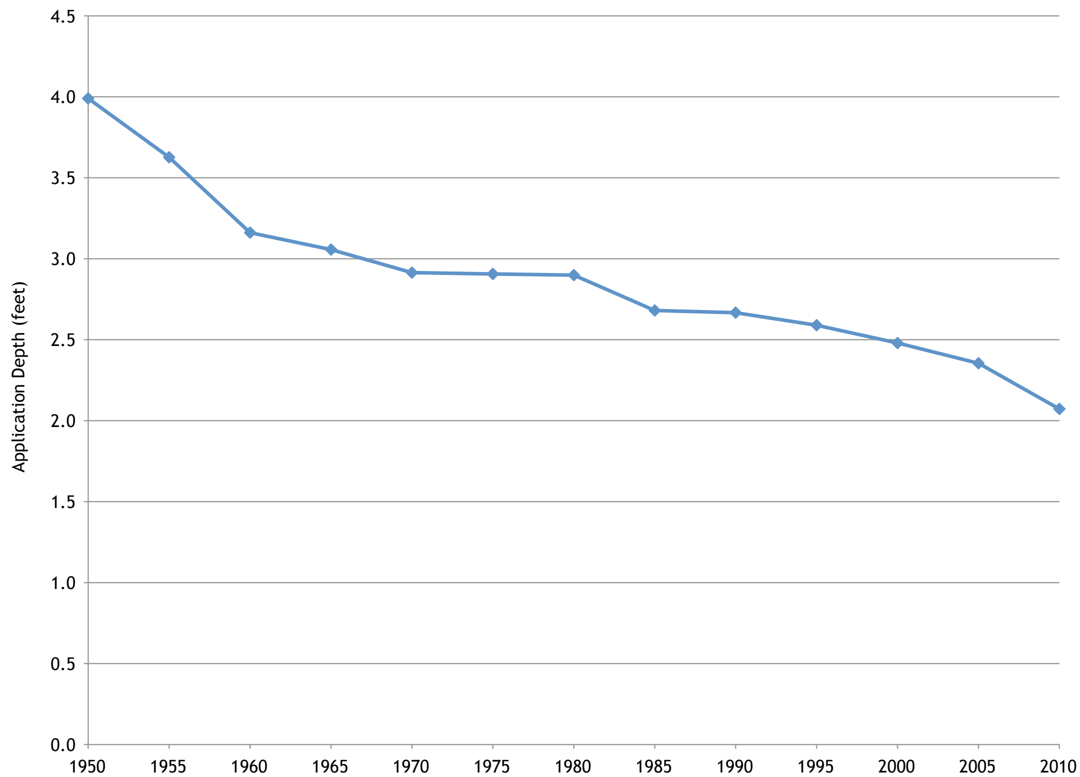

Figure 10. Average Application Depth (1950–2010)

Sources: Acreage data for 1950-1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States*, which are published along with each data release: MacKichan (1951 and 1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Acreage data for 1985–2010 from USGS (2014b). Water-use data for 1950–2010 from USGS (2014a).

However, water use for thermoelectric power plants is less than it was in 1970, an important reversal of a 25-year trend of increasing water use for producing energy. Continued water-use reductions are possible by expanding energy-efficiency efforts, installing more dry cooling systems, and relying more heavily on renewable energy, such as wind and solar photovoltaics.

Municipal and industrial (M&I) water use represents the amount of water withdrawn to meet the needs of cities, towns, and small communities, including household uses, as well as commercial, industrial, institutional, and mining uses to produce the goods and services society desires. M&I water use peaked in 1980 and has been steadily declining since. By 2010, M&I water use was less than it was in 1965. Household water use, by contrast, has been steadily increasing since 1950s but, for the first time ever, decreased between 2005 and 2010. Indeed, household per capita water use declined in 38 U.S. states and territories between 2005 and 2010, with the largest reductions in Nevada, Texas, and Nebraska.

Lastly, water use for agricultural irrigation continued its declining trend in 2010, while irrigated acres continues to increase. Water use for agricultural irrigation has followed a pattern similar to other sectors. Total water use for irrigation increased through much of

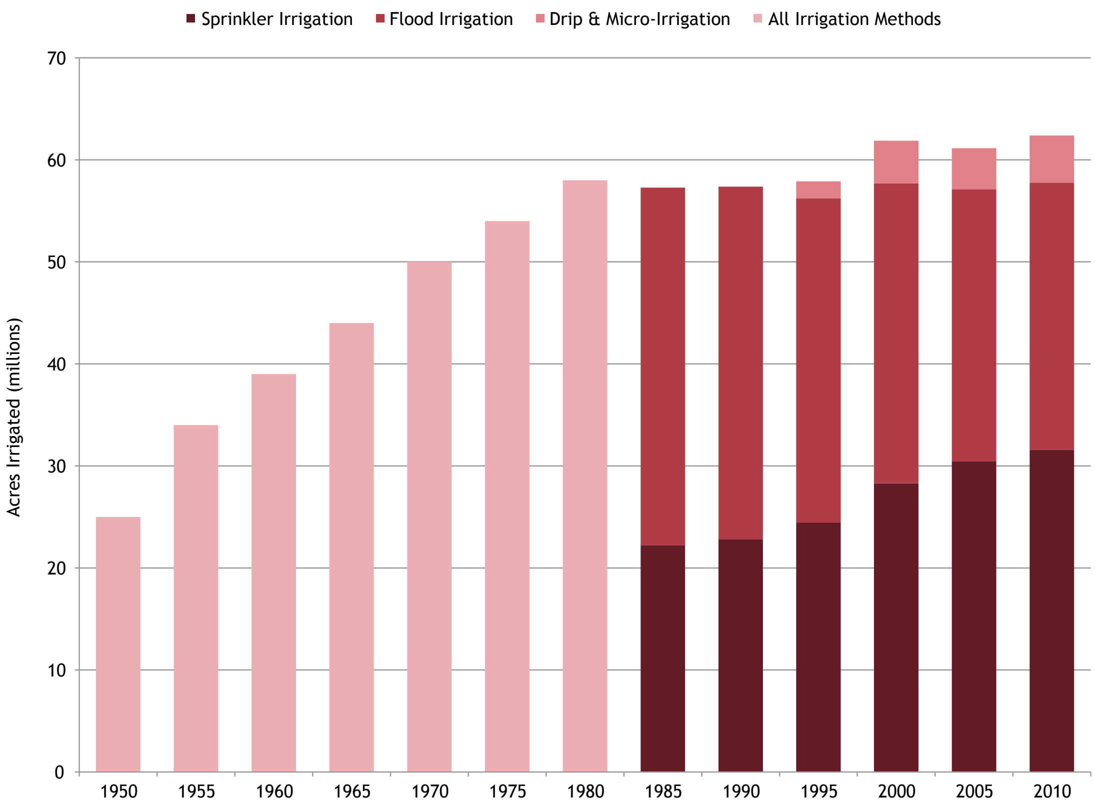

Figure 11. Acres Irrigated, by Irrigation Method (1950-2010)

Sources: Data for 1985–2010 from USGS (2014b). Data for 1950–1980 from the USGS water-use data companion publications, *Estimated Use of Water in the United States*, which are published along with each data release: MacKichan (1951 and 1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley et al. (1983). Acres irrigated by type were not available before 1985. Acreage employing drip and micro-irrigation were included in sprinkler irrigation for 1985 and 1990.

the 20th century (along with irrigated acreage), peaked in 1980, and has declined in nearly every period since. By 2010, water use for irrigation was at its lowest level in more than 40 years, despite continued growth in the number of acres irrigated.

We conclude that considerable progress has been made in managing the nation's water — but the current pace is not likely to counter the demands of continued population and economic growth, climate change, and increasing tensions over scarce water resources. National water use remains high, and many freshwater systems are under stress from overuse. While there is reason to believe this may be changing, we must continue efforts to improve water-use efficiency in our homes, businesses, and on our nation's farms.

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