

Chapter 13

The Demography of Water Use: Why the Past Is a Poor Predictor of the Future



Patricia Gober

Abstract The concept of gallons per capita per day (GPCD) expresses the relationship between population and water. US trends in GPCD between 1950 and 2015 reflect changing technology, policy, and lifestyles. Water managers use GPCD for long-term infrastructure planning and water resource management. GPCD grew from 1950 to 1980, remained steady from 1980 to 2000, and then fell sharply due to the implementation of the 1992 US Energy Policy Act. This legislation mandated water-efficient fixtures and appliances in new and remodeled homes and focused on indoor water use. The new frontier of water conservation is now outdoor use where behavioral and cultural forces interact with policy and technology to reduce GPCD. Regional trends reveal significantly higher water use in western than eastern states due in part to their warm, dry climates. California, Texas, Nevada, and New Mexico led a regional decline with some other western states unaffected by national trends. The rapidly changing and geographically dispersed pattern of declining GPCD has refocused attention to outdoor water. Uncertainties associated with climate change; city, state, and federal conservation policies; lifestyles; and public attitudes imply a change in water management practices from traditional predict-and-plan methods of long-term water planning to scenario planning, exploratory modeling, and decision-making under uncertainty (DMUU).

Keywords GPCD (gallons per capita per day) · Water conservation · Outdoor use · Climate change · Uncertainty

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13.1 Introduction

This chapter tracks the recent history of gallons per capita per day (GPCD) in the USA and discusses what it means for future planning and policy. Until recently, urban water managers treated population growth as the major determinant of future water demand and the basis for revenue projections and infrastructure capacity planning. They applied a straight-line projection, assuming that gallons per capita per day (GPCD) would remain constant, paying little attention to other determinants of water demand (Quay 2015). Since 1990, many urban communities experienced declining GPCD, averaging 0.5% per year (Coomes et al. 2010). Water managers, caught by surprise to discover that their assumption about constant GPCD was inaccurate, began to look beyond population growth to climate, technology, policy, and lifestyles for insight into future trends in water demand (Gober et al. 2016). Also significant are the uncertainties associated with these issues for traditional predict-and-plan methods of long-term water planning.

13.2 National Trends in Water Use

Trends in water withdrawals at the national level reflect basic changes in the relationship between population and water. The United States Geological Survey (USGS) has monitored water use in the nation and its constituent states at five-year intervals since 1950. Public water supplies refer to water withdrawn by public suppliers for domestic, commercial, and industrial purposes. Public suppliers refer to agencies that provide water to at least 25 people. Public supply water supports domestic, commercial, and industrial purposes. Also included are public services such as firefighting and system losses (leakages) (Deiter et al. 2019).

Water withdrawals (from surface and groundwater sources) for public supply tracked population closely until 1980 when American lifestyles favored larger homes, more outdoor irrigation, backyard pools and spas, and high water-using fixtures and appliances (Fig. 13.1). Water withdrawals grew faster than population between 1980 and 2005. Prevailing lifestyles required higher GPCD. After 2005, total water withdrawals fell significantly from 44.2 in 2005 to 39 billion gallons per day in 2015, the equivalent of 11.7% (Deiter et al. 2019). This remarkable turnaround meant that lower water withdrawals supported a growing national population.

Trends in GPCD echoed this larger story about population and water. GPCD grew steadily from 145 GPCD in 1950 to 183 in 1980. High use levels pertained through the end of the twentieth century and then fell to 157 in 2010 and 138 in 2015 (Fig. 13.2). Declining per capita use is not explained by changes in household structure as average household size steadily declined during this period from 2.62 in 1990 to 2.54 in 2015 (US Census 2019), and average household size is negatively related to per capita use. Smaller households are associated with higher per capita use because they are unable to take advantage of the economies of scale at the

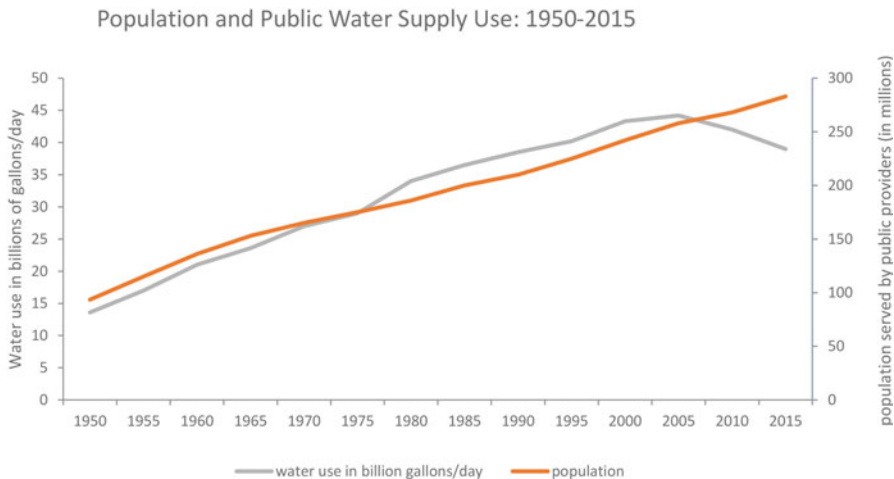


Fig. 13.1 Population and water use in the USA, 1950–2015. (Source: US Geological Survey. Estimated Use of Water in the United States in 1950–2015)

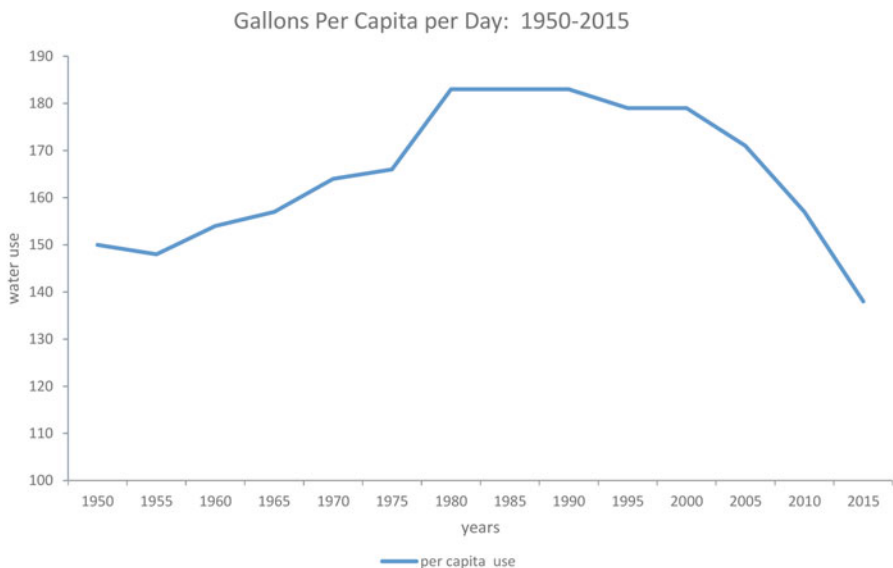


Fig. 13.2 Per capita water use in the USA, 1950–2015. (Source: US Geological Survey. Estimated Use of Water in the United States in 1950–2015)

household level (Höglund 1999; Arbués et al. 2010). Larger households spread fixed outdoor water use and indoor use associated with appliances such as dishwashers and clothes washers over a larger number of people. Much of the decline in GPCD between 2005 and 2015 occurred despite, not because of, the trend toward smaller households.

Using water utility records from Louisville, Kentucky, Coomes et al. (2010) found that homes built after 1994 used about 13 gallons per day less than homes built before 1994, controlling for size and value. They concluded that the introduction of low-flow toilets, showers, and clothes washers had a significant effect on residential water use, accounting for a decline of about 16% on average over 20 years. While the changes from 1 year to the next were relatively small, the cumulative effects of new fixtures and appliances reduced household water use by 16% in 20 years.

Indoor water conservation was largely a policy-driven process (Vickers and Bracciano 2014). The 1992 US Energy Policy Act, implemented in 1994, established national water efficiency requirements and set maximum flow rates for all plumbing fixtures installed in new and renovated homes. The Environmental Protection Agency's WaterSense Program launched in 2001 added third-party certification for water fixtures and appliances with more stringent but voluntary standards. These requirements were mandated by many communities and became the industry standard for new construction and retrofits. Declining GPCD, illustrated by USGS data, reflected the gradual penetration of low-volume fixtures and appliances in North American homes (Coomes et al. 2010; Kiefer et al. 2013).

It is unclear whether the same policy-driven process that reduced indoor water use will be equally successful for reducing outdoor use. Outdoor water use is climate sensitive and related to the host of policy, social, behavioral, and lifestyle issues. Outdoor water use goes to the heart of why and how people landscape their homes with irrigated plants, use pools and spas, maintain domestic irrigation systems, hire outside contractors to manage their lawns and gardens, and adhere to conservation directives. Reducing outdoor water use involves a far more complex set of environmental and social issues than the technologies and policies that led to decline in indoor water use.

13.3 Regional Trends in Water Use

While the national story of declining per capita water use signals the start of a new relationship between population and water use, the regional picture is more complicated. There was a clear East/West divide in per capita water use in 2005 (Fig. 13.3). Domestic per capita water rates were above 100 GPCD in the West and below that mark in most eastern states. The highest public supply use rates were in Texas (197), Idaho (180), Nevada (189), Utah (186), and Wyoming (167), with the entire West blanketed by high per capita use. In contrast, most states in the East and Midwest used significantly less water. The lowest use rates occurred in Maine (51), Pennsylvania (56), Ohio (68), and New Hampshire (75). Deiter et al. (2019) attribute the East/West divide to higher levels of outdoor water use for irrigation in the warm, dry climate of the West.

The GPCD use pattern became more complex by 2015 as some western states significantly reduced use rates between 2005 and 2015 (Figs. 13.3b and 13.4). Four

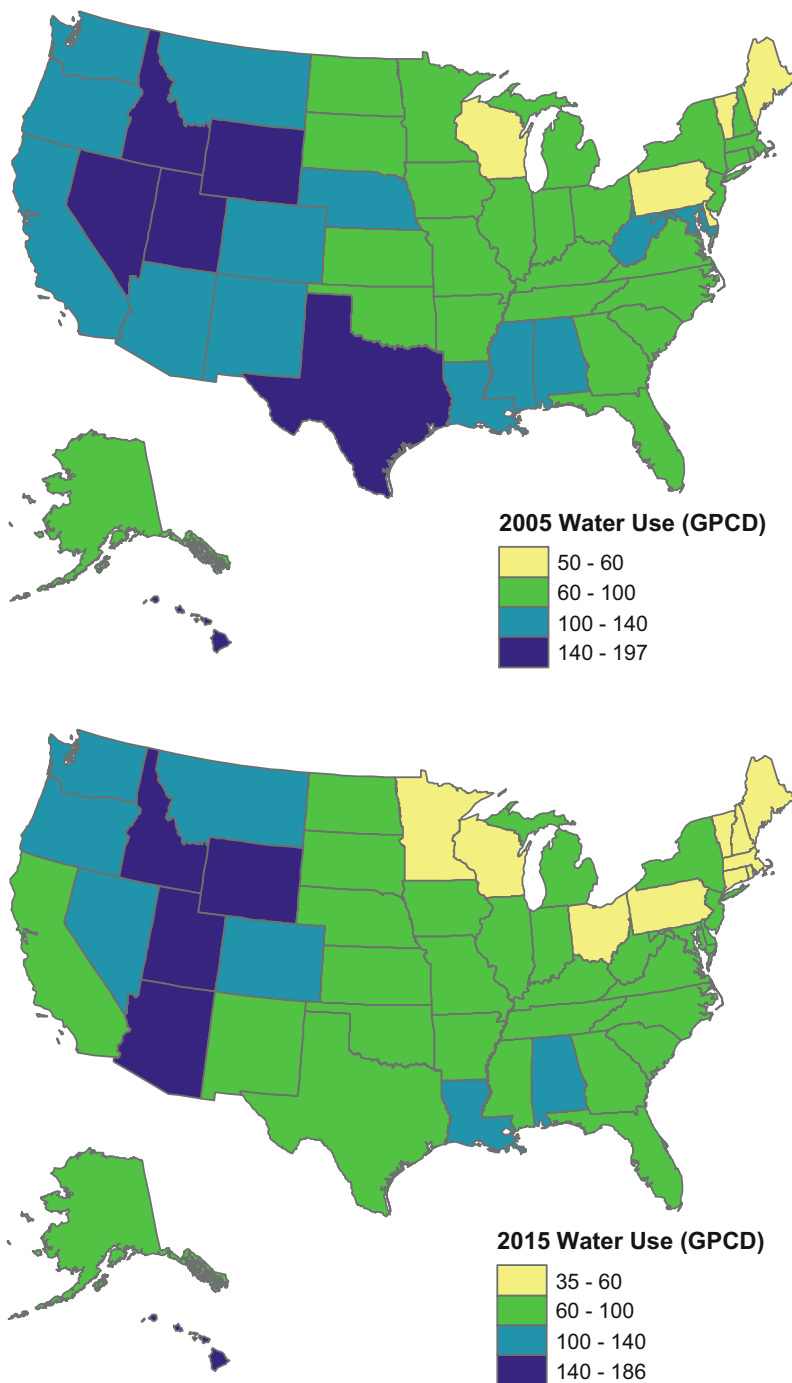


Fig. 13.3 (a and b) GPCD by state, (a) 2005 and (b) 2015. (Source: US Geological Survey. Estimated Use of Water in the United States in 1950–2015)

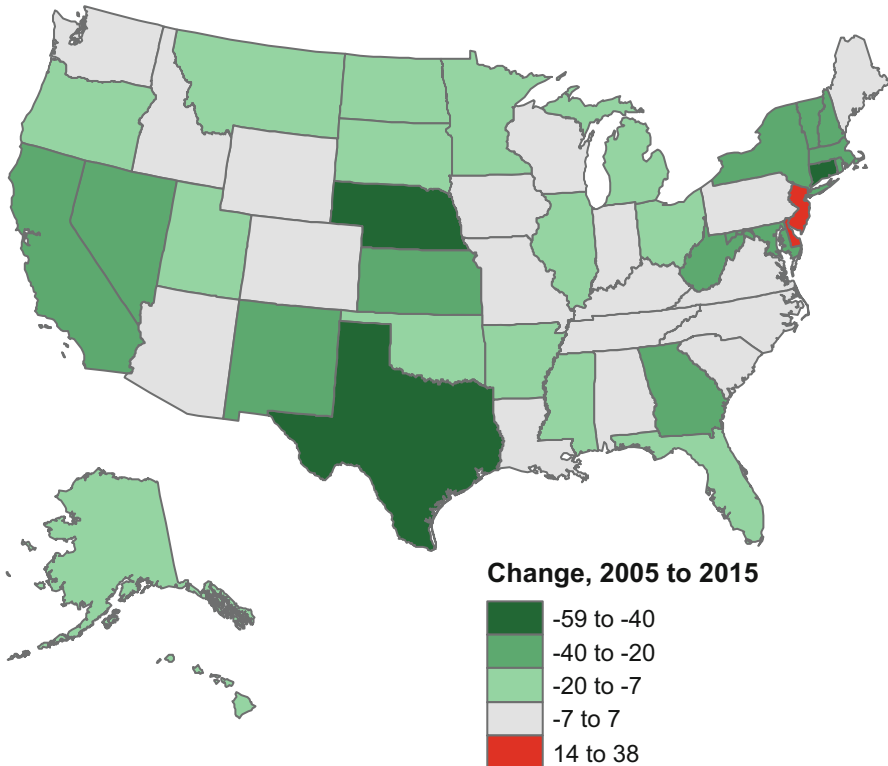


Fig. 13.4 Percent change in GPCD, 2005–2015. (Source: US Geological Survey. Estimated Use of Water in the United States in 1950–2015)

key examples were Texas (from 197 in 2005 to 81 in 2015), New Mexico (113–87), California (119 to 86), and Nevada (189–122). The four states experienced significant challenges to their water supplies, including drought in California, low water levels in Lake Mead on the Colorado River in Nevada, declining water levels in the Ogallala Aquifer in Texas where it represents 40% of the water supply, and severe declines in groundwater levels in parts of New Mexico. Together, they represented 27.7% of the nation’s public water supply withdrawals in 2005, declining to 21.3% in 2015. The decline in per capita water use in the West was not so much a sweeping regional phenomenon but one anchored in key states experiencing severe environmental stress coupled with rapid population growth. Water conservation became an important new supply source and vehicle to support continued population growth. The Southern Nevada Water Authority’s most recent plan assumes a decrease GPCD from 127 in 2017 to 116 in 2035 and 111 in 2050 (Southern Nevada Water Authority 2018). These reductions are in use and reuse of indoor water figure into supply and demand scenarios for future water resources planning. The goal is to balance

population growth with water conservation to achieve sustainable water use in the future.

California's most recent drought experience illustrated the new relationship between population and water in the West. The state, like most of the western states, owes its modern development to federally funded dams, reservoirs, and canals (Reisner 1986). These projects initially supported irrigated agriculture in downstream valleys and today support large urban populations, agriculture, and environmental flows. AghaKouchak et al. (2015) argued that California reached the limits of building infrastructure to boost supply as population and water demand grew. The most recent drought episode demonstrated the folly of overuse and poor management. The event occurred between fall 2011 and early 2016. It was the driest period since record keeping began in 1895. 2014 and 2015 were the two hottest years in the state's history (Hanak et al. 2016). Governor Edmund Gerald Brown Jr. declared a statewide drought emergency in April 2015 and ordered a 25% reduction (relative to 2013) in water use for cities and towns. Cities were able to cope as per capita water use declined sharply. Consequences for agriculture and the environment were more severe. Growers in rural areas received 50% less irrigation water. Extinction threatened 18 fish species, wildlife refuges experienced shortages, and wildfire risk increased in many areas.

Recognizing that this was not just another one-off event, Brown announced in 2016 that the water restrictions put into place during the drought event would be permanent and challenged the state to adjust to a "new normal." "Ongoing drought conditions and our changing climate require California to move beyond temporary drought measures and adopt permanent measures to use water more wisely and to prepare for more frequent and persistent periods of limited water supply." (Executive Department State of California 2016). The California experience was symbolic of the need for a new relationship between water and development in the West, a recognition that sustainable growth would require lower GPCD, difficult trade-offs between agriculture, cities, and the environment, and public policy would play an increasing important role in the relationship between population and water. California's per capita water use fell by more than 30% during this tumultuous period between 2010 and 2015.

Policy and technology played an important role in improving indoor water efficiencies. As the need for future gains in efficiencies shift to outdoor water, it is less clear that policy solutions alone can deliver the requisite declines in GPCD. Outdoor water use implicates lifestyles, identity, cultural preferences, and economic imperatives more than indoor use. Policy research has emphasized the effects of price on behavior, with far less insight into the potential effects of mandatory and voluntary drought restrictions on water use. Climate change also affects outdoor water use, translating long-term water planning from a predict-and-plan problem to one of deep uncertainties requiring new strategies for decision-making and modeling.

13.4 Outdoor Water Use: What Do We Know?

Empirical evidence indicates that homeowners and their landscaping contractors do not always efficiently manage their landscape designs. Moreover, many of these designs are ill suited to local weather and climate conditions. In a study of 700 single-family homes across California water agencies, De Oreo et al. (2011) found that 87% of homes irrigated their yards, 54% of homes that irrigate did so in excess, and 62% of excess use occurred on just 15% of lots. Results imply there are cultural and behavioral dimensions to outdoor water use and that technology and policy solutions may not be enough to reduce the use. They also suggest that targeted water conservation and educational campaigns and enforcement activities are required to target the relatively small number of households that over-irrigate.

The field of landscape architecture offers insight into why heavily watered landscapes were adapted in the US West where they were often ill suited to local environmental conditions. In the *Crabgrass Frontier*, Kenneth Jackson described a nineteenth-century society of middle-class Americans who sought after “pleasure gardens” as a sign of suburban respectability (Jackson 1985). They saw the gardens surrounding their homes as good places to raise children and a mark of suburban respectability. With westward settlement, these idealized gardens transferred to climates where they required high inputs of artificial fertilizers and irrigation water. In *Lawn People*, Robbins (2007) described the role of pride, status, identity, and political economy to explain the preference for heavily watered gardens. Green lawns and gardens are not only individual desires but also a manifestation of social status and need for collective identity. They are part of a global lawn-care industry that markets fertilizers and seeds, lawn mowers, and irrigation equipment.

Perceptions and attitudes play a role in how people use outdoor water. Russell and Fielding (2010) attribute conservation behavior to attitudes (how positively or negatively particular policies are viewed), beliefs (worldview about the relationship between humans and the natural world), routines and habits (stable behavior patterns that have been reinforced in the past), personal capabilities (knowledge and skills to implement conservation practices), and contextual factors (e.g., policies, incentives, price). Neel et al. (2014) investigated the psychological aspects of high water-use residential landscapes in an arid southwestern city. They found that that the subjects in their study associated high water-use landscapes with sexual attractiveness and family orientation. Thus, if a person wants to convey sexual attractiveness and family status, they would favor landscapes with grass trees and other high water-use plants.

Bollinger et al. (2018) studied peer effects in the use of water conservation in terms of the diffusion of dry landscaping. In a study of water use in Phoenix, they found there was a much higher probability of a switch from green to dry landscaping just after a house transaction. They investigated the effects of these changing landscapes on neighborhood peers. Results of a statistical model found that change in peer water consumption resulted in a 1.7% change in individual water consumption; a 10% change in peer landscape greenness results in a 1.4% change in the household’s landscape greenness. These social effects did not hold under heavily

discounted irrigation water indicating that landscaping peer effects were near zero when not accompanied by an economic incentive.

13.5 Climate Change and Outdoor Water Use: What We Do Not Know?

While social scientists worked to understand the effects of lifestyle choices, public policy, and demographic trends on urban water use, natural scientists introduced climate change as an issue for urban water planning. Initially, emphasis was on the effects of a changing climate on water supplies, but more recently, concern has shifted to impacts on demand. In a study of future demand for six geographically diverse North American water utilities (Colorado Springs, Durham, Boston, Las Vegas, Tampa Bay, and San Diego), Kiefer et al. (2013) found that municipal water demand was highly sensitive to regional differences and to the variability in weather conditions. Estimated demand increased for the six cities under different climate change scenarios ranged from 1% to 12% by 2055 and from 2% to 45% by 2090, depending on the climate scenario, region, and specific utility. Climate-sensitive demands accounted for a majority of total demand in some areas and seasons. Some cities experienced increases in demand that are larger than future-projected declines in water use, suggesting that the net water use gained from conservation may not compensate for losses from climate-change impacts.

Also uncertain are the impacts of policy choices on outdoor water use. Recent efforts have emphasized drought conditions because of the obvious connection between short-term drought and long-term climate change (Karl et al. 2008). Kenney et al. (2004), for example, tracked household response to mandatory and voluntary outdoor water restrictions in six Colorado Front Range cities during drought conditions in the summer of 2002 and found that mandatory restrictions reduced water use, voluntary restrictions had limited impact, and the greatest savings occurred in cities with the most aggressive and stringent mandatory restrictions. Maggioni (2015) found that outdoor water restrictions in Southern California curbed per capita water use, but water rates and subsidies to install water-saving devices did not. In a 2007 study of severe drought conditions in six North Carolina communities, Wickman et al. (2016) found low-income households in single-family detached dwellings were more sensitive to price than high-income households were. There was, however, a more uniform response across income categories to non-price policies such as voluntary and mandatory restrictions on outdoor watering. They concluded that the burden of price increases falls more heavily on poor households. Irrigation restrictions had a more equitable impact, inducing more outdoor water conservation among high-income, high water-use irrigators.

Regulators face the need to adjust to climate change with speculative policy tools and limited capacity to anticipate potential outcomes, especially with respect to outdoor water. Beyond price, it is unclear how residents, sometimes with a deep

connection to their landscaping, will respond to policy signals. As a result, water managers face deep uncertainty in planning future infrastructure and supply.

In a recent study of residential water use, De Oreo et al. (2018) concluded there is potential to reduce per capita use even further in the indoor sector. They estimated that 100% acceptance of high-efficiency devices could reduce indoor use by 35%. Additional indoor efficiency can be obtained on the customer-side through leakage control, automated metering, and leak alert programs. For a variety of reasons, as noted above, outdoor efficiencies are more difficult to anticipate as a persistent part of the population accounts for a significant proportion of wasted water. De Oreo's research involving 838 households across 22 study sites found that average outdoor use would decline by 16% if overuse was eliminated.

13.6 Problems of Deep Uncertainty

Managing the relationship between population and water (GPCD) is increasingly a problem of deep uncertainty. This relationship changed in unexpected ways over the past 65 years and is likely to change again during the next 50 years. Attempts to predict and plan water resources based on a straight-line extrapolation of the future ignored lifestyle and social issues. Added to these is the knotty problem of climatic uncertainty and the unknowns about future technology raised in the previous sections. Increasingly, water management is a problem of deep uncertainty.

Problems of deep uncertainty (often called wicked problems) involve situations in which analysts do not know or do not agree on the key drivers that will shape the future, the probability functions that describe system behavior, or how to weigh the gains and losses of particular problems. DMUU acknowledges that many aspects of the future are unknowable and that predictions and forecasts represent only one of many possible futures. DMUU does not assume that the past is an adequate guide to the future and allows for a range of potential future conditions, some of them quite dire. DMUU changes the policy question from what is the most likely future to what kind of future do we want and what policy decisions are required to achieve acceptable outcomes. This form of robust decision-making relies on community-generated scenarios of the future, focuses on the trade-offs embedded in different policy choices, and stresses community engagement with scientific modeling and decision-making processes. Emphasis is often on the search for robust solutions—those that yield an acceptable outcome across a wide range of future conditions (Lempert et al. 2003a, b).

The deep uncertainties associated with future climate impacts, water conservation strategies at state and local levels, national policy initiatives relevant to water conservation, future lifestyles, and cultural trends leave society at risk to unexpected future conditions. The Fourth National Climate Assessment (2018) articulated the central challenges to water planning and management—learning to plan for plausible futures, not only the most likely ones. Water resource management in the USA traditionally stressed a predict-and-plan approach using optimization modeling and

known relationships. Some local planning agencies have adopted “what-if” approaches that explore alternative futures looking for robust planning strategies that provide acceptable outcomes over a wide range of future conditions. Las Vegas, for example used multiple demand and supply scenarios to plan for the future, engaging its citizens in public discussions of acceptable and unacceptable outcomes.

13.7 Conclusions

Many local water managers were surprised by the steady fall in water use GPCD in the recent past because they assumed a constant relationship between population and water. In fact, it took more than 10 years for the effects of the 1992 Energy Policy Act to appear in local water use records and in the USGS’s Estimated Water Use series. A careful examination of this series showed three periods of GPCD: steady increases from 1950 to 1980, consistently high GPCD from 1980 to 2005, and sharp declines from 2005 to 2015. Using the most recent period to predict the future may be as problematic as assuming constant GPCD was in the recent past. Continued reductions in GPCD assume substantial reductions in outdoor use and relevant social, lifestyle, and perceptual changes associated with them. Also assumed are policy actions to change existing landscaping and an assumption that population will respond to them. Alternatively, communities can plan for an uncertain future, actively monitor ongoing population and water use, engage their populations in more active discussions of water use, and look for robust strategies that offer water security irrespective of climate change, public acceptance of conservation signals, and technological innovations. Demography is integral to water planning but not in the sense of plugging in GPCD based on past trends. Instead, it offers insights into the larger societal forces that influence not only population size and characteristics but in the way it affects water use.

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